RELATIVE EFFECTS OF WARM-UP WITH UNDERWEIGHT, OVERWEIGHT, AND STANDARD WEIGHT BATS ON BAT VELOCITY AND SEGMENTAL MOVEMENT

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The purpose of this investigation was to compare the effects of warming up with bats of varying weight on pre-impact bat linear velocity and on the timing and extent of segmental movement during the baseball swing. Sixteen varsity high school baseball players volunteered as subjects for the study. The subjects were videotaped from overhead while hitting wiffle balls off of a hitting tee following each of three standardized warm-up routines using bats of varying weight. Each subject performed 6-10 swings following each warm-up condition with the three best swings per condition selected for analysis. Pre-impact velocity of the impact point of the bat (measured electronically) and the timing and extent of segmental movements were compared. No significant intergroup differences for either pre-impact bat linear velocity or the segmental kinematic variables were found.

KEY WORDS: baseball, hitting, warm-up, segmental, velocity, kinetic-link.

INTRODUCTION: The movements involved in a successfully executed swing proceed sequentially, with the pelvic girdle, trunk, arms, hands, and bat being moved forcefully toward the incoming ball (Hay, 1993). Through the application of the kinetic-link principle, the momentum generated by the rotation of the pelvic girdle is passed on to the adjoining segments, resulting in a progressive increase in the velocity of each successive segment (Kreighbaum & Barthels, 1996). When the momentum is effectively transferred to a smaller mass, the velocity of the smaller mass will tend to increase because of the principle of conservation of momentum. In the case of baseball hitting, players who demonstrate proper sequential movement can develop greater momentum and attain a greater maximum linear bat velocity, possibly leading to increased performance at the plate.

The effect of warm-up overload and underload on bat swing velocity has previously been researched. DeRenne et al. (1992) concluded that the greatest bat velocity was achieved by a warm-up with implements having a weight identical or very close to the bat used in competition. Additionally, DeRenne (1982), DeRenne et al.. (1992), and Southard & Groomer (2003) concluded that the popular donut ring has a negative impact on bat swing velocity. Also, only one study has been found (Southard & Groomer, 2003) examining the effects of the relative weights of warm-up implements on the mechanics of the swing phase of hitting. They reported a disruption in the timing of the leading elbow and wrist joint actions due to the overweight warm-up. However, none of these studies involved measurement of the pre-impact bat velocity during a targeted swing, making generalizations of results to field conditions questionable. The purpose of this study was to examine the relative effects of warm-ups with underweight, standard, and overweight bats on bat velocity and segmental movements with targeted swings.

METHODS: Sixteen male varsity baseball players ranging in age from 16 to 18 years from a Midwestern high school interscholastic baseball team volunteered to participate in the study. Subjects were required to have had a minimum of 40 appearances at bat in interscholastic competition or intercity competition during the previous season. Informed consent was obtained from all subjects and their parents prior to participation.

Prior to each testing session, contrasting markers were painted to indicate the location of the shoulder, leading elbow, and leading wrist joints as viewed from overhead. Also, pelvic girdle and trunk belts with rays projecting posteriorly were worn to indicate orientation of the pelvic girdle and trunk in the horizontal plane when viewed from overhead. Contrasting rings of tape were placed on the handle, center of percussion (COP), and a point .15 m toward the knob end of the standard bats used for all trials. Each testing session was preceded by a warm-up with either an underweight (32 in, 22 oz), standard weight (32 in, 29 oz; or 33 in, 30 oz), or overweight (standard weight bat + 28 oz donut ring) bat. The moment of inertia (MOI) about the impact axis (.168 m from knob end) and distance of the COP from the knob end of the bats used in the study as determined through use of the compound physical pendulum method using a specially constructed clamping assembly of the three bats used in study (Noble, 1985) were: (1) underweight bat - .0973 kgm2, .508 m; (2) smaller standard bat - .1328 kgm2, .537 m; and (3) larger standard bat - .1564 kgm2, .589 m. The MOI for the smaller and larger standard bats about the impact axis after applying the 28 oz (7.8 N) donut ring was .2257 kgm2, .2565 kgm2, respectively. All bats used in the study were constructed of high performance aluminum alloy. All subjects used the same bat during regular practice and games that they used during the standard weight warm-up. The warm-up protocol included one minute of stretching, three swings with the warm-up implement, and then two swings with each subject's standard weight bat. Bat weight selection and protocol for the warm-up conditions were selected to approximate field conditions as closely as possible. Subjects then hit official baseball-sized wiffle balls off of a hitting tee until five error-free bat velocity recordings were taken with a photo sensing electronic timer. The photo sensing timer and a hitting tee were placed so that the velocity of the impact point was measured during the final .15 m of bat movement prior to impact. Both tee height and distance reference was changed for each subject. Trials were videotaped at 120 fps with a shutter speed of .004 s with a digital video camera (JVC GR-DVL 9800). The camera was mounted directly overhead 4.27 m above the hitting tee and vertically oriented so that movements in the horizontal plane could be accurately viewed and measured. The angular displacement, peak angular velocity, and timing of peak angular velocity of the pelvic girdle, trunk, shoulder girdle (vector from the right shoulder joint to the left shoulder joint), leading arm, leading forearm, and bat were measured from videotaped records using the Hu-M-An software program (HUman Movement ANalysis Program, Version 3.0, HMA Technology Inc., King City, Ontario Canada). Means of the three best trials were used as the criterion value for each condition. Each subject participated in three hitting bouts following warm-up with each of the three warm-up bats during one testing session. The order of warm-up bat weight condition was rotated across subjects using a balanced Latin square method. A repeated measures ANOVA was used for all intergroup comparisons with an alpha level of .05.

RESULTS: Figure 1 presents pre-impact bat velocity means and standard deviations for each warm-up condition. Intergroup differences were not significant (F=. 46, p<. 638).

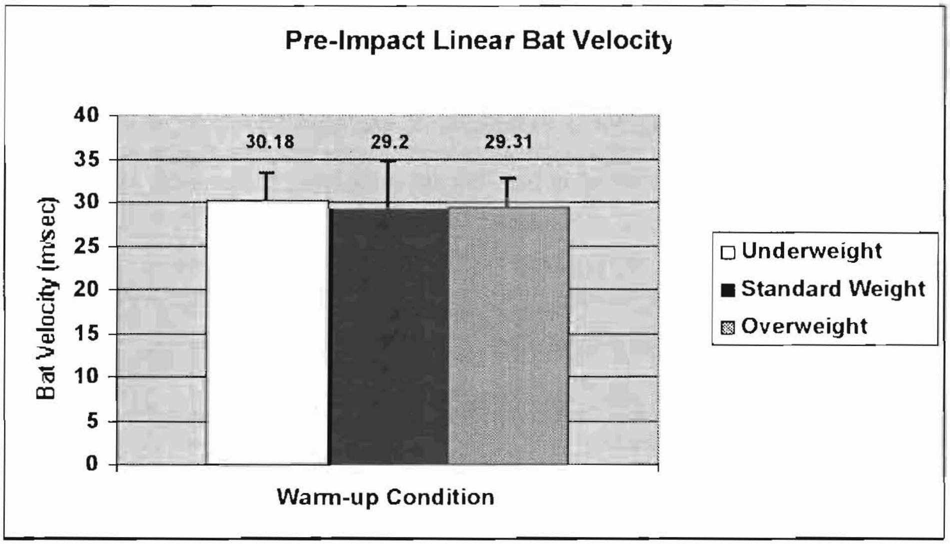

Figure 1: Mean pre-impact bat velocity for each warm-up condition (error bars indicate SD's; warm-up treatment groups were not significantly different).

Table 1 provides means and standard deviations for segmental movements with standard weight bats. ANOVA revealed no significant differences among the three warm-up conditions for angular displacement, peak angular velocity, and timing of peak angular velocity relative to impact for all of the segments.

Table 1 Segmental movement for swings with standard weight bats (means + SD; N=16).

Segment	Angular Displacement (^{0})	Peak Ang Vel (^{0}•sec^{-1})	Time of Peak Ang Vel Prior to Contact (sec)
Pelvic girdle	100.39+12.12	691.39+79.91	.081+.020
Trunk	115.9+14.14	850.63+95.16	.063+.019
Shoulder girdle	117.6+13.72	948.76+99.20	.046+.019
Leading arm	134.55+19.84	1142.44+162.07	.062+.010
Leading forearm	134.01+11.84	1206.00+154.52	.054+.020
Hands and bat	225.79+18.22	2405.50+186.24	-.003+.008

DISCUSSION: The finding of no effect of warm-up bat weight on bat velocity is inconsistent with those of previous studies. DeRenne et al.. (1992) conducted a study to determine which of 13 weighted batting warm-up implements would produce the greatest bat velocity in subsequent trials. As in our study, high school varsity baseball players volunteered as subjects. The greatest bat velocity was achieved by a warm-up with implements having a weight identical or very close to the standard 30 oz bat, and there was a trend of decreasing velocities subsequent to warm-up as players moved farther from the standard weight bat (DeRenne et al., 1992). In a similar study using collegiate and semi-professional baseball players as subjects, DeRenne (1982) reported a negative effect on bat velocity when using a donut ring during warm-up, and a positive effect on bat velocity when using a slightly lighter bat (27 oz, 7.5 N) during warm-up. Southard & Groomer (2003) also found lowest bat velocities following warm-up with an overweight bat. Also, linear bat velocities for the warm-up bat conditions used in our study were higher than those reported by DeRenne et al. (1992) and Southard & Groomer (2003). These differences are likely due to differences in procedures used to measure bat velocity. Neither DeRenne et al. (1992) nor Southard & Groomer (2003) employed targeted swings in their studies. Thus, these measurements were not pre-impact velocities, but peak velocities during a "dry swing". Also, their measurement procedures did not allow bat velocity measurements to be taken on the impact point of the bat. In our study, subjects and the ball were positioned so that the velocity measurements of the impact part of the bat during the final .15 m prior to impact were taken. The bat velocity measurements in our study were higher, perhaps because measurements were taken on a more distal portion of the bat than in the other studies. It is well known that the bat movement is largely rotary and that the more distal portions of the bat have greater linear velocity.

Our finding of no significant difference in bat velocity among warm-up differences is inconsistent with those of DeRenne et al. (1992) and Southard & Groomer (2003). All testing sessions for each subject in our study were conducted within one testing session. Subjects were tested on different days for each different warm-up condition in both of the previous studies. Day to day variations in performance could possibly have affected the results of the previous studies.

Unlike the other most recent related studies that were reviewed examining segmental actions involved in baseball hitting (Welch et al., 1995; Southard and Levi, 2003), this study used video analysis procedures to allow the examination of the movement of the shoulder girdle relative to the trunk and movement of the leading arm relative to the shoulder girdle. As expected, this study found a sequential pattern of increasing segmental velocities from the pelvic girdle to the trunk, shoulder girdle, leading arm, leading forearm, and hands and bat. This pattern was not affected by warm-up condition.

Proper timing facilitates successively higher rotational velocities, which in turn, produces bat speed and power (Welch et al., 1995; Southard & Groomer). An essential aspect of the skilled baseball swing is the timing of the peak angular velocity of selected segments relative to ball contact. Results on the timing of the peak segmental velocities relative to impact were not as expected as the angular velocity of the shoulder girdle peaked .046 s prior to impact (PC), well after peak values for the leading upper arm (.062 s PC) and leading forearm (.054 s PC). This pattern was not affected by warm-up condition, indicating that warming up with underweight or overweight bats has no effect on the finely tuned and well-developed movement patterns of the skilled hitters. Southard & Levi (2003) reported a disruption of the magnitude and timing of the leading wrist and elbow joints following a warm-up with an overweigh bat, resulting in lower peak bat velocity. Findings in our study were not consistent with those. These differences may be due to methodological differences between the two studies. Our study involved targeted swings and bat velocity measurements to be taken at the specific part of the bat impacting with the ball and during the few milliseconds prior to contact while Southard and Levi (2003) examined non-targeted "dry swings". Also, our study involved two-dimensional movements of segments in the horizontal plane while theirs used three-dimensional analysis of joints.

CONCLUSIONS: The results of this study suggest that a warm-up with bats of varying weight has no effect on the pre-impact linear velocity of the hitting area of the bat. Furthermore, warming up with bats weighing more than, less than, and the same as a player's preferred bat has no effect on the magnitude, velocity, and timing of segmental actions during the execution of the swing.

PRACTICAL IMPLICATIONS: Swinging an overweight bat or a standard weight bat equipped with a donut ring while in the on-deck circle is a common practice of players for all levels of play in baseball and softball. Most players believe they will be able to achieve a faster bat velocity when stepping into the batter's box and swinging at the pitched balls following warm-up with an overweight bat. Players seem confident that they are indeed swinging the bat faster following a warm-up with an overweight bat. Findings of this study do not support this practice. We hypothesize that the perception of a faster swing following a warm-up with an overweight bat is perhaps an illusion, as this study found no effect whatsoever of warm-up bat weight on either the outcome (pre-impact linear bat velocity) or the process of the baseball swing (segmental movements).

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