AFTER-EFFECTS OF USING A WEIGHTED BAT ON SUBSEQUENT SWING VELOCITY AND BATTERS' PERCEPTIONS OF SWING VELOCITY AND HEAVINESS

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Summary.—In baseball and softball, warm-up swings with a weighted bat have been believed to increase swing velocity when an ordinary bat is used in the subsequent competitive situation. The purpose of this study was to investigate the aftereffects of using a weighted bat on subsequent swing velocity and batters' perceptions of swing velocity and heaviness. Eight men in varsity softball and baseball hit a ball suspended from the ceiling 45 times (3 sets of 15 trials). For each set, the initial 5 trials were done using an ordinary 920-g wooden bat (Control condition), and the following 5 trials by a bat with an 800-g bat ring (Weighted condition), and the final 5 trials again by the ordinary bat (post-Weighted condition). Analysis of variance showed a significant decrease of 3.3% in the measured linear velocity of the bat prior to impact with the ball for the first swing of the post-Weighted condition compared with the Control condition. From the second swing the velocity returned to the level of the Control condition. Subjective judgment of the heaviness and velocity of swings for the Weighted and post-Weighted conditions by each participant showed that the ordinary bat felt lighter and swing speed felt faster for the post-Weighted condition. The advantage of the warm-up with a weighted bat was thus psychological and not biomechanical.

In baseball and softball, warm-up swings with a weighted bat prior to competitive batting are routinely employed and considered to provide advantageous effects on the subsequent batting. Kauffman and Greenisen (1973) used electromyography (EMG) to compare muscle activities of the upper arm when swinging with an ordinary bat and with a weighted bat. They found that during swings with a weighted bat the extensor muscle (the triceps brachii) was more active than that using an ordinary bat. On the other hand, they also found simultaneous increase in activity of the flexor muscle (the biceps brachii muscle). The authors stated that the magnitude of the biceps brachii involvement with the use of a weighted bat could nullify the advantage of additional involvement of the triceps brachii motor unit. They

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also postulated that swinging a weighted bat prior to competitive batting would not offer any advantage in terms of improved batting mechanics or the ability to generate greater angular bat velocity. However, several problems were noted in their study. First, the muscle activity during the swing with a normally weighted bat immediately after the use of a weighted bat was not examined. Second, although they discussed the velocity of the bat, actual bat velocity was not measured. Using high-speed film analysis, several attempts have been made to examine batting velocity in male collegiate baseball players (Race, 1961; Shapiro, 1979; McIntyre & Pfautsch, 1982; Matsuo, 1998), professional baseball players (Welch, Banks, Cook, & Draovitch, 1995), and female collegiate softball players (Messier & Owen, 1984). Maximum linear bat velocity was found in the period less than 45 msec. before ball contact (Race, 1961; Shapiro, 1979; McIntyre & Pfautsch, 1982; Messier & Owen, 1984; Welch, et al., 1995). The maximum linear velocities of the bat ranged from 141.5 to 151.9 km · hr⁻¹ when calculated for a point at the tip of the bat (McIntyre & Pfautsch, 1982) and from 93.8 to 124.8 km · hr⁻¹ at the center of bat mass for baseball players (Shapiro, 1979; Welch, et al., 1995; Matsuo, 1998) and 68.7 km · hr⁻¹ for female softball players (Messier & Owen, 1984). Matsuo (1998) reported that increase in bat weight from 853 g to 954 g changed mean maximum linear velocity of the bat from 118.8 to 115.6 km · hr⁻¹ for seven collegiate baseball players. However, none of these studies examined the after-effects of swinging a weighted bat on batting velocity. The purpose of the present study was, therefore, to use a photoelectric timing device and subjective judgment scales for swing speed and bat heaviness to investigate the effect on swing velocity of the subsequent batting after swinging a weighted bat.

Method

Participants

Participants were eight university men who were members of the varsity softball or baseball teams. They had a mean age of 20.9 yr. (SD = 1.4), height of 1.70 m (SD = .03), and weight of 63.8 kg (SD = 6.0). All participants were volunteers and gave their written consent to participate in this study after all procedures as well as the possible risks and benefits of participation were explained.

Measurement of Bat Velocity

Two photoelectric switches (Model: E3S-3L and EE3S-3D, Omron Ltd., Kyoto, Japan) and a digital data recorder (Model: DR-M3a MK2, TEAC Ltd., Tokyo, Japan) were used to measure bat velocity. The experiment was conducted at one of the gymnasiums in Osaka University. A baseball was suspended from the ceiling of the gymnasium using a string. Off- and On-
sensors for the photoelectric switches were positioned 10 and 25 cm away from the center of the ball and in front of the home plate. The height of the sensors was 40 cm from the floor, and they were aligned toward the center of the field. An ordinary wooden baseball bat (weight = 920 g, length = 865 mm) was used by all participants. The bats used for their usual playing weighed between 840 g and 950 g (M weight = 895 g, M length = 850 mm) so between the test bat and their game bats, there was a mean difference of 25 g with the maximum of 80 g. To create a weighted bat, a commercially available 800-g bat ring (Model: slugger Rings, Tokyo Surpass Co., Tokyo) was added to the end portion of the bat. The bat ring was a lead cylinder covered by a rubber material, and its inner and outer diameters were 55 and 105 mm, respectively. Its height was 40 mm. Pass time of the bat between the two sensors during a swing was recorded at a sampling frequency of 20 kHz, and average linear velocity of the swing was subsequently computed based on the pass time and the distance between the sensors. This average value was used as swing velocity prior to the ball’s impact. During the experiment, the subjects swung to hit the hung ball for a T-batting net at their maximum speed toward the center of the field. The net was set 3 m in front of the suspended ball.

Procedure

Prior to the experiment, the height of the suspended ball was adjusted to a position where each participant felt most comfortable hitting it. The participant then practiced hitting the ball until he felt that it was natural (10 to 20 swings). Four to five practice hits were also made using the bat with the bat ring. During the experiment, three sets of 15 hits were performed by each participant. Prior to each set, the participant rested for about 10 min. He first hit the ball five times using the bat without the bat ring (the Control condition). The bat ring was then added to the bat, and the ball was hit five times (the Weighted condition), followed by five hits without the bat ring (the post-Weighted condition). For these 15 hits, an interval of 15 sec. was given between the swings. An average velocity for each swing was computed, and the mean of all swings for each condition was also computed for each participant. The difference between the two conditions was tested using a one-way repeated-measures analysis of variance, using an alpha level of .05.

After the fifth swing for the Weighted condition and the first, third, and fifth swings for the post-Weighted condition, each participant was asked to make a subjective judgment of the heaviness of the bat during the swing and the speed of the swing itself compared with the Control condition. A 5-point scale was used for each judgement: apparently lighter (5), slightly lighter (4), equal (3), slightly heavier (2), and apparently heavier (1) for the
bat weight, and apparently faster (5), slightly faster (4), equal (3), slightly slower (2), and apparently slower (1) than the Control condition. The difference from the equal point for each trial mean was tested using a $t$ test and an alpha level of .05.

**Results**

**Effect of Weighting**

In Fig. 1, the swing velocity for the Control and Weighted conditions for each participant is shown. For all participants the velocity decreased with the addition of the bat ring. This velocity decrease ranged from 21.1 to 40.7 km·hr$^{-1}$. Mean velocity of the Control condition for all subjects was 104.3 km·hr$^{-1}$ ($SD=11.5$), while that for the bat-ring condition was 72.4 km·hr$^{-1}$ ($SD=7.8$). The difference was significant ($F_{17}=188.07$, $p<.0001$). The correlation between the two conditions was also significant ($r=.83$, $p<.01$), indicating a similar decrease occurred for each participant. The mean decrease with the bat ring was 30.6% ($SD=4.6$). Subjective judgment by the participants showed that they not only perceived that the weighted bat was heavier (heaviness scale $M=1.5$, $SD=.6$) than the normal bat, but also that the swing felt slower than that for the Control condition (speed scale $M=1.9$, $SD=.7$). To examine if fatigue occurred by swinging the weighted bat, the initial and fifth swings for the Weighted condition were compared. The velocities for these were 74.8 ($SD=6.8$) and 72.5 ($SD=8.6$) km·hr$^{-1}$, respectively, and the difference was insignificant ($F_{17}=1.89$, ns).

![Fig. 1. Swing velocities for the Control and bat-ring conditions for each participant. • indicates the means for all eight men.](image-url)
After-effects of Weighted Bat Swing

Mean swing velocity for the Control and post-Weighted conditions for all participants are illustrated in Fig. 2. The mean swing velocity for all participants for each swing of the post-Weighted condition is shown on the right-hand side of Fig. 2. The mean velocity of the five swings for the post-Weighted condition was 104.7 km · hr⁻¹ (SD = 10.8), so it was not significantly different from that for the Control condition (F₁,₇ = .10, ns). Analysis of variance, on the other hand, indicated a significant decrease in the velocity of the first swing in the post-Weighted condition (100.9 km · hr⁻¹, SD = 8.9) when compared with the Control condition (F₁,₇ = 5.65, p < .05). The percent decrease in velocity in the first swing from the Control condition was 3.3%. The mean swing velocity of the subsequent swings did not differ from that for the Control condition. Subjective evaluation of heaviness of the bat and that of swing speed during the post-Weighted trials indicated that for the first swing the rating of heaviness was 4.4 (SD = .7; t = 5.60, p < .01) and the rating of speed was 4.3 (SD = .5; t = 6.67, p < .01). The participants, therefore, perceived the bat to be clearly lighter and the swing to be faster than those of the Control condition. They also indicated a difficulty

![Graph showing mean swing velocity for Control and Post-Weighted conditions](image)
comparing the swing with the Control condition because the residual sensation of swinging the heavily weighted bat on previous trials was strong. After the third swing seven participants and after the fifth swing five participants reported that the bat was slightly heavier and the swing was slightly faster. The mean points for heaviness and speed after the third swing were 3.9 (SD = .3; t = 8.81, p < .01) and 3.8 (SD = .4; t = 3.61, p < .01), respectively, and those after the fifth swing were 3.6 (SD = .4; t = 3.81, p < .05) and 3.5 (SD = .5; t = 3.05, p < .05), respectively. All the participants reported that changes in the sensation were gradual over the five swings.

**DISCUSSION**

The mean linear velocity of the normal bat prior to ball impact in the present study was 104 km·hr⁻¹, with a range between 88 and 124 km·hr⁻¹. The mean value was similar to those reported in the previous studies using a high-speed motion camera. For example, Welch, et al. (1995) reported the mean value of 104 km ·hr⁻¹ for 59 professional baseball players, and Shapiro (1979) reported the mean value of 107 km ·hr⁻¹ for three collegiate baseball players. Therefore, our participants had swing velocity equivalent to those found in previous studies.

Before discussing the present findings concerning the after-effects of a weighted bat, a qualification about the generality of the results may need to be mentioned. That is, although batters often swing the bat with the bat ring, the actual game situation is only a part of their complicated warm-up routines which may include other exercise drills, stretching, swing movement with their game bat, swinging the weighted bat overhead, and so on. The effects of these were not considered in this study. In addition, the batters often swing the weighted bat at a submaximum effort instead of the maximum effort we used in this experiment. It also must be mentioned that, although we asked the participants to swing the bat as done in the game situations, hitting a still, hung ball using a single test bat is undoubtedly different from hitting a pitched ball with their self-chosen bat. These temporary and unfamiliar experimental conditions are apparently different from those during playing games. Also, each participant could have experienced differences between their normal bat and that used in the experiment. These might have affected the type of swing the players use and could have made the swing different from what they would use in an actual game situation. With these limitations in mind, we would like to discuss the findings of the present experimental study.

It was demonstrated clearly that swing velocity prior to ball impact did not increase after swings with a weighted bat despite the fact that all participants perceived the normal bat in the post-Weighted condition to be lighter and to move faster than during the pre-Weighted swings. Interestingly, the
weighted bat led to a decrease in velocity on the very first swing with the normal bat. A mismatch between the results of sensory judgment and measures in the actual batting trials suggests that the participants experienced sensory illusions for both load to the limb and speed of motion after the swings with the weighted bat. The decrease in batting velocity on the very first swing following swings with the weighted bat can be attributed to an altered pattern of batting movements, which most likely occurred by the motor command formed during the swings with the weighted bat. Indeed, for the Weighted condition, the generated batting action produced a much lower maximum swing velocity than that with the normal bat. In a study of force generation and associated muscular activity for lifting of an object by the fingers, Johansson and Westling (1988) also found that the weight of the object handled is centrally memorized based on the experience during a current lift. This is then used for the generation of forces via muscular activity in grasping and lifting in the next trial. When swinging a heavier bat than a lighter one, greater neural activity is found not only in the agonist muscles for arm extension but also in antagonist muscles, which presumably contributes to stabilizing the joints (Kaufman & Greenisen, 1973). Although these researchers examined only the arm muscles, increased activity of agonist and antagonist muscle pairs in the other portions of the body can also be expected. Shaffer, Jobe, Pink, and Perry (1993) studied a muscle firing pattern during baseball batting and reported that there was a sequence of coordinated muscle activity, beginning with the leg and hip, followed by the trunk, and terminating with the arms. Since the duration between the initiation of bat swing movement and ball impact is known to be less than 200 msec. (Shapiro, 1979; Messier & Owen, 1984; Kinoshita & Yoshida, 1987), the swing action can be considered a ballistic movement, which relies largely on the preprogrammed central motor command (Brooks, 1986). These findings suggest that the decreased swing velocity is attributed to unnecessarily elevated activity of muscle pairs most likely to be produced by residual motor memory of the previous experience with swinging the weighted bat.

After one swing with the normal bat, the swing velocity returned to that of the Control condition, and thus at least from the view of mechanical aspects of batting, contribution of the motor commands for swinging the weighted bat had been largely nullified. However, the psychological aspects persisted much longer. Even after the fifth swing, five of the eight participants reported that they still had the sensation that the swing speed was faster and that the bat weighed less. This may relate to their claim concerning the difficulty of comparing the sensation for the Control condition due to the lingering effect of the sensory experience of batting with the weighted bat. Nevertheless, the kinesthetic illusion perhaps along with their expectations of the effects of the weighted bat seems to last for some period of time.
(at least four swings), and this perhaps is one advantage of warm-up with a weighted bat, which should not be underestimated for the athletes.

In conclusion, our data confirmed that the purported benefit of attaining faster batting speeds following warm-up with a weighted bat was solely psychological in nature and not biomechanical.

REFERENCES


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