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Immediate effect of assisted and resisted training using different weight balls on ball speed and accuracy in baseball pitching

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The purpose of this study was to investigate the immediate effects of assisted and resisted training using different weight balls on ball speed and accuracy in baseball pitching. Eight male university baseball players were assigned as subjects. The experiment used a standard 145-gram baseball and two heavier or lighter balls with weights increased or decreased by 10% respectively. The subjects were required to pitch these balls and/or standard ball either six or eighteen times under different training trial conditions: 1) pitching the weighted ball only, 2) pitching the lightened ball only, 3) pitching the standard ball only, and 4) pitching three kinds of balls in order of the weighted, standard and lightened balls. Immediately after each training trial, the standard ball was pitched five times respectively (test trial). The ball speed of each trial was measured with a speed gun, and the distance from the center of target to the position of the ball pitched on the target was calculated using a video digitizing system. The results are summarized as follows: 1) In the training trials, the ball speed increased as the ball weight was decreased. 2) In the test trials, immediately after pitching the lightened ball both six ($6A_{test}$) and eighteen times ($18A_{test}$), and the three different kinds of balls eighteen times ($18C_{test}$), the ball speeds were seen to be significantly higher than that of other test trials ($p<0.01$). 3) Although there were no significant differences in the ball speed in the above three test trials, a relatively higher ball speed was observed in $18A_{test}$. 4) As for the distance from the center of target to the position of the ball pitched on the target, there were no significant differences among any trials.

Keywords: immediate effect of training, ball speet, pitching accuracy

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1. Introduction

Training methods to improve specific speed-strength include those conducted by decreasing external load (e.g. air resistance, body weight and weight of equipments) and conversely, those by increasing loads. The former methods conducted by decreasing loads are generally called assisted training, which aims to master feelings of high-speed, rhythm and timing under conditions where performance can be realized at the supramaximal speed level, which is impossible in normal conditions. The latter methods utilizing increased loads are called resisted training which enables trainees to improve elements of muscle strength that are required for a certain movement by performing the exercise with over load [Costello, (1981); Faccioni, (1994a); Faccioni, (1994b); Jakalski, (1998)]. When applying these methods to baseball pitching, it is expected that decreasing the ball weight would enable trainees to develop speed elements in particular among speed-strength required in pitching, and that increasing ball weight would improve strength elements [DeRenne et al., (1990); DeRenne et al., (1994); Escamilla et al., (2000)].

Using seven male university baseball players, Morimoto et al. (2003) compared the ball speed of a standard ball (145g) pitched immediately after nine balls each of different weights were pitched. The weight of the nine balls was increased/decreased by 20% of a standard ball, and each ball weight differed by 5%. The results of this research showed that the ball speed increased immediately after pitching 10% lightened ball compared to the speed after pitching the standard ball. Meanwhile, the study did not show any difference in speed immediately after weighted balls were pitched. And the ball speed also didn't increase immediately after pitching 15% and 20% lightened balls because a ball was released earlier than intended thus entering a "hanging" state. These results demonstrate that 10% lightened ball has an immediate effect in pitching training. However, the research of Morimoto et al. fixed the number of pitches of different weight balls to four, and did not examine how the number of pitches may affect the experiments.

Moreover, the research of Morimoto et al. used each kind of different weight balls separately, while the combination of weighted, standard and lightened equipment is recommended in training methods [Bondarchuk, (1994)]. This combined method aims to achieve synergistic effect of resisted and assisted training in stimulating the central nervous system by throwing weighted equipment before lightened ones. In this case, the combination of weighted, standard and lightened equipment used in this order is considered to be effective as it increases speed gradually [Matveyev, (1981)]. Focusing on this method, DeRenne et al. (1994) investigates the effect of training which uses both different weight and standard weight balls in baseball pitching. However, this investigation examined the effect after a ten week training, whereas a study focusing on the immediate effect of this method has yet to be conducted enough in baseball pitching.

Therefore the aims of the present study is to clarify the influence of the number of pitches and the effect of combining different weight and standard weight balls in assisted and resisted trainings which use different weight balls, and analyzing the immediate effect.

2. Methods

2.1. Subjects

The subjects were eight male pitchers belonging to university baseball team (age: 20.4±1.4 years, height: 174.4±4.2cm, weight: 70.6±4.7kg, experience: 10.0 ±1.9 years). On starting the experiment, the theme, contents and possible danger of this study were explained to the participants in advance and each subject gave consent to participate in the experiment.

Figure 1 Standard, lightened and weighted balls used in this study.

2.2. Weighted and lightened balls

This study uses three balls of different weights. In addition to the standard 145g ball, a ball weighing 10 % more than the standard ball (weighted ball hereafter) and one whose weight was decreased by 10 % (lightened ball hereafter) were used. These balls are similar to ordinary hardballs in appearance, shape, diameter and surface material. The only difference is their weight. The ball is made by inlaying six lead particles of a certain adjusted weight in a cork ball of 50 mm in diameter to change the weight of the cork ball, with the position of gravity center being unchanged. Then the cork ball is substituted for a rubber core at the center of an ordinary hardball, coiled with polyester thread and wool as usual and covered with leather (**Figure 1**).

2.3. Experiment trials

The experiment consists of training trials pitching standard, weighted and lightened balls under different conditions and test trials to pitch the standard ball immediately after training trials of each condition. In the training trial, four different pitching conditions were used, including pitching the standard ball only (Standard training: S_{tra}), pitching the lightened ball only (Assisted training: A_{tra}), pitching the weighted ball only (Resisted training: R_{tra}) and pitching combination of weighted, standard and lightened balls in order (Combined training: C_{tra}). Under each condition, subjects were required to pitch the ball six and eighteen times respectively. In the test trial, the standard ball was pitched five times. Hereafter, a training trial which pitched the ball six times is

Table 1 Experimental protocol in this study.

Signage	Training trial		Test trial
6A	L (6)	→	S (5)
6R	W (6)	→	S (5)
6C	W (2) → S (2) → L (2)	→	S (5)
6S	S (6)	→	S (5)
18A	L (18)	→	S (5)
18R	W(18)	→	S (5)
18C	W (6) → S (6) → L (6)	→	S (5)
18S	S (18)	→	S (5)

L = lightened ball; W = weighted ball; S = standard ball.
The parentheses indicate the number of repetitions.

shown as $6A_{tra}$, eighteen times as $18A_{tra}$, and a test trial is represented with the word 'test' as in $6A_{test}$ and $18A_{test}$ corresponding to each condition of a test trial. The ball was changed every two trials in $6C_{tra}$ and six trials in $18C_{tra}$ respectively. The protocol of these experiment trials is shown at **Table 1**. Subjects were instructed to pitch a ball as fast as possible aiming at the center of a target fixed at a distance18.44 m, and being 1 m high (an ☓ was marked with two strips of yellow plastic tape 30 cm long and 1.9 cm wide on a green ball defense net). We divided the experiment to be conducted during eight days, and randomly selected a training trial under one condition every day. Subjects were not informed about the weight of ball used in training trials. Warm-ups including jogging, stretching and simple catching exercises were performed before starting each trial. Catching exercises were performed for ten minutes using a standard ball. In order to check fatigue of subjects in each trial day and the efficiency of training effects caused by previous experiment trials, subjects were requested to pitch twice a standard ball as fast as possible, and the ball speed was measured by a method which will be described later. After the measurement, subjects again did simple catching exercises for five minutes using the ball for training trial (weighted ball for $6C_{tra}$ and $18C_{tra}$).

2.4. Measured items

The ball speed of each trial was measured by speed gun (Mizuno, PSK-DSP) placed at 10m behind the target and 1.6m off the ground. The speed of a moving ball is measured intermittently, and the maximum (approximate value of the speed at release) and minimum values among measurements were indicated. For the analysis, the former, maximum values were used. A video camera (Canon, DM-XV1) was placed 20 m behind a subject, with the angle adjusted to allow filming of the whole ball defense net (3.5m in width☓40 m in height) that had the target on it. On the filmed image, we read two-dimensional coordinates of the target center, the position of the ball pitched on the target. Four calibration points of which the actual length was known were also filmed. The coordinate, whose original point is the target center, of the position of the ball pitched on the target was converted using actual length to calculate the distance between the target center and the position of the ball pitched on the target. Subjects were also asked to self-observe how they felt when pitching immediately after training and test trials (every two trials in $6C_{tra}$ and every six trials in $18C_{tra}$). The question "How did you feel compared to an ordinary pitching?" was asked and the subjects were asked to respond by rating using a nine point Likert Scale from '-4' to '4' with the setting of "not changed" as point '0'. These data mean "very heavy" to "very light" (Question 1), and from "very hard to pitch" to "very easy to pitch" (Question 2).

Table 2 ICC data calculated from the ball speed of the standard ball measured before the experimental trials for each day.

ICC (formula 2,2)	0.96
95% confidence interval	$0.92<\rho<0.98$
SEM	0.34

ICC = intraclass correlation coefficient; SEM = standard error of measurement.

2.5. Statistical analysis

Intraclass correlation coefficient (ICC) (formula 2,2) (Shrout and Fleiss, 1979) was calculated based on the speed of a standard ball measured before the experiment as an index to show consistency of ball speed under ordinary conditions each day of the experiment. One-way analysis of variance was used in order to examine: statistically significant differences in ball speed, distance from the target center to the position of the ball pitched on the target, responses to the question of self-observation on how they felt pitching in training and test trials. Multiple comparison was conducted on significant differences using Tukey-HSD method. Significance level was set to be less than 5% in any case.

3. Results

3.1. Ball speed

Table 2 shows the ICC calculation based on the

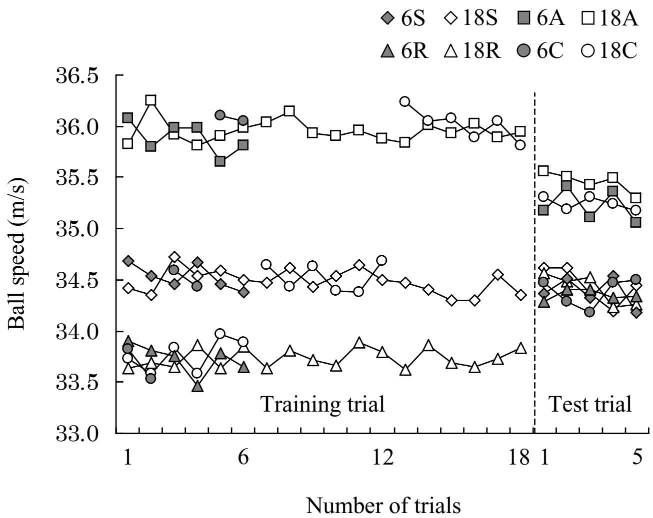

Figure 2 Changes in the mean ball speed at each training and test trial.

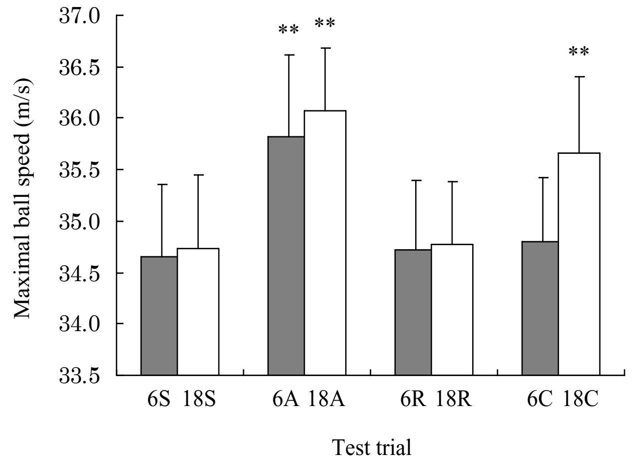

Figure 3 Mean value and standard deviation of the maximum ball speed at each test trial. **Significantly different from other test trials (p<0.01).

Table 3 Mean value and standard deviation of the distance from the center of the target to the ball pitched on the target at each training and test trial.

	6S	18S	6A	18A	6R	18R	6C			18C		
							W →	S →	L	W →	S →	L
Training trial	35.9 (14.7)	34.8 (16.8)	36.4 (16.2)	34.6 (15.6)	37.0 (14.5)	34.6 (15.7)	39.2 (12.5)	38.6 (11.5)	37.9 (12.1)	35.1 (17.4)	38.3 (18.6)	36.2 (14.4)
Test trial	39.7 (12.6)	41.8 (17.5)	36.0 (15.3)	34.6 (14.6)	38.2 (14.4)	35.0 (15.7)		36.4 (19.2)			34.4 (14.7)	

W = weighted ball; S = standard ball; L = lightened ball.
The parentheses indicate SD.

speed of a standard ball measured before starting the experiment each day, the 95% confidence interval and the standard error of the mean (SEM)(SD√1-ICC). Since the ICC value was 0.96, the speed of a standard ball was shown to be highly consistent during the experiment period. Furthermore, the result of a one-way analysis of variance each day did not indicate any significant difference in ball speed.

Figure 2 shows the mean value of the ball speed during training and test trials. In training trials, the ball speed tended to increase as the weight of a ball decreased. After examining the difference in speed of each ball under each condition from the first to the eighteenth trial, there were significant differences in speed between pitching lightened ball and the other conditions regardless of the trial number ($p<0.01$). Significant difference was not observed between the conditions of pitching weighted ball and standard ball but was observed between the conditions where the difference in means was comparatively large in each variation. For instance, significant difference was observed in the first trial between $18R_{tra}/18C_{tra}$ and $18S_{tra}$ ($p<0.01$), but was not observed between $6R_{tra}/6C_{tra}$ and $18S_{tra}$. In the test trials, the ball speed was faster in $6A_{test}$, $18A_{test}$ and $18C_{test}$ than the other conditions, and in regard to the comparison of each trial from the first to the fifth trial among different conditions, significant difference was observed among $6A_{test}$, $18A_{test}$ and $18C_{test}$ compared with the other conditions at every repeat count ($p<0.01$).

Figure 3 shows the mean value and standard deviation of the highest ball speed of each subject in the test trial. The maximum ball speed was comparatively higher in $6A_{test}$, $18A_{test}$ and $18C_{test}$, and the maximum speed of every subject was higher in these conditions than in $6S_{test}$ or $18S_{test}$ even with some dispersion in degree. After examining the difference among conditions, significant difference was observed between $6A_{test}/18A_{test}/18C_{test}$ and the other conditions. Although significant difference was not recognized between $6A_{test}$, $18A_{test}$ and $18C_{test}$, the ball speed tended to be comparatively higher in $18A_{test}$, and seven out of eight subjects recorded the maximum ball speed in this condition during the whole test trials.

Table 4 Mean value and standard deviation of the answer to question 1(top) and question 2 (bottom) at each training and test trial.

Question 1	6S	18S	6A	18A	6R	18R	6C W →	6C S →	6C L	18C W →	18C S →	18C L
Training trial	0.0 (0.0)	0.0 (0.0)	0.5 (0.5)	0.6 (0.7)	$-0.5^{A,a}$ (0.5)	$-0.5^{A,a}$ (0.5)	$-0.5^{A,a}$ (0.5)	0.4 (0.5)	0.5 (0.5)	$-0.5^{A,a}$ (0.5)	0.5 (0.5)	0.6 (0.7)
Test trial	0.0 (0.0)	0.0 (0.0)	$-0.9^{A,B}$ (0.4)	$-1.4^{A\text{-}C}$ (0.5)	0.6 (0.5)	1.1^{B} (0.8)		-0.3^{A} (0.5)			-0.8^{A} (0.5)	

(Training trial) $^{A}p<0.01$; vs. 18A and 18C (L). $^{a}p<0.05$; 6A, 6C (S), 6C (L) and 18C (S).
(Test trial) $^{A}p<0.01$; vs. 6R and 18R. $^{B}p<0.01$; vs. 6S and 18S. $^{C}p<0.01$; vs. 6C.

Question 2	6S	18S	6A	18A	6R	18R	6C W →	6C S →	6C L	18C W →	18C S →	18C L
Training trial	0.0 (0.0)	0.0 (0.0)	0.6 (0.7)	0.8 (0.9)	$-1.3^{A,b}$ (0.9)	-1.1^{A} (0.8)	$-1.4^{A,B}$ (0.7)	0.4 (0.5)	0.5 (0.8)	$-1.3^{A,b}$ (0.9)	0.6 (0.5)	0.8 (0.9)
Test trial	0.0 (0.0)	0.0 (0.0)	$-0.8^{A,B}$ (0.7)	$-1.3^{A\text{-}C}$ (0.5)	0.6 (0.5)	0.8^{B} (0.7)		-0.1^{A} (0.4)			-0.9^{A} (0.6)	

(Training trial) $^{A}p<0.01$; vs. 6A, 6C (S), 6C (L), 18A, 18C (S) and 18C (L). $^{B}p<0.01$, $^{b}p<0.05$; vs. 6S and 18S.
(Test trial) $^{A}p<0.01$; vs. 6R and 18R. $^{B}p<0.01$; vs. 6S and 18S. $^{C}p<0.01$; vs. 6C.

W = weighted ball; S = standard ball; L = lightened ball.
The parentheses indicate SD.

3.2. Distance from the target center

Table 3 shows the mean value and standard deviation of the distance from the center of the target to the position of the ball pitched on the target during training and test trials. Each value in this table was calculated from all trials by each condition (separately shown by weighted, standard and lightened balls in $6C_{tra}$ and $18C_{tra}$). The difference of distance among conditions was examined by each trial, from the first to eighteenth trial in training trials, and from the first to fifth trial in test trials with the result that significant difference was not recognized at any repeat count in training and test trials. Moreover, balls didn't tend to concentrate to hit a specific point such as some upper or lower part of the target center.

3.3. Self-observation report

Table 4 (top) shows the mean value and standard deviation of the answer to the first question about subjects' self observation of the ball pitched during training and test trials. In $6C_{tra}$ and $18C_{tra}$, answers to the question as to the pitch of each ball were shown in order of weighted, standard and lightened ball respectively. In training trials, minus numbers in the Likert Scale corresponding to feelings of heaviness tended to be observed in $6R_{tra}$, $6C_{tra}$ (W), $18R_{tra}$ and $18C_{tra}$(W)which used the weighted ball, while plus numbers indicating feels of lightness seen in $6A_{tra}$, $6C_{tra}$(L), $18A_{tra}$ and $18C_{tra}$(L) which used the lightened ball, and in $6C_{tra}$(S) and $18C_{tra}$(S) which were conducted immediately after pitching the weighted ball. Although a significant difference was observed between these conditions showing minus numbers and plus numbers, there was not any significant difference in answer compared to $6S_{tra}$ and $18S_{tra}$ which used the standard ball only. In test trials, subjects selected minus numbers to answer the question as to conditions immediately after pitching the lightened ball, while plus numbers were selected as to conditions immediately after pitching the weighted ball. Significant difference was observed between $6A_{test}$ and $6R_{test}$/$18R_{test}$/$6S_{test}$/$18S_{test}$, between $18A_{test}$ and $6R_{test}$/$6C_{test}$ /$18R_{test}$/$6S_{test}$/$18S_{test}$, between $6C_{test}$/$18C_{test}$ and $6R_{test}$/$18R_{test}$, and between $18R_{test}$ and $6S_{test}$/$18S_{test}$ respectively.

Table 4 (bottom) shows the mean value and standard deviation of the answer to the second question about how subjects felt about pitching in training and test trials. As in the first question, answers were shown in the order of weighted, standard and lightened balls pitching in $6C_{tra}$ and $18C_{tra}$. Both in training and test trials, minus numbers indicating the degree of difficulty in pitching tended to be selected in the condition mostly degree of heaviness in question 1, and plus numbers indicating ease of pitching to be selected in the condition degree of lightness. Significant difference was observed between the condition answered by minus numbers and the other conditions, except between $18R_{tra}$ and $6S_{tra}/18S_{tra}$ in training trials, while significant difference was observed between the same conditions as in the first question during test trials.

4. Discussion

Our study apportioned experiments to eight days, and conducted experiment trials each day randomly selecting one condition among eight training trials. The purpose of this procedure was to avoid the influence of fatigue caused by the increase in the number of pitches on the experiment. However, when an experiment is conducted over several days, it is possible that both the physical conditions of the subjects each day, and training effects brought by previous experiment trials influenced the result of experiment. Therefore, the ICC was calculated from the standard ball speed measured before the commencement of an experiment trial each day so as to confirm consistency of ball speed under normal conditions during the experiment period. Significant findings of 0.96 on the ICC verify high consistency (**Table 2**). This suggests that subjects were able to perform experiment trials under very close to similar conditions each day of the experiment

The ball speed increased in order of weighted, standard and lightened balls, as ball weight decreased, in training trials (**Figure 2**). Toyoshima et al. (1973) report that ball speed increased as ball weight decreased after investigating the influence of ball weight on ball speed using nine different balls weighing 100g, 150g, 200g, 250g, 300g, 350g, 400g, 450g, and 500g. Our study used the weighted and lightened balls increased or decreased their weight by 10 % of the standard ball. Although the difference in weight was smaller than the balls used by Toyoshima et al., the relationship of ball weight and ball speed showed the similar tendency, which suggests that ball speed can be staged even when the difference in weight is comparatively small.

Significantly higher ball speed was measured in test trials including $6A_{test}$, $18A_{test}$ and $18C_{test}$ than in the other conditions (**Figure 2** and **Figure 3**). In these three conditions, lightened balls were pitched immediately before the test trial. This result corresponds to prior research (Morimoto et al., 2003) which reports that the standard ball speed increased significantly immediately after pitching the lightened ball whose weight was 10% less than the standard 145g ball. It can therefore be suggested that under these conditions, the pitching which used the lightened ball with supramaximal speed level activates neuromuscular system [Bompa, (1999)], resulting in higher ball speed in pitching which used the standard ball. However, the ball speed did not increase in $6C_{test}$ where the lightened ball were also pitched immediately before this test trial. One possible condition is that the lightened ball was pitched twice during the training trial. Moreover, in $18A_{test}$ before which the lightened ball had been pitched eighteen times in the training trial, a higher ball speed tended to be observed compared to $6A_{test}$ and $18C_{test}$ before which the lightened ball had been pitched six times, although the difference was not statistically significant. These results indicate the possibility that whether or not immediate effect can be obtained immediately after pitching the lightened ball, and the degree of the effect depend on the number of pitches using the lightened ball.

Meanwhile, significant difference in ball speed was not observed in $6R_{test}$ and $18R_{test}$ before which only the weighted ball had been pitched in training trials, compared to $6S_{test}$ or $18S_{test}$, before which only the standard ball had been pitched in training trial. This indicates that we cannot expect immediate increase in ball speed immediately after pitching the weighted ball regardless of the number of pitches. Besides, the ball speed in $18C_{test}$ before which three different kinds of weight balls had been pitched in training trial remained almost the same as in $6A_{test}$, which suggests that there wasn't any effect in pitching the weighted and standard balls before pitching the lightened ball. Nelson and Nofsinger (1965) compared the speed of elbow flexion before and after loading four different loads (no load, 15 %, 30 % and 45 % of maximum bending force) when doing elbow flexion. They reported that significant differences were not observed in flexion speed even though all subjects had feelings of increased speed in the trial after loaded exercises. They suggest that the feeling immediately after loaded exercise is "kinesthetic illusion" [Cratty and Hutton, (1964)] which possibly has no actual influence on movement speed. The result of our study supports the suggestion of Nelson and Nofsinger.

With regard to the distance from the target center aimed at pitching to the position of the ball pitched on the target, significant difference was not recognized under any condition during training or test trials. In order to pitch a ball in an intended direction, it is required to put proper centripetal force using the fingers on the ball until just before release. Morimoto et al. (2003) report that this finger force is adjusted to become greater for a weighted ball and lesser for a lightened ball. Any difference in pitching accuracy (distance from the target center to the ball hitting point) is not observed even when using different weight balls if the difference in weight is within 20 % of the standard 145g ball. However, they also report that accuracy declines when the standard ball is pitched immediately after pitching considerably weighted or lightened balls. A possible cause is that memory of dynamical senses are reflected on the pitching of the standard ball immediately after pitching the different weight ball because the finger force used for a considerably weighted or lightened ball is different from that for the standard ball that it remains in the memory [Johansson and Westling, (1988)]. Morimoto et al. suggest that the dynamical sense of fingers will not change so much when the difference in weight is within 10 % of the standard ball, and that the accuracy of standard ball pitching will not be influenced immediately after pitching those different weight balls. Our study verifies this and results were similar when the number of pitches using the weighted or lightened ball was different in training trials. It is considered that though dynamical sense of fingers was more adjusted to each ball weight by increasing the number of repetitions [Kawai, (2002)], pitching accuracy was not influenced immediately after pitching these balls whose weight doesn’t intrinsically change the sense so much compared with that of pitching the standard ball.

Self-observation reports during the training trials show significant difference in the sense of weight between pitching conditions of the weighted ball and lightened ball, which supports the fact that the 29 g of difference in weight between the weighted and lightened balls can be noticed. Subjects tended to feel the ball was "hard to pitch" when it felt "heavy", while feel the ball was "easy to pitch" when it felt "light" (**Table 4**). Meanwhile, in test trials, subjects tended to have feelings of "lightness" and "ease of pitching" immediately after pitching the weighted ball and feelings of "heaviness" and "difficult to pitch" immediately after pitching the lightened ball. The result of test trials can be explained by the "after-effect" [Singer, (1968)]. However, subjects felt $18R_{test}$ lighter and easier to pitch than $6R_{test}$ and felt $6A_{test}$ heavier and harder to pitch than $6C_{test}$, $18A_{test}$ than $6A_{test}$. A possible reason is the comparatively distinct "gap" of feeling occurred when pitching the standard ball immediately after pitching different weight balls, because pitching feeling adjusted to each weight of balls as the number of pitches using weighted and lightened ball increased. The dynamic senses in the fingers do not differ distinctly in pitching different weight balls within 10% from in pitching the standard ball as was mentioned above. Although the fact that less finger force is needed when pitching lightened ball tends to influence subsequent feelings of heaviness of the standard ball immediately after pitching the lightened ball, the self-observation reports suggests that the change in dynamical sense occurs even within the degree where the weight difference isn’t large enough to affect pitching accuracy.

5. Practical Applications

Among the eight conditions of test trials in our study, a significant higher ball speed was seen in $6A_{test}$, $18A_{test}$ and $18C_{test}$ compared to the other conditions. Therefore, $6A_{tra}$, $18A_{tra}$ and $18C_{tra}$, which are training trials of these test trials, are considered to be effective in immediately increasing ball speed under normal conditions. This immediate effect may break through dynamic stereotypes created under normal conditions [Matveyev, (1981)] and can be applicable in stimulating neuromuscular systems either a day before the game or on the day of the game [Mero and Komi, (1985)]. However, since the ball speed of $18C_{test}$ was similar to $6A_{test}$, the effectiveness of pitching the weighted and standard balls before pitching the lightened ball as in $18A_{test}$ was unable to be verified. Higher ball speeds, though not so significant, were more apparent in $18A_{test}$ than in $6A_{test}$ and $18C_{test}$. This indicates that $18A_{tra}$ was most effective in obtaining immediate effect among the training trials of this study. However, subjects felt the ball heaviest and hardest to pitch in $18A_{test}$ compared to the other test trials. Therefore, it seems necessary to acknowledge the intrinsic negative aspect of this method when applying it during the competitive period when the sense under normal conditions becomes most important [Escamilla et al., (2000)].

6. Conclusion

The purpose of this study is to clarify the immediate effects upon baseball pitching of assisted and resisted trainings using balls of different weights. Eight male university baseball players were assigned as subjects. They were requested to pitch the standard, lightened and weighted balls (10% lighter or heaver than standard) six and eighteen times under different training trial conditions:

1) Pitching the weighted ball only,
2) Pitching the lightened ball only,
3) Pitching the standard ball only, and
4) Pitching three kinds of balls in order of weighted, standard and lightened balls.

After the training trial under each condition, the subjects were requested to pitch the standard ball five times respectively as test trials. The results are summarized as follows:

1) In training trials, the ball speed increased as the ball weight decreased.
2) In test trials, significantly higher ball speed was observed immediately after pitching the lightened ball both six ($6A_{test}$) and eighteen ($18A_{test}$) times, and three different kinds of balls eighteen times ($18C_{test}$) compared to the other test trials.
3) Although there were no significant differences in the ball speed in above three test trials, comparatively higher ball speed was observed in $18A_{test}$.
4) With regard to the distance from the target center to the position of the ball pitched on the target, a significant difference was not observed during either training or test trials.
5) Subjects tended to feel that the standard ball was lighter and easier to pitch immediately after pitching the weighted ball, and heavier and harder to pitch immediately after pitching the lightened ball in test trials. This tendency became more noticeable as the number of pitches was increased.

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