Effects of Various Warm-Up Devices and Rest Period Lengths on Batting Velocity and Acceleration of Intercollegiate Baseball Players

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Abstract

Wilson, JM, Miller, AL, Szymanski, DJ, Duncan, NM, Anderson, JC, Alcantara, ZG, Bergman, CJ, and Morrison, TJ. Effects of various warm-up devices and rest period lengths on batting velocity and acceleration of intercollegiate baseball players. *J Strength Cond Res* 25(X): 000–000, 2011—It is common among competitive baseball players to swing bats while in the batter's box in an attempt to improve their batting performance. Players use bats of different weights during this time, and only a few studies have evaluated the optimal bat weight to increase performance. Previous studies have not investigated the optimal rest period after a warm-up with bats of varying weights. Therefore, we tested the peak bat velocity of 16 National Collegiate Athletic Association Division II intercollegiate baseball players at 1, 2, 4, and 8 minutes, after warming up with bats of 5 different weights. Measured variables were peak bat velocity at peak acceleration (PVPA), peak bat velocity of the swing (PV), peak acceleration (PA), and time to reach peak acceleration (TPA) using a chronograph, which measured the batting velocity in real time every 10 milliseconds throughout the swing. A repeated measure analysis of variance was run to assess group, time, and group by time interactions. If any main effects were found, a Tukey post hoc was employed to locate differences. There were significant ($p \leq 0.05$) time effects for PVPA, PV, and PA but not for TPA. The PVPA, PV, and PA all increased over time, peaking from 4 to 8 minutes. There were no significant differences in any of the variables among the 5 bat weights used in the warm-up ($p > 0.05$). However, there were significant differences in PVPA, PV, and PA after 2, 4, and 8 minutes of rest compared with the preexperimental warm-up and 1-minute post–warm-up. From a practical standpoint, batters should warm up early and quickly in the batter's box to maximize the amount of recovery time before they swing at the plate. In addition, batters may want to take their time getting ready at the plate or take some pitches while at-bat in an attempt to maximize performance. Alternatively, the data imply that pitchers should throw their fastest pitch near the beginning of the at-bat to correspond with the potentially slower bat speeds of the batter.

Key Words baseball, warm-up, bat speed, bat velocity, bat acceleration

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Introduction

Hitting a baseball ranks as one of the most complex competitive skills, regardless of the sport (18). The reason for this is batters have between 400 and 500 milliseconds to track the ball, decide to swing, and then swing, if they are to be successful. It requires nearly 300 milliseconds to visually process the pitch and to swing the bat, leaving just >100 milliseconds for decision time for the average batter (1). Because of physiological constraints, it is not possible to speed up the neural processing of the ball leaving the pitcher's hand. However, if batters were to increase their bat velocity, thereby decreasing their swing time, they would gain a competitive advantage by increasing their available time for making a decision.

Baseball players have attempted to increase their bat velocity through different warm-up routines on-deck. Players use heavier bats, multiple bats, weighted donuts, weighted implements, and resistance devices in an attempt to obtain greater bat velocity. However, relatively few studies have attempted to examine the ideal warm-up bat weight for enhancing velocity. DeRenne et al. (5) tested high school baseball players with 13 different warm-up implements ranging from 652 to 1,446 g (23–51 oz.) and found warming

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Journal of Strength and Conditioning Research

up with bats between 765 and 964 g (26–34 oz.) produced the greatest velocities swinging a standard bat. These results were supported in a more recent study, which demonstrated that a 764-g (28-oz.) lead donut added to a standard (normal) baseball bat (33 in., 34 oz.) significantly altered swing pattern (14), resulting in a decline in velocity with the standard bat. Furthermore, Montoya et al. (9) found swinging a 1,559-g (55-oz.) bat during warm-up caused a bat velocity of a 33-in., 31.5-oz. bat to decline. Most recently, Szymanski et al. (15) found that 10 different warm-up devices ranging from 623.7 to 2,721.5 g (22–96 oz.) did not change the mean bat velocity of a 33-in., 30-oz. standard baseball bat in Division I intercollegiate players. They suggested that high-level athletes could use any of the 10 warm-up devices on-deck and maintain their bat velocity.

Interestingly, the previous studies have not examined the importance of rest periods between warming up and achieving maximal bat velocity. All previous studies tested bat velocity with no more than a minute of rest. Investigating rest period may demonstrate that batters swinging heavy bats exhibit postactivation potentiation, which is a phenomenon whereby muscular performance is enhanced acutely by a previous activity that is executed at a relatively higher intensity (e.g., a 1 repetition maximum back squat performed before a vertical jump) (17). For example, Kilduff et al. (6) examined countermovement jump peak power, immediately after a heavy back squat in professional rugby players and at 4, 8, 12, 16, and 20 minutes. They found that peak power declined immediately after but increased and peaked at 8–12 minutes, suggesting an ideal time period for potentiation to occur in a given explosive activity. It is plausible that batters would not see potentiation in their swing until several minutes after swinging a heavier bat, thus explaining the lack of increase or decrease in bat velocity observed in previous studies. Additionally, Dawson et al. (4) suggested replenishment of the adenosine triphosphate-phosphocreatine system has a half-life of 3–5 minutes and as force requirements of a given warm-up increase, the use of substrate also increases. Thus, it is likely that general fatigue and depletion of substrate with heavy bats require greater rest between the actual warm-up and use of the standard (test) bat. Otsuji et al. (10) demonstrated indirect support for this contention. They found that varsity male softball and baseball players demonstrated declines in velocity in the first swing after warming up with a heavy bat (standard bat with donut ring totaling 1,720 g or 60 oz.), yet the 4 following swings, with 15 seconds rest between the swings, demonstrated no declines in velocity. Kim and Hinrichs (8) found a significant decrease of bat velocity for the first swing 2 minutes after warm-ups with a 885-g (31-oz.) standard bat and 1,452-g (51-oz.) overweighted bat. It is therefore possible that the fatigue from swinging the heavy bat was decaying, thus allowing bat velocity to improve. However, Szymanski et al. (14) did not report any differences in the 3 bat swing velocities with 20 seconds of rest between each swing used to report bat velocity in their study. Hence, the mean bat velocity of the 3 swings was used to represent each player's bat speed for each condition. To date, no study has investigated what the ideal rest period is after warming up with bats of varying weights. Therefore, the purpose of this study was to investigate the effects of 5 differently weighted warm-up bats on batting velocity and acceleration of a standard bat after different rest intervals.

Methods

Experimental Approach to the Problem

This investigation was designed to compare the effects of swinging 5 differently weighted bats in the on-deck circle on baseball bat velocity and acceleration with an 83.8-cm, 850.5-g (33-in., 30-oz.) standard aluminum baseball bat. Further, we wanted to investigate the effects of different rest intervals on these variables. All the subjects were tested on 5 separate days and randomly assigned to 1 of the 5 experimental warm-up bats each day that were classified as "light," "standard" (normal), "moderately heavy," "heavy," and "very heavy." The bat weights were selected to represent a standard or normal baseball bat weight, 1 slightly lighter

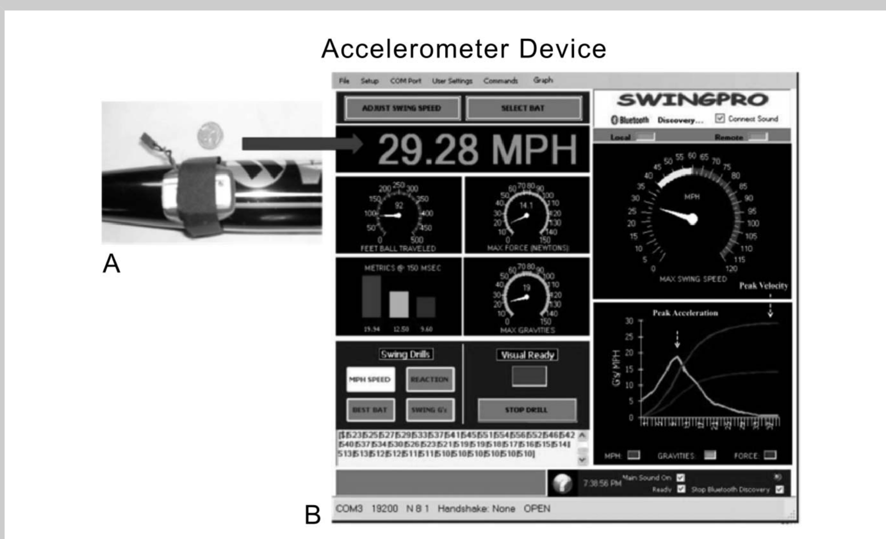

Figure 1. A) Baseball accelerometer placement on the bat. B) Graphic depiction of peak acceleration and peak velocity from the accelerometer software.

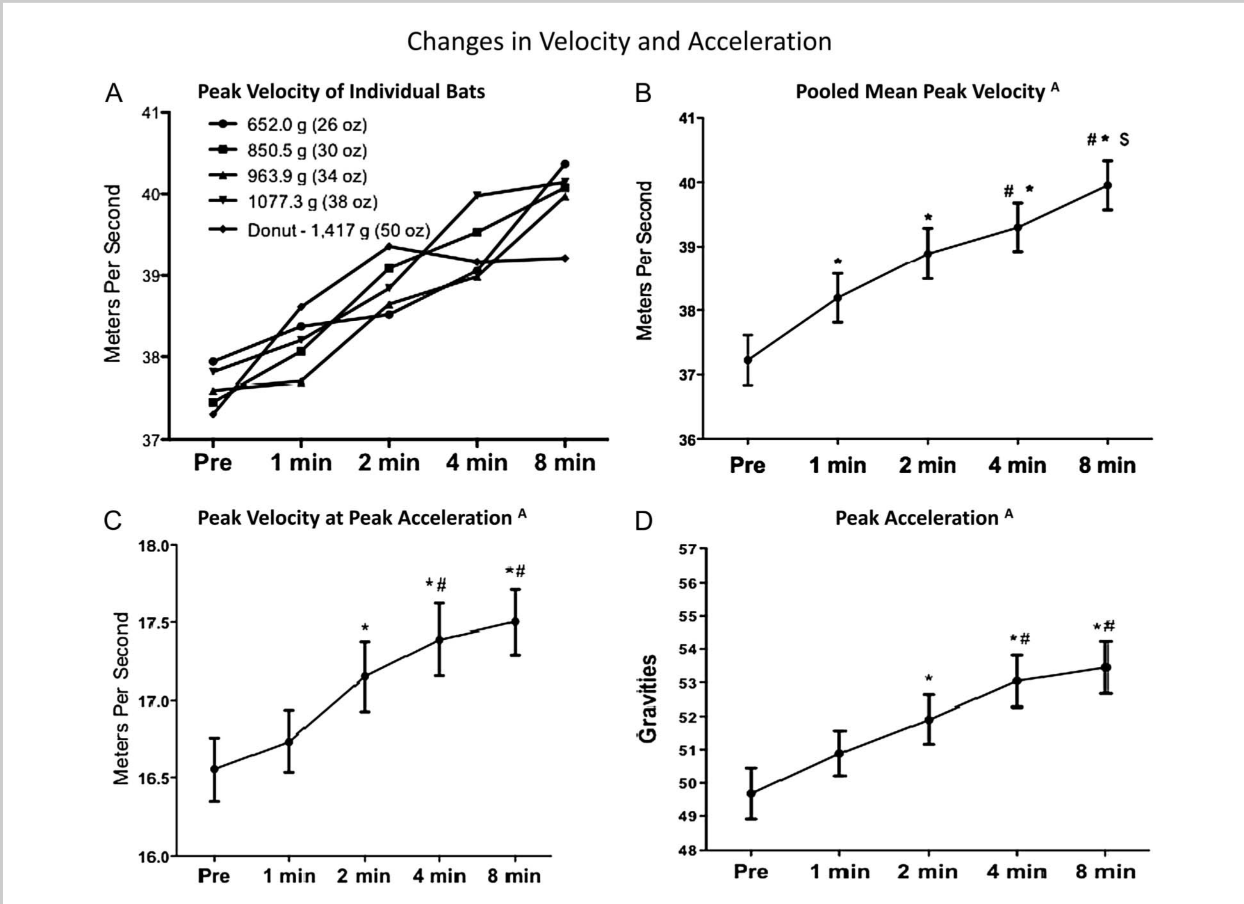

Figure 2. A). Peak velocity of differently weighted experimental bats after 5 rest intervals. B) Pooled mean peak velocity after 5 rest intervals. C) Pooled mean peak velocity at peak acceleration after 5 rest intervals. D) Pooled mean peak acceleration after 5 rest intervals. "A" Signifies a main time effect ($p \leq 0.05$); *significantly different from pre ($p \leq 0.05$); #significantly different from 1 minute ($p \leq 0.05$); $significantly different from 2 minutes ($p \leq 0.05$). Pre = baseline data. Pooled mean peak velocity was derived from the average of the peak values across all the 5 days with the 30-oz. bat, swung at pre, and at 1, 2, 4, and 8 minutes after the warm-ups.

than the standard weight, 2 bats progressively heavier than the standard weight, and a bat with an added weight typically used in baseball that makes the standard bat much heavier. Each session began by establishing a subject's baseline bat velocity (peak velocity) followed by a 10-minute rest period. After the rest period, the subjects swung the assigned experimental bat a total of 5 times, 1 every 20 seconds, to allow time for the chronograph to process acceleration and velocity. After the warm-up swings with the experimental bat, the subjects swung the standard baseball bat after 1, 2, 4, and 8 minutes had elapsed to evaluate the effect of time on peak bat velocity of the swing (PV), peak bat velocity at peak acceleration (PVPA), peak bat acceleration (PA), and time to
AU2 reach peak acceleration (TPA).

Subjects

Sixteen NCAA Division II baseball players, (age = 20.0 ± 2 years, body mass = 88.3 ± 15.8 kg, playing experience = 13.5 ± 3.5 years) volunteered to participate in the study. Only position players (no pitchers) were used in this study. An Institution Review Board approved the study for human subjects, and written informed consent was obtained from each subject before any testing.

Instrumentation

The SwingProPlus chronograph (Athnetix, Inc., Arcade, New York, NY, USA) measured peak acceleration in gravities and newtons, velocity in miles per hour (converted to meters per second) every 10 milliseconds, allowing us to obtain velocity at peak acceleration and TPA (Figure 1B). This F1
device consisted of a transceiver positioned 51 cm (20 in.) from the bottom knob of a bat (Figure 1A). The 19200 software was used to record and measure all variables. The transceiver itself consisted of an analog 1-axis high-G accelerometer and a microcontroller. During each trial, when an individual swing was started, the microcontroller recorded and saved data at 10-millisecond intervals for 400 milliseconds. The SwingProPlus chronograph measured the AU3
greatest bat velocity, which occurred during the swing (PV), the greatest differences in velocity between 2 10-millisecond

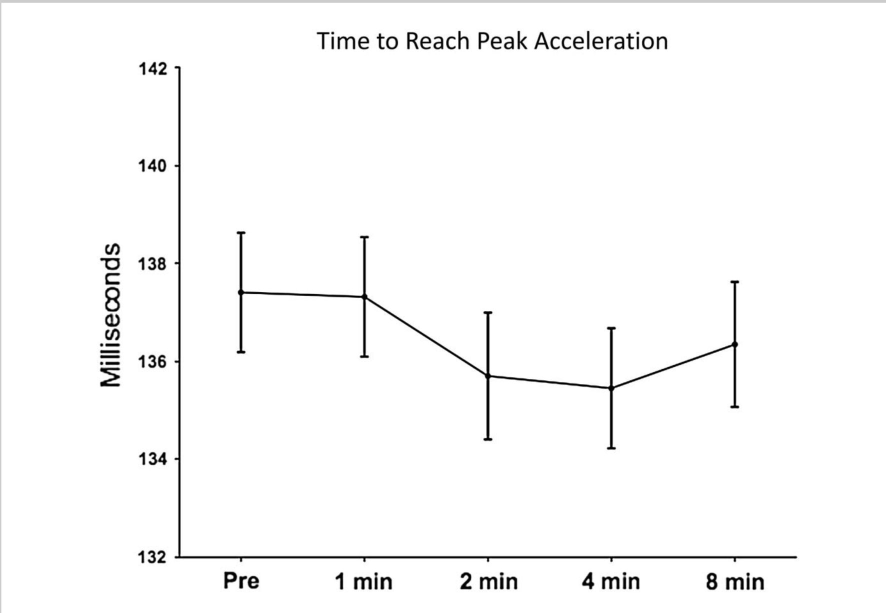

Figure 3. Time to reach peak acceleration after 5 rest intervals after a warm-up.

sampling time points divided by time (PA) and the velocity at the instance peak acceleration had been reached (PVPA). The TPA was also recorded. Variables were recorded in real time every 10 milliseconds throughout the swing to assess the effects of the warm-up devices on these variables at the different time periods. The mean test–retest reliability of PV, PA, and PVPA were all $r > 0.91$ for the 3 control swings over the 5 test days.

Procedures

All the players were medically cleared by the university athletic training staff before being involved in this study. This was provided by the university before the athletes could participate in National Collegiate Athletic Association athletics. During the initial session, the subjects answered a modified Physical Activity Readiness Questionnaire (PAR-Q) to assess their health. If they progressed through the athletic training and PAR-Q screenings, they were considered healthy to participate in this study. The subjects also completed a Descriptive Data Questionnaire, which described their playing and exercising experiences. The procedures for testing bat velocity and the various warm-up devices used in this study were verbally explained and demonstrated to the subjects by the prinicipal investigator. To control for outside influences, all the participants were instructed to consume a normal diet and fluids and to abstain from additional resistance training and taking ergogenic aids during the study. Furthermore, the athletes were asked to maintain normal sleep habits (6–8 hours per night).

After the initial session, all 16 subjects were tested on 5 separate days, at the same time of the day, within a 2-week period and randomly assigned to 1 of the 5 experimental warm-up bats each day during the off season. Proper bat swings were demonstrated and verbally explained by the principal investigator.

Warm-Up Devices. The 5 different warm-up devices used in this study were a standard 83.8-cm, 850.5-g (33-in., 30-oz.) DeMarini Voodoo (DeMarini Sports, Hillsboro, OR, USA) aluminum baseball bat, 3 overweighted implements that included a standard 33-in. baseball bat with 113.4 g (4 oz.) of lead tape added to the center of percussion (sweet spot) for a total of 963.9 g (34 oz.), a standard 33-in. baseball bat with 226.8 g (8 oz.) of lead tape added to the center of percussion for a total of 1,077.3 g (38 oz.), and a 567.0-g (20-oz.) donut added to a standard bat totaling 1,417.5 g (50 oz.). The underweighted bat was an 83.8-cm, 652.0-g (33-in., 23-oz.) Louisville Slugger FP12C Catalyst (Hillerich & Bradsby, Louisville, KY, USA) aluminum softball bat with 85.0 g (3 oz.) of lead tape added to the center of percussion for a total of 737.1 g (26 oz.). The reason why a commercially available very light warm-up device (10-oz. plastic bat) was not used in this study was because it was significantly shorter in length (63.5 cm, 25 in.) compared with the 83.8-cm (33-in.) warm-up bats used in this study.

Warm-Up and Testing Protocol. Upon entering the laboratory, a standardized warm-up procedure, reported in previous research (4,14), was followed by all the subjects for each experimental trial. These procedures included having the players perform overhead and behind the back dynamic stretching exercises with each warm-up device for 1 minute as commonly done by players in the on-deck circle during an actual game. The subjects were then instructed to swing the 83.8-cm, 850.5-g (33-in., 30-oz.) standard bat 3 times, with full force as though they were warming up in the batter's box, separated by 30 seconds to establish their baseline bat velocity. The subjects were then given 10 minutes of rest, where they sat quietly without interaction with the investigator before swinging the assigned experimental bat 5 times separated by 20 seconds between swings. Twenty seconds was selected as the necessary time for the SwingProPlus chronograph to calculate and store data for the measured variables. During the 20 seconds of rest, the players could not take any practice swings between trials. After warm-up with experimental bats, the subjects swung the standard 30-oz. baseball bat at 1, 2, 4, and 8 minutes.

Statistical Analyses

AU4 A 5 × 5 (condition × time) repeated measures analysis of variance was used to test for significant differences of PV, PA, PVPA, and TPA. A Tukey honestly significant difference post hoc test was used to locate the significance between time points if there was a main group or time effect. All significance was accepted at $p \leq 0.05$. All statistical procedures were carried out on Statistica (StatSoft®, Tulsa, OK, USA).

Results

There were no significant weight effects on any of the F2 variables associated with velocity or acceleration (Figure 2A). Therefore, we pooled the data when looking for time effects by taking the average of the peak values across all the 5 days with the 30-oz bat, swung at pre, and at 1, 2, 4, and 8 minutes after the warm-ups. Our analysis revealed there were no differences in the baseline bat velocity within the subjects across the 5 days. However, with the exception of TPA F3 (Figure 3), there were significant time effects for all the variables measured (Figures 2B–D, $p \leq 0.05$). Post hoc analysis revealed that PVPA and PA were not significantly different from baseline values at 1 minute but were significantly greater at 2 minutes. Moreover, both values increased significantly above the 2-minute time period at 4 and 8 minutes. Peak batting velocity showed significant increases above baseline at 1 and 2 minutes, with an additional increase occurring at 4 and 8 minutes ($p \leq 0.05$).

Discussion

To date, this is the first study to investigate specific rest periods after warm-up swings and the third study to demonstrate a velocity time effect after warm-up swings with various implements on a standard baseball bat. In 2002, Otsuji et al. (10) reported that the first swing post–warm-up significantly decreased (3.3%), whereas by the second swing, the velocity returned to the level of the control condition (32-oz. bat) after swinging a standard bat with a donut ring (1,720.0 g or 60 oz.) added to it. In 2008, Kim and Hinrichs (8) reported that in experienced high school and college baseball players, the bat velocity of the first swing 2-minute post–warm-up with a 885-g (31-oz.) standard bat was significantly lower than that of some subsequent swings after using a standard bat and a standard bat with a donut ring (1,452 g or 51 oz.) as a warm-up implement. They recommended that hitters take a 3-minute break to maximize performance. The results of this study suggest that regardless of the warm-up weight of the bat, Division II baseball players should try to rest at least 2 minutes between warming up and batting to maximize velocity and acceleration while using a standard 83.8-cm, 850.5-g (33-in., 30-oz.) bat. The results of the standard bat PV after using different weighted bats during warm-up were in agreement with those of the most recent research of Szymanski et al. (15). The observed PV at our 2-minute mark for the standard bat after swinging all warm-up implements was nearly identical to all the mean bat velocities reported in this most recent study (14). Albeit slight, the PV of individual bats at baseline (pre) and at the 1-minute mark was lower (±2.0 and 1.5 $m \cdot s^{-1}$) in our study group than all the standard mean bat velocities listed in the previously mentioned study after completing the various warm-ups (15). These differences could be attributed to where bat velocity was being measured. In this study, bat velocity was measured 20 in. from the bat's knob, whereas bat velocity in the Szymanski et al. (15) study was measured at the bat's end cap (33 in. from the bat's knob). Bat velocity will be faster at the bat end compared with that closer to the knob. Other possible reasons for bat velocity variability could be the 2 warm-up protocols, the time taken between post–warm-up swings, or the instrumentation itself. Furthermore, this could be because they tested Division I players (15) and we tested Division II players. The primary and novel findings of our study were that the greater amount of rest time after warming up with various weighted implements produced a significantly greater bat velocity and acceleration over time. Moreover, these effects were independent of the warm-up implement used.

According to Adair (1), it takes approximately 150 milliseconds from the beginning of forward movement in the swing phase until bat-ball contact. Peak velocity at peak acceleration occurs at approximately 140 milliseconds placing it, theoretically just before bat-ball contact. Therefore, considering applicability to baseball players, this is likely the most important variable measured in our study. Our findings that baseball players did not become significantly faster until 2 minutes after warm-up and peaked at 4–8 minutes are in agreement with those of past research, which used explosive movements. Specifically, Kilduff et al. (6) found that countermovement jump power in elite rugby players did not peak until 8 minutes after a warm-up with back squats. It is likely that their results, and ours, are explained by Banister's Fitness Fatigue model (3). This model suggests that performance is a balance between fitness and fatigue and that the former changes last longer than the latter. It is therefore likely that fatigue build-up that occurred during the warm-up dissipated as more time elapsed between swings until velocity reached its peak values.

It is intriguing to note that our baseball players obtained warm-up effects, independent of the batting implement used. In fact, in a more extensive comparison of warm-up batting implements (10 different conditions), Szymanski et al. (15) found no significant differences on batting velocity of NCAA Division I baseball players. Therefore, the combined effects of our studies seem to suggest that NCAA Division I or II baseball players can select whichever bat they prefer during a given warm-up. However, the results from DeRenne et al. (5) in high school baseball players demonstrated their greatest velocities when warming up within ±12% of the standard bat weight. It is conceivable that our athletes had an overall greater skill level and perhaps were more resistant to the fatigue from heavier bats because of greater maturation status and potentially greater upper and lower body strength because of years of resistance training. It would be interesting to conduct a similar study with high school players to see if they would demonstrate equal velocities despite warm-up implements used, if given a longer rest period. Perhaps, we would see fatigue dissipate with time, leading to no difference between warm-up implements at the 4- or 8-minute mark.

The results of this study that PV (bat velocity) was not significantly different immediately after swinging any of the warm-up implements are also statistically similar to those of Reyes and Dolny (13). They had Division III college baseball players swing 9 different combinations of "light" (794 g or 28 oz.), "standard" (850 g), and "heavy" (1,531-g or 54-oz.) bats over 9 days. They did not find any weighted bat warm-up protocol that significantly increased standard bat velocity. Their purpose was to evaluate whether complex training changed bat velocity. The intent of using a heavier set in complex training is that skeletal muscle has been shown to be more explosive after completing near-maximal contractions (2). They were the first researchers to change the warm-up combination in this way before a hitter stepping into the batter's box. Similar to our results with college baseball players, Kim and Hinrichs (7) also demonstrated that there was no significant difference in "standard" bat velocity after warming up with a wiffle bat (113 g or 4 oz.), "standard" bat (909 g or 32 oz.), or "standard" bat with a donut ring (1,477 g or 52 oz.) for 8 male and 5 female subjects ranging in age from 22 to 28 years, or for 20 competitive high school and college baseball players who swung a "standard" bat (885 g or 31 oz.), "standard" bat while wearing an overweighted arm device (2,327 g or 82 oz.), and "standard" bat with a donut ring (1,452 g or 51 oz.) (8).

Practical Applications

For the batter, it is important to assess when batting velocity peaks after a given warm-up. The primary findings of this study were that velocity peaked at 4–8 minutes after a warm-up with various weighted implements ranging from 26 to 50 oz. Because an average at-bat takes approximately 75–80 seconds (calculated from 2010 Major League Baseball data [11] of 3.85 pitches per at-bat plus the Potteiger et al. [12] data of 20 seconds of rest between pitches), it is recommended that batters should complete their warm-up swings as soon as they step into the on-deck circle (1–2 minutes before the start of the at-bat of the player ahead of him) and then simply use their time in the on-deck circle to practice timing the pitcher and watch the type and sequence of the pitcher's pitches. Furthermore, we suggest that coaches have their hitters practice this approach during intrasquad games, because this is relatively new data being presented.

AU5 From a hitter's prospective, baseball coaches usually instruct their players to take some pitches during their at-bat to "see what the pitcher is throwing" (type of pitches and throwing velocity), and to increase the number of pitches thrown by the pitcher in an attempt to get them out of the game sooner. Currently, in baseball, there is a major concern of having a pitcher throw too many pitches in a game because coaches do not want to contribute to a potential overuse arm injury, such as rotator cuff tear or medial collateral ligament tear in the throwing arm. It is generally accepted by professional, college, and high school baseball coaches to not have pitchers throw $>$120 pitches per game. Based on the results of this study, bat velocity is greater when a hitter takes more time after performing warm-up swings, suggesting that after 2 minutes in the on-deck circle, or taking some pitches immediately after warming up, a player's bat velocity is greater than in immediately post–warm-up with any of the 5 implements used in this study. This practice could increase the hitter's chances of being more successful because a greater bat velocity means that a hitter will arrive at bat-ball contact sooner (swing time decreases), thus potentially enabling the hitter to increase his contact average (16). Additionally, this will give the hitter more time to see a pitched ball (increase decision time), enabling the hitter to make a successful decision whether to swing at a pitched ball (16). Finally, this practice will potentially increase the number of pitches thrown by a pitcher and achieve the coaches' goal of getting a pitcher out of the game sooner.

For the pitcher and the catcher, it is important to be aware that a batter's swing may become faster as the at-bat continues as long as the hitter does not swing early in the at-bat. Therefore, they might choose the type of pitch they throw accordingly. For example, it is suggested that pitchers throw their fastest pitch at the beginning of an at-bat because batters may not yet be fully recovered from the warm-up and be able to produce their greatest bat velocity.

For the researcher, we suggest repeating our protocol with professional players and little league through high school players. It is possible that in less skilled, less fatigue resistant players that time to reach peak velocity may differ from our results and comparatively between different warm-up bats (e.g., within vs. outside of the ±12% standard weight). However, for professional athletes with greater fatigue resistance, time to reach peak velocity may occur at an earlier time point. This remains to be investigated.

Acknowledgments

The authors would like to thank Athnetix Inc. for donating several accelerometers to our laboratory, to assist in the completion of the project. The authors would also like to thank Michael Cannata and Chris Baietto for their help in the study.

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