THE CHARACTERISTICS OF HITTING MOTION USING BATS HAVING DIFFERENT LENGTH AND MASS BUT EQUAL MOMENT OF INERTIA

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The aim of this study was to investigate the characteristics of hitting motion when using training bats with altered length and mass. Four different long bats (LB) and four different weight bats (WB) that had the equal moment of inertia (MOI) were manufactured based on a normal bat (NB; 0.84 m, 0.90 kg). Eleven male collegiate baseball players performed tee batting with maximal effort. The hitting motion was analyzed using a VICON (250 Hz) to collect nine reflective markers fixed on the body and bat. Results indicated that the angular displacement of the trunk twist tended to be larger in LB with increasing MOI. And it was remarkable in subjects with smaller angular displacement of trunk twist in NB. Thus, compared to WB, LB may contribute to a larger angular displacement of trunk twist, particularly in players with smaller angular displacement of trunk twist in NB.

KEY WORDS: swing velocity, training bat, trunk twist.

INTRODUCTION: In baseball, hitting performance is important to win the game. Increasing bat swing velocity improves hitting performance. One method of training to improve swing velocity is to train with a bat with altered length or mass. This changes the moment of inertia (MOI) of the bat. There have been previous studies investigating the training effects of using weighted bats (DeRenne et al., 1983; Sergo, 1993) and the differences in bat angular velocity between a normal bat grip and a choke-up bat grip (Escamilla, 2009). Although some studies have focused on bat mass and grip position, changes in bat length or weight with the equal MOI can change swing velocity or the characteristics of hitting motion. However, there is no study that has evaluated the differences in hitting motion when players use bats with the equal MOI but different the length and mass. The purpose of the present study was to investigate the characteristics of using training bats with altered length and mass to have the equal MOI on hitting motion. In this study, the trunk twist was evaluated because of its important contribution to swing velocity (Fleisig et al., 2013).

METHODS: Eleven male collegiate baseball players participated in this study (Age; 19.09 ± 1.04 years, baseball career; 10.91 ± 1.81 years, height; 1.75 ± 0.05 m, mass; 72.45 ± 8.12 kg, mean ± SD). Four subjects batted right-handed and seven batted left-handed. Informed written consent was obtained from all of the subjects prior to participation in this study. All procedures undertaken in this study were approved by the Ethics Committee for the Institute of Health and Sport Sciences, University of Tsukuba, Japan.
All subjects performed tee batting with maximal effort. One normal bat (NB; 0.84 m, 0.90 kg), four long bats (1LB; 0.95 m: 0.90 kg, 2LB; 1.10 m: 0.90 kg, 3LB; 1.25 m: 0.90 kg, 4LB; 1.40 m: 0.90 kg, respectively), and four weight bats (1WB; 0.84 m: 1.28 kg, 2WB; 0.84 m: 1.70 kg, 3WB; 0.84 m: 2.20 kg, 4WB; 0.84 m: 2.75 kg, respectively) were manufactured. All pairs of LB and WB had an equal MOI. MOI of each bat was calculated using a single pendulum and the equation (Shibukawa, 1969; Spurr et al., 2014) :

$$MOI = T^2gML/4\pi^2$$

where T is the period of oscillation (s), g is gravity (cm·s^2), M is the mass of the bat (kg), and L is distance from the bottom of the grip to the bat's center of mass (cm).
The three-dimensional co-ordinates of nine reflective markers fixed on the body and bat were collected by the Vicon system (Vicon Motion System, Ltd.) using 10 cameras operating at 250 Hz. The analysis section was from the take-off of the stride leg to ball impact. In this study, the bat head speed and angular velocity were calculated. The angular displacement of trunk twist, pelvic rotation, and upper trunk rotation were investigated from the transverse plane during analysis section (Figure 1).
Two-way analysis of variance (ANOVA) with Bonferroni post hoc contrasts was used to detect differences in the means of the three bats. Relationships between the variables were determined by Pearson's correlation test. The significance was accepted at $p < 0.05$.

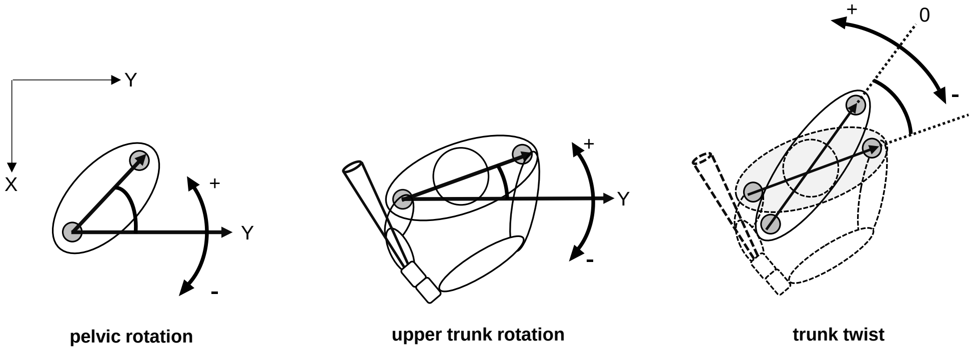
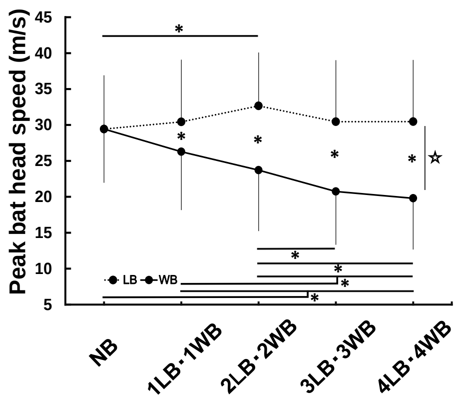


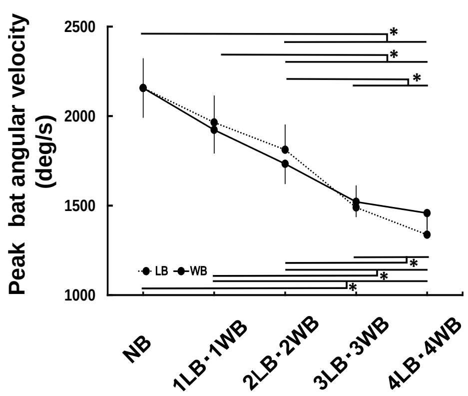
Figure 1: Angle of pelvic rotation, upper trunk rotation, and trunk twist from the transverse plane.

RESULTS: Figure 2 shows the peak bat head speed in LB and WB. There were interactions in both bats. Peak bat head speed in LB was significantly higher than that of WB. In LB, peak bat head speed in 2LB was higher than that of NB. In WB, peak bat head speed was significantly lower with an increase in the MOI. Figure 3 shows the peak bat angular velocity in LB and WB. The peak bat angular velocity in both LB and WB was significantly decreased with an increase in the MOI. Figure 4 shows the angular displacement of trunk twist, upper trunk rotation, and pelvic rotation in LB and WB. There were no significant differences between each bat. However, in LB, the angular displacement of trunk twist and upper trunk rotation tended to be larger with an increase the MOI.



＊ : p < 0.05
☆ : Interactions between LB and WB

Figure 2: Peak bat head speed for each bat.



＊ : p < 0.05

Figure 3: Peak bat angular velocity for each bat.

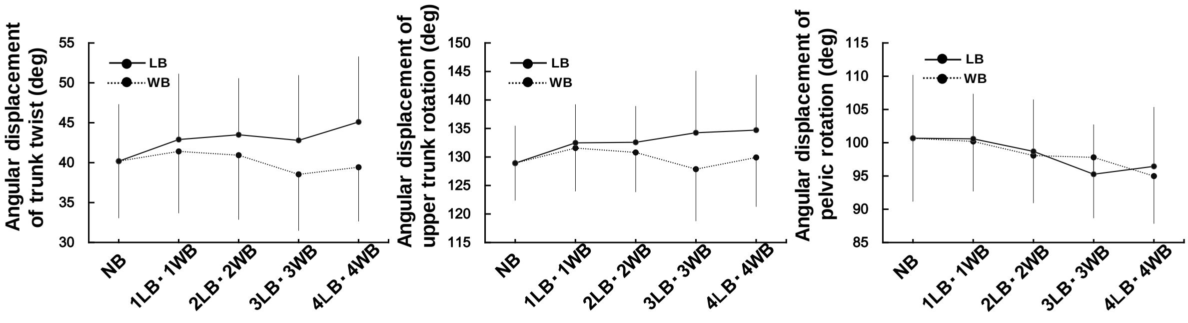


Figure 4: Angular displacement of trunk twist, upper trunk rotation, and pelvic rotation for each bat.

Figure 5 shows the relationship between the difference of angular displacement of trunk twist from NB to 4LB (subtraction of the angular displacement of trunk twist in NB from that of 4LB) and that of NB. There was a correlation between the angular displacement of trunk twist from NB to 4LB and that of NB. Furthermore, figure 5 also shows the results of the comparison of angular displacement of trunk twist between the two groups. Subjects were divided into larger and smaller groups based on the mean value of angular displacement of trunk twist in NB. The differences of angular displacement of trunk twist between NB and 4LB in the smaller group were significantly larger than in the larger group.

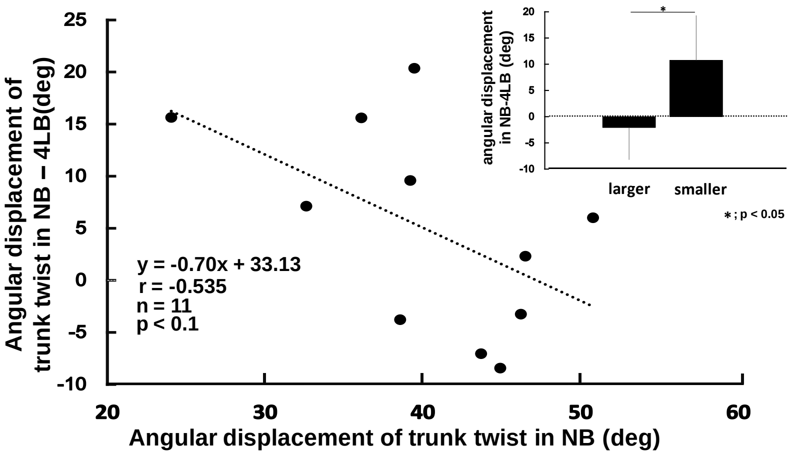


Figure 5: Relationships in the angular displacement of trunk twist between NB and 4LB-NB.

DISCUSSION: In the present study, the characteristics of hitting motion were investigated using various bats with different length and mass but the equal MOI. As a result, bat angular velocity was significantly decreased in both LB and WB as the MOI increased (Figure 3). These results support previous studies that studied the relationship between bat mass and angular velocity (DeRenne, 1983) or the relationship between grip position and angular velocity (Escamilla et al., 2009). On the other hand, peak bat head speed in LB did not decrease with an increase in the MOI. Escamilla et al. (2009) studied the differences in hitting motion with normal grip and choke-up grip. Their results indicated that the radius of bat rotation was shortened when subjects used the choke-up grip. Therefore, the bat head speed was decreased when using the choke-up grip. Considering this research, because LB have a larger radius than WB, LB head speeds were higher than those of WB in the present study.
The trunk twist affects bat swing velocity. Activation of oblique muscles decelerates pelvic rotation and accelerates upper trunk rotation (Fleisig et al., 2013). Therefore, the present

study investigated the effects of training bats with equal MOI through alterations in the length and mass on trunk twist. The changes in angular displacement of trunk twist were significant in neither LB nor WB modes of MOI increase. However, in LB, the angular displacement of trunk twist and upper trunk rotation tended to be larger with an increase in the MOI (Figure 4). These results may indicate that a higher MOI in LB resulted in a larger angular displacement of trunk twist in the bat swing; however, this was highly variable among individuals. Therefore, the present study focused on the amount of angular displacement of trunk twist in NB to investigate the differences among individuals. Changes resulting from an increase in the MOI by LB were evaluated (Figure 5). The results indicated that there tended to be a correlation between the angular displacement of trunk twist from NB to 4LB and that of NB. The angular displacement of trunk twist in the smaller group was significantly larger than the larger group. Therefore, the subjects that had a small angular displacement of trunk twist in NB showed the larger angular displacement of trunk twist when they used the LB with the higher MOI.
In these results, although there were differences among individuals, LB may contribute to the range of trunk twist angle size in the bat swing. This result was particularly evident in subjects with smaller angular displacement of trunk twist in NB. Thus, in subjects with smaller angular displacement of trunk twist in NB, using LB is an effective training method to improve the angle of trunk twist. This study cannot investigate the characteristics of WB clearly. In the future, research into the characteristics of WB should be performed from different points of view.

CONCLUSION: The purpose of the present study was to investigate the characteristics of using training bats with altered length and mass to have the equal MOI on hitting motion. Results indicated that with increasing MOI, the angular displacement of trunk twist tended to be larger in LB than WB. The angular displacement of trunk twist was larger with an increase in the MOI in LB when subjects with smaller angular displacement of trunk twist in NB used those bats. Thus, compared to WB, LB may contribute to larger angular displacement of trunk twist, particularly in players with smaller angular displacement of trunk twist in NB.

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