International Journal of EXERCISE SCIENCE

Original Research

The Relationship between Cognition, Preseason Hitting Assessments, and In-Game Batting Performance in Collegiate Baseball and Softball Players

AMANDA CARROL[*#1], TONYA KRUPP[†#1], KARA TUCKER[*2], NICHOLAS J. SIEKIRK[‡1], and BRADLEY J. KENDALL[‡2]

[1]Department of Health Sciences and Kinesiology, Georgia Southern University, Statesboro, GA, USA; [2]Kinesiology Department, Taylor University, Upland, IN, USA

[#]Denotes authors contributed equally, *Denotes undergraduate student author, [†]Denotes graduate student author, [‡]Denotes professional author

ABSTRACT

International Journal of Exercise Science 16(6): 23-30, 2023. Successful hitting performance may be related to perceptual processing of visual information. The purpose of this investigation was to examine the relationship between preseason cognitive assessments, off-field preseason hitting assessment, and in-game batting performing in collegiate baseball and softball athletes. Collegiate varsity baseball (n = 10, 20.5 ± 1.0 years) and softball (n = 16, 20.3 ± 1.3 years) underwent Flanker Task and Trail Maker Tests A (TMT-A) and B (TMT-B) 24 hours prior to a pre-seasoning indoor hitting assessment. During pre-season hitting assessment, athletes selected 10 underhand pitches and were outfitted with commercially available measurement tools (i.e., HitTrax and The Blast) to quantify swing characteristics. Batting average (BA), slugging percentage (SLUG) and on-base percentage (OBP) was obtained from subsequent 14 non-conference baseball and softball games. The data from this study demonstrated a relationship between the ball's exit velocity (r = .501), bat velocity (r = .524) and average distance traveled (r = .449) during the hitting assessment and in-game BA, p < 0.05. No relationship between hitting assessment outcomes and OBP or SLUG were detected, p > 0.05. Furthermore, the Flanker-Task, TMT-A and TMT-B were not related to in game batting outcomes, p > 0.05. Therefore, these data suggest that off-season preparation should be designed to maximize swing velocity while maintaining performance (i.e., skill) of the coordinated swing.

KEY WORDS: Flanker, Trail-Making Test, batting average, slugging percentage, on-base percentage, exit velocity, distance, swing velocity

INTRODUCTION

Motor skill performance is thought to be constrained by a performer's characteristics (e.g., experience, anxiety, and arousal states), the task itself, and the environment for which it is performed. The athlete must often hone the capacity to attend to and regulate how environmental information can influence movement decisions to coordinate the appropriate response. Integrating and processing information to shape stored procedural memory in baseball and softball is vital in coordinating the skilled swing. Performance may depend on the hitter's perceptual integration of sensory information from multiple origins. Thus, swing initiation may be related to perceived or actual environmental information. Higuchi et al. found that a hitter has around 400 milliseconds (msec) to initiate the swing (10). In this externally paced task, the hitter attempts to identify pitch type (e.g., fastball, change-up) and the resultant pitch's location. Moreover, skilled pitchers aim to consistently wind up and deliver the pitch towards home plate to strategically limit the hitter's predictive ability, increasing the task difficulty.

Although cognitive abilities and movement execution appear to be essential factors relating to batting performance, research has primarily assessed physical characteristics related to movement execution such as strength, power, and acceleration (8, 12, 21). Simulated in-game batting performance has been shown to improve following strength gains from a preseason resistance training program (3). Currently, it appears that upper and lower body strength and upper body force production relate to bat velocity and ultimately hitting ability.

Contrary to physical characteristics, less is known regarding cognition and batting performance. Previous works have examined the relationship between visual reaction time (RT) tasks and batting performance (4, 6, 17). Currently, findings from previous work are mixed on whether improvements in visual RT are associated with in-season and simulated batting performance (4, 6, 17). Moreover, researchers have found that concussions result in reduced batting performance due to likely slowed information processing speed (25). However, the authors highlighted the need to investigate further how measures of information processing are related to batting performance to determine any relationships. Furthermore, of the limited research on RT and batting performance, few studies have investigated the relationship between RT and in-game performance, limiting the application to game settings. Therefore, the purpose of this study was to investigate how physical and cognitive characteristics of softball and baseball players relate to in-game batting performance.

METHODS

Participants

Collegiate varsity baseball (n = 10, 20.5 ± 1.0 years) and softball (n = 16, 20.3 ± 1.3 years) players at a National Association of Intercollegiate Athletics (NAIA) University participated in this study. Participants were included in this study if they had a minimum of 20 at-bats. Twenty-two participants were deemed adequate to detect a small to moderate correlation and achieve a power of 0.80 and an $\alpha = 0.05$. The University's Institutional Review Board (IRB) approved all study procedures, and informed consent was obtained from all participants prior to data collection. This research was carried out in accordance with the ethical standards of the International Journal of Exercise Science (16).

Protocol
Cognitive testing was performed in the laboratory and during the morning hours. Researchers instructed participants to avoid vigorous exercise 24 hours prior to laboratory visits. Participants were also instructed to refrain from caffeine consumption the morning of laboratory testing. Cognitive testing consisted of a pencil paper assessment (i.e., Trail Making A and B) and a computer-based assessment (i.e., Modified Flanker) and took place approximately 1-week prior to the participants' first game.

Modified Flanker Task Cognitive Assessment: The Modified Flanker Task (MFT) was used to assess the effect of cognitive interference (5, 24). The MFT is an 8.5-minute computer test that accessed visual processing and inhibitory control by quantifying reaction time (RT) in milliseconds (msec) and the percentage (%) of accurate responses. The task required participants to respond under visual conditions containing relevant and irrelevant stimuli. Participants were instructed to respond only to the middle arrow in a set of five arrows. The MFT is consistent with both congruent and incongruent sections. In a congruent situation, all arrows face the same direction (e.g., > > > > >). In an incongruent situation, the middle arrow faces opposite of the rest (e.g., < < > < <). Participants were placed at a computer and instructed to place their left index finger on the Z key to respond to left arrows (<) and their right index finger on the backslash key (/) to respond to right arrows (>). Researchers confirmed that the participant could see the computer screen and clarified any questions before starting the MFT. Participants were instructed to respond as fast as possible while remaining accurate.

Trail-Making Tests: The Trail-Making Test (TMT) consisted of two sections (TMT-A and TMT-B). The TMT can provide information on the capacity to perform executive functions including visual search (e.g., visual scanning), speed of processing, task-switching (23). For TMT-A, a consecutive line is drawn between 25 circles numbered 1 through 25, while the TMT-B requires a connecting line between numbers 1 through 13 and letters A through L, alternating between numbers and letters. Participants were instructed to complete TMT-A and TMT-B as quickly as possible while remaining cognizant of accuracy. Performance times of the TMT-A and TMT-B are reported in seconds in Table 1.

Preseason – Hitting Assessment: Preseason hitting assessments were conducted at the University's indoor batting cage 24-hours after the initial laboratory visit. Each team's respective coach served as the pitcher for each team's participants. Batting performance was, in part, assessed using the HitTrax (HitTrax, InMotion Systems, LLC, Northboro, MA, United States). HitTrax outcomes included the ball's exit velocity (mph), launch angle (degrees) (i.e., relative to the transverse plane), and the ball's estimated distance of travel (feet). In addition, the Blast (Blast Motion, San Marcos, CA, United States), attached to the bat's proximal knob and, according to manufacturer instructions, provided the bat's peak swing velocity (mph) and rotational acceleration (mph).

All participants had prior task experience. Participants were instructed to select which pitch they chose to swing, allowing them to swing only at their chosen pitches. Each player completed

10 swings at pitches of their choice. Performance outcomes were recorded for each swing. Pitchers were positioned approximately 15 feet in front of the hitter behind a safety net. Pitch velocity was standard across all samples (M = 19.0 mph).

Non-Conference In-Game Hitting Performance: Participants had to obtain > 20 at-bats to be included in the analysis. Non-conference in-game (n = 14) statistics were obtained from publicly available box scores on the University's athletics webpage. Batting average (BA) was calculated by dividing the number of successful, safe hits by the total times at bat (i.e., hits/at-bats) (11). As noted by Albright, walks are not counted in batting averages (1). Therefore, we also utilized on-base percentage (OBP), the frequency a batter reaches base ([Hits + Walks + Hit by Pitch]/ Plate appearances). Finally, the slugging percentage (SLUG) was calculated by Total Bases/At Bats. SLUG represented the total number of bases a player records per at-bat.

Statistical Analysis
Pre-season hitting assessment outcomes are reported as means (M) and standard deviations (SD) in Table 1. All data were checked for and met the required statistical assumptions. Pearson's product correlations were calculated between all variables in Table 2. Following Fitt's Law, a Pearson's Partial Product was utilized to examine RT when controlling for response accuracy (7). SPSS Version 26.0 (SPSS Inc., Chicago, IL, USA) was used for all statistical analyses. Alpha was set at $p < 0.05$.

RESULTS

Table 1. Preseason Demographics and Pre-Season Hitting Assessment Outcomes

Performance Outcomes	Softball *M ± SD*	Baseball *M ± SD*
Age (years)	20.25 ± 1.28	20.56 ± 1.01
BMI (kg/m²)	22.79 ± 3.03	26.26 ± 2.38
ǂExit Velocity (mph)	60.79 ± 4.17	84.69 ± 3.79
◆Swing Velocity (mph)	57.01 ± 3.97	75.76 ± 3.61
ǂLaunch Angle (degrees)	19.01 ± 5.59	16.33 ± 3.24
ǂAvg. Distance of Travel (feet)	131.01 ± 23.97	216.41 ± 40.63
◆Rotational Acceleration (g)	10.19 ± 4.51	15.46 ± 3.17
TMT-A (seconds)	17.36 ± 4.42	15.27 ± 3.76
TMT-B (seconds)	41.36 ± 8.46	47.17 ± 11.77
Flanker Reaction Time (msec)	425.06 ± 35.86	403.33 ± 20.76
Flanker Accuracy (%)	0.94 ± 0.06	0.94 ± 0.03

Notes: Mean (M) and Standard Deviation (SD); ǂ HitTrax Machine (HitTrax, InMotion Systems, LLC, Northboro, MA, United States); ◆Blast (Blast Motion, San Marcos, CA, United States).

Participant demographic data and preseason hitting assessment's outcomes are outlined in Table 1. In addition to swing velocity *(r = .524)*, the ball's exit velocity *(r = .501)* and distance of travel *(r = .449)* were all positively correlated with the in-season batting average ($p < 0.05$) in Table 2.

In contrast, launch angle and rotational acceleration were not related ($p > 0.05$) [Table 2].

Table 2. Correlations between Non-Conference, In-Game Batting Statistics and Preseason Hitting Assessment Outcomes

Performance Outcomes	BA *r*	OBP *r*	SLUG *r*
Avg. Exit Velocity (mph)	.501*	.305	.450
Avg. Swing Velocity (mph)	.524*	.294	.413
Avg. Launch Angle (degrees)	.079	.036	-.276
Avg. Distance (feet)	.449*	.308	.368
Avg. Rotational Acceleration (g)	.160	.042	-.203

*Notes: Batting Average (BA), On-Base Percentage (OBP), Slugging Percentage (SLUG); *designates p < 0.05.*

When controlling for accuracy, no cognitive measure was statistically associated with in-game performance metrics ($p > 0.05$) [Table 3].

Table 3. Correlations between In-Game Batting Statistics and Cognitive Performance Outcomes

Performance Outcomes	RT *r*	TMT-A *r*	TMT-B *r*
BA	-.174	-.156	.038
OBP	-.202	.037	.046
SLUG	-.123	.180	.268

*Notes: Reaction Time (RT), Trail-Making Tests (TMT-A) (TMT-B), Batting Average (BA), On-Base Percentage (OBP), and Slugging Percentage (SLUG); * designates p < 0.05*

DISCUSSION

The present study sought to examine the relationship between preseason hitting performance (i.e., exit velocity, swing velocity, launch angle, hit distance, and rotational acceleration) with non-conference in-game batting performance (i.e., BA, OBP, SLUG). Additionally, this study investigated if preseason cognitive functions were related to non-conference in-game batting performance. Our data demonstrated a relationship between the ball's exit velocity and distance traveled to non-conference in-game BA. In addition, swing velocity was also related to non-conference in-game BA, whereas the ball's launch angle and the bat's rotational acceleration were not related to BA. These findings support previous work that reported exit velocity and swing velocity to be critical for batting performance (15, 20). It has been hypothesized that faster swing velocities allow for a greater delay in the initiation of the swing. However, this may be subject to pitch type and skill of the batter, relative to the pitcher, or vice versa. With enhanced time for perceptual-based decisions, the player may improve the initial coordination of the swing (2, 26). This may be, however, limited by how effective early information can be integrated into the batter’s swing instructions. Therefore, these data suggest that off-season preparation should be designed to maximize preseason swing velocity while maintaining performance (i.e., skill) of the coordinated swing.

However, a hitter's cognitive ability to skillfully process and integrate environmental information also shapes the swing's parameters. Currently, research examining both cognition outcomes and batting performance are limited. Previous research has noted how attention and visual recognition influence game batting performance (10, 13). In this research, participants attempted to predict pitch type from videos of skilled baseball pitchers at 80ms and 200ms after ball release. Albeit low, a correlation was found between the participant's predictions of pitch type and location (i.e., 200 milliseconds after ball release) and OBP (r = 0.23) and walk to strike ratio (r = 0.25) (13).

Moreover, a more recent investigation has reported that baseball players who skillfully process and match movement to visual information are skilled in laboratory measurements (e.g., computer tests with random mobile targets) (22). However, the results from this study did not find any significant relationships between cognitive variables and batting performance. Cognitive tasks without sufficient difficulty may prevent the differentiation between the athletes and result in a weaker correlation with batting average and other in-game performance metrics. Therefore, cognitive tasks with appropriate complexity should be investigated for relationships with cognitive-motor abilities.

Incorporating the simulated (i.e., preseason hitting assessment) and in-game batting performances was a key strength of this investigation. It is common for previous work only to utilize simulated games or practice (14, 18, 19). Researchers have highlighted the need for in-game performance metrics since swing mechanics may be altered in simulated hitting tasks to be more successful (9, 15). In another study examining cognition on in-game batting, the researchers reported that cognition only predicted 34% of batting average (15). In the present investigation, this outcome showed that cognitive abilities were not strongly related to batting performance. Seated cognition-only assessments, void of a coordinated whole-body response (e.g., a motor task such as swinging a bat), are too regressed to capture the relationship between cognition and in-game batting performance. Therefore, the utility of laboratory cognition tests should be evaluated to determine if they can adequately capture the cognitive-motor integration required during batting performance. Despite the plausible transfer, performance on the Flanker and TMT-A/TMT-B did not relate to in-game batting outcomes.

Overall, our findings demonstrate that preseason assessments of swing velocity, exit velocity, and averaged hit distance are associated with in-game batting performance. However, these findings should be implemented with caution. Acute attempts to swing harder are thus unaccustomed and may compromise acute task performance. Relative to the less skilled, skilled batters have an increased range of motion (ROM). However, that increased ROM is thought to be progressed gradually. Over time, ROM is optimized to coincide with the task's constraints. With practice, the optimized ROM can balance force generation with not unnecessarily compromising movement time. When a player attempts to reduce movement time by reducing distance the bat must travel, ROM is reduced and thus, the player compromises absolute force production. This reduced ROM may be a strategic advantage where the batter's goal is merely to put the ball into play (e.g., sacrifice fly). Adjusting for increased ROM by increasing the bat speed can result in swing variability and compromise coordination of the swing. Therefore, coaches and athletes can focus on training regiments that progressively augment swing velocity (i.e., ball exit velocity, bat swing velocity), factors our data demonstrates to be related to in-game BA.

Given task similarity, the studied sample was a combination of male baseball and female softball players. Although preseason cognitive outcomes were not significantly related to in-game BA, future research should consider the examination of cognitive assessments that have greater specificity to cognitive-motor requirements of the bat swing. It is possible the null findings were due to the lack of task specificity. Moreover, a limitation of in-game data are game situations where circumstantial at-bat outcomes are positive (e.g., advancing an on-base runner) despite the batter not reaching base. Future work may want to control or exclude such at bats. In addition, the relationship between cognitive functions and additional in-game performance outcomes, not examined in the present investigation (e.g., runs batted in) may also be of interest. Overall, future work may help enhance the translation of sports science research into sport and clarify the utility of cognitive measures and preseason hitting assessments for baseball and softball coaches alike.

REFERENCES

1. Albright SC. A statistical analysis of hitting streaks in baseball. JASA 88(424): 1175-1183, 1993.

2. Breen JL. What makes a good hitter? J health Phys Ed Rec 38(4): 36-39, 1967.

3. Burke T, McCargo T, Bell R, Burke D, Stafford C. Improved batting performance through a novel resistance training program. PM&R 1(1): 5, 2018.

4. Classe JG, Semes LP, Daum KM, Nowakowski R, Alexander LJ, Wisniewski J, Beisel JA, Mann K, Rutstein R, Smith M. Association between visual reaction time and batting, fielding, and earned run averages among players of the southern baseball league. Optometry 68(1): 43-49, 1997.

5. Eriksen BA, Eriksen CW. Effects of noise letters upon the identification of a target letter in a non-search task. Percept Psychophys 16(1): 143-149, 1974.

6. Feldhacker DR, Lucas Molitor W, Athmann A, Boell M, Kaiser A, Musch A, Willhite L. Efficacy of high-performance vision training on improving the reaction time of collegiate softball athletes: a randomized trial. JSMAHS 4(3): 6, 2019.

7. Fitts PM. The information capacity of the human motor system in controlling the amplitude of movement. J Exp Psychol 47(6): 381, 1954.

8. Fry A, Honnold D, Hudy A, Roberts C, Gallagher P, Vardiman P, Dellasega C. Relationships between muscular strength and batting performances in collegiate baseball athletes. The J Strength Cond Res 25: S19-S20, 2011.

9. Gray R, Cañal-Bruland R. Integrating visual trajectory and probabilistic information in baseball batting. Psychol Sport Exerc 36: 123-131, 2018.

10. Higuchi, T., Nagami, T., Nakata, H., Watanabe, M., Isaka, T., & Kanosue, K. Contribution of visual information about ball trajectory to baseball hitting accuracy. PloS One 11(2): e0148498, 2016.

11. Marchi M, Albert J. Analyzing baseball data with R. Chapman and Hall/CRC; 2018.

12. Miyaguchi K, Demura S. Relationship between upper-body strength and bat swing speed in high-school baseball players. J Strength Cond Res 26(7): 1786-1791, 2012.

13. Morris-Binelli K, Müller S, Fade P. Use of pitcher game footage to measure visual anticipation and its relationship to baseball batting statistics. J Mot Learn Dev 6(2): 197-208, 2018.

14. Müller S, Fadde PJ, Harbaugh AG. Adaptability of expert visual anticipation in baseball batting. J Sports Sci 35(17): 1682-1690, 2017.

15. Nasu D, Yamaguchi M, Kobayashi A, Saijo N, Kashino M, Kimura T. Behavioral measures in a cognitive-motor batting task explain real game performance of top athletes. Front Sports Act Living 2: 55, 2020.

16. Navalta JW, Stone WJ, Lyons TS. Ethical issues relating to scientific discovery in exercise science. Int J Exerc Sci 12(1): 1-8, 2019.

17. Nielsen D, McGown C. Information processing as a predictor of offensive ability in baseball. Percept Mot Skills 60(3): 775-781, 1985.

18. Paull G, Glencross D. Expert perception and decision making in baseball. Int J Sport Psychol 1997.

19. Renshaw I, Fairweather MM. Cricket bowling deliveries and the discrimination ability of professional and amateur batters. J Sports Sci 18(12): 951-957, 2000.

20. Szymanski DJ, DeRenne C, Spaniol FJ. Contributing factors for increased bat swing velocity. J Strength Cond Res 23(4): 1338-1352, 2009.

21. Taliep MS, Prim SK, Gray J. Upper body muscle strength and batting performance in cricket batsmen. J Strength Cond Res 24(12): 3484-3487, 2010.

22. Tochikura I, Sato D, Imoto D, Nuruki A, Yamashiro K, Funada R, Maruyama A. Baseball players' eye movements and higher coincident-timing task performance. Percept Mot Skills skills 127(3): 571-586, 2020.

23. Tombaugh TN. Trail making test a and b: normative data stratified by age and education. Arch Clin neuropsychol 19(2): 203-214, 2004.

24. Voss MW, Prakash RS, Erickson KI, Basak C, Chaddock L, Kim JS, Alves H, Heo S, Szabo A, White SM. Plasticity of brain networks in a randomized intervention trial of exercise training in older adults. Front Aging Neurosci 2: 32, 2010.

25. Wasserman EB, Abar B, Shah MN, Wasserman D, Bazarian JJ. Concussions are associated with decreased batting performance among major league baseball players. Am J Sports Med 43(5): 1127-1133, 2015.

26. Welch CM, Banks SA, Cook FF, Draovitch P. Hitting a baseball: a biomechanical description. J Orthop Sports Phys Ther 22(5): 193-201, 1995.