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Abstract

To clarify the influence of the introduction of metal bats on the physique and batting records of the players in the National Summer High School Baseball Tournaments, a comparative analysis was conducted between height, body weight, body-weight ratio (body weight/height), batting average and home run average of the best four teams' players ($n = 493$) and those of the other teams' players ($n = 4,590$) in three periods: the period of the use of wooden bats, that of the use of both wooden and metal bats and that of the use of metal bats. In the period of metal bat use, the mean values of physique of the best four teams' players were significantly larger ($P < 0.05$) and their average number of home runs was significantly higher than those of the other teams' players ($P < 0.01$). The only significant differences between the two groups in those indices for each time period were for height in the wood and metal/wood periods. This study demonstrated that the differences between the home run average and physique, including height, body weight and body-weight ratio of the best four teams and the rest of the teams were the greatest after the use of metal bats. These findings suggest that the importance of the home run average increased and was associated with large-size of physique after the use of metal bats in the National Summer High School Baseball Tournaments.

KEYWORDS: male high school students, baseball players, height, body weight, body-weight ratio, batting records

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Comparative Analysis on the Physique and Batting Records of the Players in the National Summer High School Baseball Tournaments Before and After the Adoption of Metal Bats

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To clarify the influence of the introduction of metal bats on the physique and batting records of the players in the National Summer High School Baseball Tournaments, a comparative analysis was conducted between height, body weight, body-weight ratio (body weight/height), batting average and home run average of the best four teams' players ($n = 493$) and those of the other teams' players ($n = 4,590$) in three periods: the period of the use of wooden bats, that of the use of both wooden and metal bats and that of the use of metal bats. In the period of metal bat use, the mean values of physique of the best four teams' players were significantly larger ($P < 0.05$) and their average number of home runs was significantly higher than those of the other teams' players ($P < 0.01$). The only significant differences between the two groups in those indices for each time period were for height in the wood and metal/wood periods. This study demonstrated that the differences between the home run average and physique, including height, body weight and body-weight ratio of the best four teams and the rest of the teams were the greatest after the use of metal bats. These findings suggest that the importance of the home run average increased and was associated with large-size of physique after the use of metal bats in the National Summer High School Baseball Tournaments.

Key words: male high school students, baseball players, height, body weight, body-weight ratio, batting records.

In Japan, there are five large newspaper companies, and two of them are sponsors of big high school

baseball tournaments, which are held in the spring and summer every year. There are two different national baseball tournaments; one takes place from late March to early April and the other in August. Thirty-two teams from ten parts of the country are chosen after the regional autumn tournaments and they compete with one another in the spring tournaments. On the other hand, forty-nine championship teams in East Tokyo, West Tokyo, North Hokkaido, South Hokkaido and all the other prefectures compete with each other in the summer tournaments. Thus, the preliminary procedure and competitive season of the spring tournaments differ from those of the summer tournaments (1, 2). As both tournaments are held at Koshien Stadium, the former one is called the spring Koshien tournaments, and the latter one is the summer Koshien tournaments. The Koshien tournaments games are the climax of high school baseball in Japan because each team has to be strong enough to win the championship in each prefecture. As of 1994, the number of games in the spring and summer tournaments are 66 and 76, respectively.

In 1974, The Japan High School Baseball Federation adopted metal bats which did not break as easily and were more economical than wooden bats. After the introduction of metal bats, batting records went up drastically in both tournaments, especially the number of home runs. In the summer tournaments of 1984, home runs were recorded in every game. The reason why home runs have increased is due to the batted ball velocity (3, 4) and the reaction coefficient (4) of metal bats. In addition, the average height of the Japanese population has increased since World War II (5, 6); high school students' height has increased steadily (7, 8) and the Koshien players in the summer tournaments have been taller each successive

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year (9). Moreover, Tokushima Prefectural Ikeda High School won the summer championship by powerful hitting through weight training programs (1). Therefore, the combination of physique and body function may have influenced batting and game records. However, it is not clear whether the batting records and physique of each winning player were larger than those of each losing player.

The purpose of this study was to examine the physique and batting records of the winners in the summer Koshien tournaments after the adoption of metal bats. The influence of introducing metal bats on the records of high school baseball teams and players was investigated.

Subjects and Methods

The subjects were the members playing in the summer Koshien tournaments. Wooden bats were used from 1969 to 1973, both wooden and metal bats were used from 1974 to 1977, and only metal bats have been used since 1978, but the cut off for the period of metal bats is 1982 for the purposes of this study. As metal bats were introduced into high school baseball in the summer of 1974, the players used both wooden and metal bats for 3-4 years after that, from 1974 to 1976 or 1977 (2). The number of subjects for this study is presented in Table 1.

To analyze the factors contributing to winning baseball games, the subjects were divided into two groups: the best four teams' players who are designated here as 'winners' and the other teams' players as 'losers'. Height and body weight were analyzed as indicators of their physique. To estimate the body muscle mass, body-weight ratio (10), which was calculated as the body weight (kg) divided by height (m), was employed because the relative body fat and fat-free mass could not be obtained from information concerning the body composition of

players. Batting and home run averages were calculated as numbers of hits and home runs divided by the times at bat, respectively.

The differences in physique and batting records between the winning and losing players were determined by comparing the mean values of all indices in the observation periods. They were compared with height and body weight of national average of 17-year-old male high school students in the Report on School Health Statistics (11), in order to clarify differences in physique. Student's *t*-test was used to determine statistically significant differences. The level of significance was set at 95 % ($P < 0.05$, two-sided).

The data of physique and batting records were obtained from the published records and official members' lists of teams in Koshien tournaments from the Shukan-Asahi and the Asahi Shimbun. The anthropometric data with rounded integer values were based on the results of physical examination tests carried out in each high school.

Results

Tables 2, 3 and 4 indicate the differences between winners and losers in the mean values of height, body weight and body-weight ratio, respectively, in each observation period. Differences in the mean for body weight and body-weight ratio between the two groups in the period of the use of metal bats were larger than those in the previous periods ($P < 0.01$). The heights were reported as 168.3 cm, 169.0 cm and 169.6 cm and the weight as 58.9 kg, 59.4 kg and 60.5 kg for 17-year-old male high school students in the Report on School Health Statistics in 1971, 1976 and 1980 (11). The winning four teams' players were taller and heavier than the national average of 17-year-old male high school students by 3.3 cm and 7.0 kg from 1969 to 1973 ($P < 0.01$), 4.0 cm and 7.2 kg from 1974 to 1977 ($P < 0.01$), and 4.3 cm and 8.7 kg from 1978 to 1982 ($P < 0.01$), respectively. Similarly, the losing teams' players were taller and heavier than the average by 3.8 cm and 7.0 kg, respectively, from 1969 to 1973 ($P < 0.01$), 3.3 cm and 6.9 kg, respectively, from 1974 to 1977 ($P < 0.01$), and 3.3 cm and 6.3 kg, respectively, from 1978 to 1982 ($P < 0.01$).

Physique was annually compared between the winning and losing teams' players to show the yearly changes of the differences from 1969 to 1982. Figs. 1, 2 and 3 show a comparison of physique between the winning and losing teams' players for each year. The winning teams' players

Table 1 The number of subjects who played during three observation periods

Group	Number of subjects					
	1969—1973 ^a		1974—1977 ^b		1978—1982 ^c	
	Teams	Players	Teams	Players	Teams	Players
Winners	20	172	16	143	20	178
Losers	148	1,332	138	1,242	225	2,016

a: wooden bats; b: both wooden and metal bats; and c: metal bats, were used in each observation period.

Table 2 The mean with standard deviation of height (cm) of each group in three observation periods

Group	Height (cm)		
	1969—1973 ^a	1974—1977 ^b	1978—1982 ^c
Winning teams	171.6 ± 5.4	173.0 ± 5.0	173.9 ± 5.0
Losing teams	172.1 ± 4.9	172.3 ± 5.2	172.9 ± 5.1
Difference between the two groups	-0.5	0.7* ^d	1.0** ^d

d: Significant differences compared with the value in the wooden bats period (a) analyzed by Student's *t*-test. *, *P* < 0.05; **, *P* < 0.01. a, b and c: See Table 1.

were larger than the losing teams' players in 1970 (*P* < 0.01). In 1969, however, the losing teams' players were taller than the winning teams' players (*P* < 0.05), and were taller and heavier than the winning teams' players in 1971 (*P* < 0.01 and *P* < 0.05, respectively). There were no distinct differences between the winning and losing players in terms of physique from 1969 to 1976. Conversely, the winning teams' players were heavier in body weight and higher in body-weight ratio than the losing teams' players 3 years after the introduction of metal bats. In particular, the winning teams' players were larger by 3.4-3.5 kg and 1.5-1.8 in body-weight ratio, compared with the losing teams' players in 1981 and 1982 (*P* <

Table 3 The mean with standard deviation of body weight (kg) of each group in three observation periods

Group	Body weight (kg)		
	1969—1973 ^a	1974—1977 ^b	1978—1982 ^c
Winning teams	65.9 ± 6.0	66.6 ± 5.7	69.2 ± 6.5
Losing teams	65.9 ± 5.6	66.3 ± 5.8	66.8 ± 5.8
Difference between the two groups	0.0	0.3	2.4** ^d

d: Significant difference compared with the value in the wooden bats period (a) or in both wooden and metal bats period (b) analyzed by Student's *t*-test. **, *P* < 0.01. a, b and c: See Table 1.

Table 4 The mean with standard deviation of body-weight ratio (kg/m) of each group in three observation periods

Group	Body weight ratio (kg/m)		
	1969—1973 ^a	1974—1977 ^b	1978—1982 ^c
Winning teams	38.4 ± 2.6	38.4 ± 2.5	39.7 ± 3.1
Losing teams	38.2 ± 2.5	38.4 ± 2.6	38.6 ± 2.7
Difference between the two groups	0.2	0.0	1.1** ^d

d: Significant difference compared with the value in the wooden bats period (a) or in both wooden and metal bats period (b) analyzed by Student's *t*-test. **, *P* < 0.01. a, b and c: See Table 1.

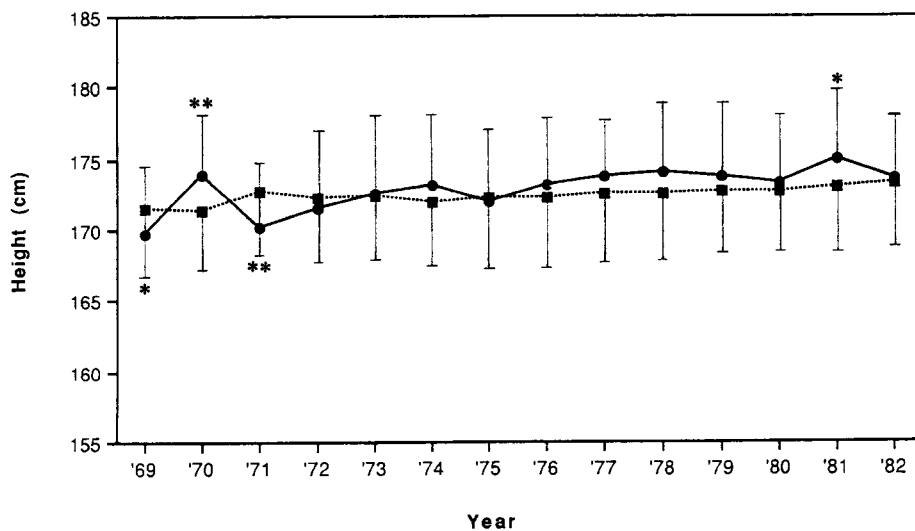


Fig. 1 Heights of the winning and losing players before and after the adoption of metal bats, from 1969 to 1982, in the National Summer High School Baseball Tournaments. Data represent the means with standard deviations. Asterisks show significant differences between the two groups analyzed by unpaired *t*-test. *, *P* < 0.05; **, *P* < 0.01. ●—●: Winning teams, ■-----■: Losing teams.

0.01).

The differences between the two groups for batting average and home run average in each observation period are shown in Tables 5 and 6, respectively. The batting

average was not significantly different between the winning and losing groups in each observation period. Conversely, the difference in the mean for home run average between the two groups in the period of the use

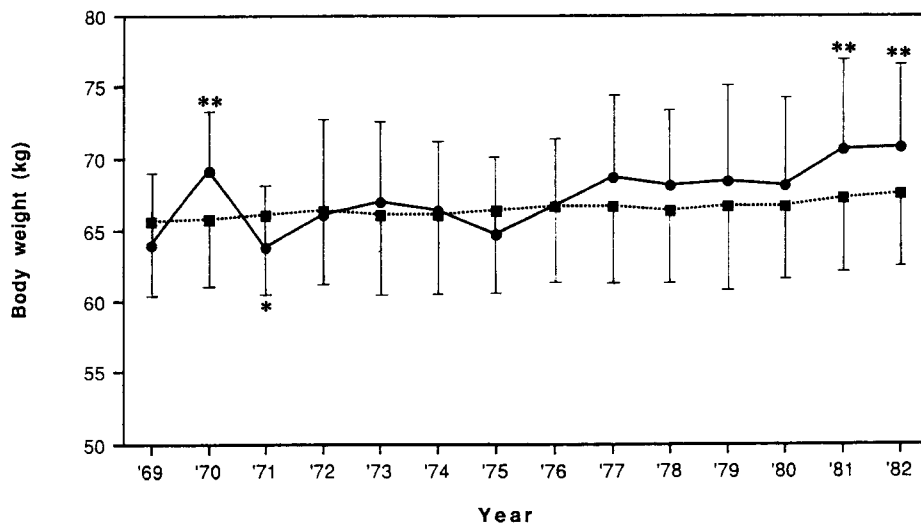


Fig. 2 Body weights of the winning and losing players before and after the adoption of metal bats, from 1969 to 1982, in the National Summer High School Baseball Tournaments. Data represent the means with standard deviations. Asterisks show significant differences between the two groups analyzed by unpaired *t*-test. *, $P < 0.05$; **, $P < 0.01$. ●—●: Winning teams, ■—■: Losing teams.

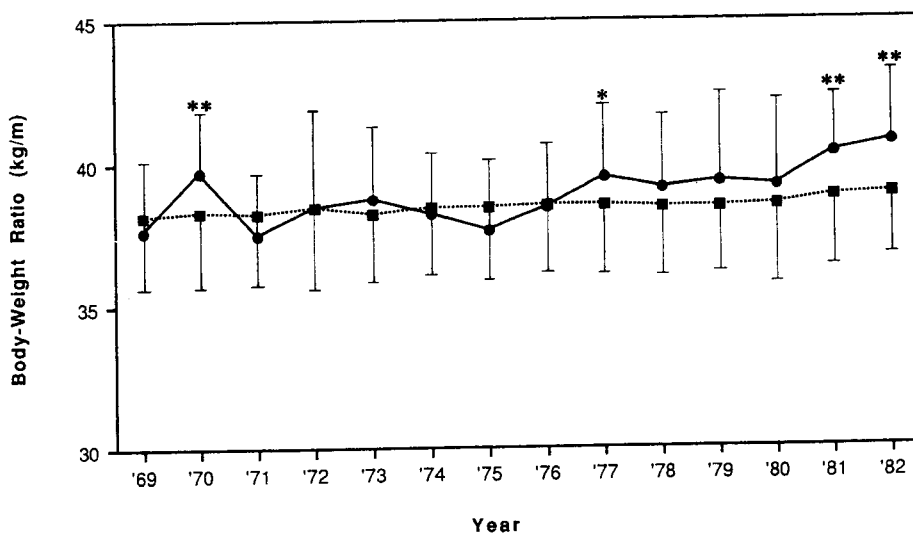


Fig. 3 Body-weight ratios of the winning and losing players before and after the adoption of metal bats, from 1969 to 1982, in the National Summer High School Baseball Tournaments. Data represent the means with standard deviations. Asterisks show significant differences between the two groups analyzed by unpaired *t*-test. *, $P < 0.05$; **, $P < 0.01$. ●—●: Winning teams, ■—■: Losing teams.

Table 5 The mean with standard deviation of batting average (numbers of hits/the times at bat) of each group in three observation periods

Group	Batting average		
	1969—1973 ^a	1974—1977 ^b	1978—1982 ^c
Winning teams	0.273 ± 0.042	0.274 ± 0.055	0.287 ± 0.046
Losing teams	0.206 ± 0.083	0.213 ± 0.078	0.224 ± 0.075
Difference between the two groups	0.067	0.061	0.063 ^d

d: Insignificant difference compared with the value either in the wooden bats period (a) or in both wooden and metal bats period (b) analyzed by Student's *t*-test. $P > 0.05$. *a*, *b* and *c*: See Table 1.

Table 6 The mean with standard deviation of home run average (number of home runs/the times at bat) of each group in three observation periods

Group	Home run average		
	1969—1973 ^a	1974—1977 ^b	1978—1982 ^c
Winning teams	0.006 ± 0.007	0.010 ± 0.009	0.014 ± 0.010
Losing teams	0.003 ± 0.007	0.004 ± 0.010	0.004 ± 0.009
Difference between the two groups	0.003	0.006	0.010** ^d

c: Significant difference compared with the value in the wooden bats period (a) analyzed by Student's *t*-test. $P < 0.01$. *a*, *b* and *c*: See Table 1.

of metal bats was larger than that in the period of the use of wooden bats ($P < 0.01$).

To verify whether the results of this study are influenced by differences in observed team numbers, the best eight teams were compared with the rest of the teams. The results were found to be similar to those obtained by comparing the best four teams and the other teams. Differences in the mean body weight and body-weight ratio between the winning and losing groups in the period of the use of metal bats were larger than those in the previous periods ($P < 0.05$, $P < 0.01$, respectively). The difference in the mean home run average between the winning and losing groups in the period of the use of metal bats was larger than that in the period of the use of wooden bats ($P < 0.01$).

Discussion

Nukada and his co-workers (12) pointed out that the summer Koshien players from 1965 to 1967 were taller and heavier by 4.7 cm and 8.5 kg, respectively, compared with the national average of 17-year-old male high school students in 1966. We confirmed this observation on the summer Koshien players in all observation periods. The height and body weight of summer Koshien players gradually increased from 1958 to 1967 according to Nukada *et al.* (12). Sawada (9) reported that Koshien players' height in the summer tournaments from 1950 to 1985 increased year by year. The present study demonstrated that height, body weight and body-weight ratio of the summer winning teams' players also increased from 1969 to 1982. In this study, indices of physique of the best four teams' players were greater than those of the other teams after the use of metal bats, although there were no significant differences between them in the periods of the use of wooden bats and both wooden and metal bats. The significant differences in means of height, body weight and body-weight ratio between the best eight teams' players and the rest of the other teams' players were observed in the period of the use of metal bats. It was confirmed that the winning teams' players after the introduction of metal bats were taller than previous winning teams.

According to books on the history of the National High School Baseball Tournament (1, 2), most teams earned runs mainly by hits and sacrifice bunts; skill and strategy took precedence over powerful hitting. Therefore, physique had less influence on the outcome of the games before metal bats were introduced. After the use of metal bats, the winning teams players' body weight and body-weight ratio were larger than those of the other teams' players in every tournament, especially in 1981 and 1982. These changes might have influenced the batting record. In this study, a significant increase in the home run average of the winning teams was observed after metal bats were introduced.

Several studies (13-18) have investigated effects of exercise or physical activity on physical constitution. Significant increases in body weight and in fat-free weight were observed, whereas a decrease in relative body fat was observed. Pařizková (19) conducted a longitudinal study of the physique of 143 boys from the age of 10.7 through 17.7 years old on the average. The subjects were

divided into three subgroups on the basis of their habitual levels of activity. The most active group made more statistically significant increases in body weight and fat-free weight than the other groups over 14.7 years old. Pařízková concluded that the reason for the increase in body size of the most active boys was related to the improvements of body muscle mass that have been attained by regular physical activity. Fukunaga (20) reported that significant relationships were observed between the body weight and cross-sectional muscle area of the upper arm and forearm. It was shown, furthermore, that the summer Koshien players' body constitution in the late 1960s had little fat stored for heavy training and playing (12). Recently, the results of the National Nutrition Survey (21) suggests that the amount of protein intake has been increasing. The ratio of fat energy in the total energy intake was 1.7 times greater for Japanese in 1985 than in 1965. Therefore, body weight gain might have represented an increase of body fat weight in the 1980s. However, Sasaki and his colleagues (22) indicated that the skinfold fat was lower among 46 high school baseball players compared with the standard male high school students from 1981 to 1983.

Although it requires serious consideration whether body weight gain and fat-free weight development are correlated, the above findings mean that there is a close relationship between body weight, body-weight ratio and body muscle mass (*e. g.*, muscle strength) in the summer Koshien players. Primarily, a high degree of skill is one of the essential factors in baseball (23). It was not to be overlooked that the favorable alterations in batting practice methods such as using pitching machines influenced present batting records, whereas this study demonstrated that, in addition to skill, a strong physique has become an important factor in winning the summer Koshien tournaments after the introduction of metal bats. According to the Seventy Years History of National Summer High School Baseball Tournament (1), Tokushima Prefectural Ikeda High School won the championship by powerful hitting in 1982. The present results confirmed that physique in winners of the summer tournaments was superior to that in losers after metal bats introduction, but such was not the case when wooden bats were used.

The reason why the physique of the winning teams' players who used metal bats is larger than those when wooden bats were used is considered to be because the team's managers must have selected larger athletes and trained them to increase their muscle power to take

advantage of metal bats after their introduction. Before metal bats, the winning teams won their games by continuous hits, sacrifice bunts and squeeze plays. After metal bats were adopted, the winning teams won by using offensive methods consisting mainly of long hits which relied on players' muscle strength that had been developed by weight training programs. Therefore, body weight and body-weight ratio of the winning teams' players became greater than those of the other teams' players after metal bats were introduced.

It is considered that the best four teams in the summer tournaments recruited large-size players after metal bats were adopted. The winning players' physique and home run average in the summer tournaments were remarkably larger than the losing players after metal bats were introduced. However, it is not clear whether it is the result of selection of the large-size players or winners are well trained, as a reason for the winning teams' players increased in size after the introduction of metal bats. Further investigation is necessary to clarify this issue.

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