

Article

Pilot Study on Exercise Performance Level and Physiological Response According to Rest Intervals between Sets during 65% 1RM Bench Press Exercise

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Abstract: The purpose of this study was a pilot study to determine the performance level and physiologic responses (heart rate and heart rate recovery (%)) of six different rest interval conditions during the performance of seven sets of a 65% 1RM bench press exercise. Eight healthy male university students who were 20 years of age and enrolled at University C were tested. The subjects' bench press 1RM was measured before the experiment, and they performed bench press exercises with six different rest intervals (30 s, 1 min, 2 min, 3 min, 4 min, and 5 min), which were randomized and crossed over. The experimental measurements were performed once a week and repeated six times per rest interval condition (six intervals) to minimize the learning effect for the subjects. A two-way repeated measures ANOVA was used to verify the data, post-comparison (contrast: repeat) was used to establish statistical significance, and the following results were obtained. First, the level of exercise performance (reps) between sets across the six rest interval conditions showed significant differences ($p < 0.000$) and high effect sizes ($ES \geq 0.70$) across the rest interval conditions. In addition, more reps (in terms of volume) were performed in the relatively longer rest interval conditions. The number of reps over the progression of the sets also showed a significant difference ($p < 0.000$) for the shorter rest interval condition, with a high effect size ($ES \geq 0.64$). There was also an interaction effect ($p < 0.000$) between the rest interval condition and the set, with the number of repetitions at the beginning of the set decreasing significantly as the set progressed for the relatively short rest interval condition, with a high effect size ($ES \geq 0.60$). Second, there was no statistically significant difference in after-exercise heart rate among the rest interval conditions between sets, but the longer rest interval conditions of 4 and 5 min showed a significant difference ($p < 0.005$) as the set progressed, with a high effect size ($ES \geq 0.41$). In each of the six rest interval conditions, heart rate levels were similar in sets 1 and 2 but increased from set 3 to set 7. Immediately after each bout of exercise, the resting heart rate according to rest interval condition was statistically highest in the shorter rest intervals (30 s, 1 min), with a high effect size ($p < 0.020$) and a high $ES \geq 0.39$. Heart rate was also higher in the 2, 3, 4, and 5-min rest intervals, and increased significantly ($p < 0.000$) as the sets progressed, with a high effect size. Third, heart rate recovery (%) according to the rest interval condition between sets was significantly higher in the longer rest interval conditions (1, 2, 3, 4, and 5 min) than in the 30 s rest interval condition ($p < 0.039$), with a high effect size ($ES \geq 0.37$). In addition, heart rate recovery in all rest interval conditions significantly decreased as the sets progressed ($p < 0.05$), with a high effect size ($ES \geq 0.37$). Taken together, there were significant differences in performance levels (reps), physiological responses, and recovery between rest interval conditions during the equal-intensity resistance exercises in this study. Furthermore, the performance levels between rest interval conditions during the 65% 1RM bench press exercise in this study suggest that rest intervals of 2–3 min may be effective for improving muscular endurance, while rest intervals of 4–5 min may be effective for improving muscle hypertrophy. This suggests that manipulating the rest intervals between sets during resistance training at the same intensity may lead to better training outcomes.



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Keywords: 65% 1RM bench press; rest interval; number of repetition (volume load); heart rate recovery rate

1. Introduction

Muscle strength and muscle hypertrophy adaptation in resistance training can be changed by the rest intervals between sets [1–4]; correction [5–7] is possible according to the goal of training. The rest interval (the length of time between sets) [7] and the exercise load (%-1RM), which are important factors influencing both the one-time response and long-term adaptations during resistance training [8], are modifiers of exercise intensity [8,9] that vary depending on the training objective.

In terms of the load zone continuum, light-load (65% 1RM or less) resistance training, with the energy required for more than 15 repetitions per set and more than 45 s of muscle contraction, mostly being provided by the fast corresponding fast-processes, is also associated with a large amount of metabolic stress [10]. In contrast, moderate-load (65–85% 1RM) resistance training is provided by fast corresponding processes, with most of the energy required for 15 or fewer repetitions per set and muscle contractions of 20–40 s, but this type of training generates higher metabolic stress due to the differences in exercise intensity providing the optimal combination of mechanical strain and the metabolic stress required for adaptation to muscle hypertrophy [11]. Furthermore, physiological recovery from exercise intensity is positively correlated with both muscle contraction strength and heart rate [12], with a cascade of responses immediately following maximal exercise whereby the increased heart rate is reduced to a stable level by homeostatic mechanisms [13–16].

These physiological recovery responses occur relatively rapidly in healthy, well-trained athletes, who report that a rapid level of heart rate recovery from the previous exercise is positive for the next exercise task [13]. This suggests that the quantitative measurement of physiological (heart rate) responses and recovery levels during rest intervals between sets in resistance training may provide insight into an individual's level of conditioning, which can then be used to modify the levels of mechanical strain and metabolic stress, allowing for more efficient training outcomes in terms of volume or physiological adaptations.

In the previous studies on the strength of exercise and rest intervals, 50–90% 1RM intensity and 3–5 min of rest interval between sets were considered to enable the completion of more repetitions by up to three sets because the ability to maintain mechanical tension is greater than the short rest interval, even if the number of sets increases [6,17,18].

Conversely, the 30 s of rest interval between sets was considered to be a factor that reduced the momentum by more than 50% during five sets at a 10RM load created by increased metabolic stress according to set progression [18,19]. With increased metabolic stress as the 90-s rest interval condition progressed over 5 min during resistance exercise under the same muscle hypertrophy load condition, the authors of [10] reported that the amount of exercise decreased. However, most of the previous research on exercise intensity and inter-set rest intervals has been conducted using uniform inter-set rest intervals, while there is a paucity of research that has examined the performance and the physiological responses between rest interval conditions during resistance exercise at a single exercise intensity. This is taken to mean that the level of repetition (workload) performed during resistance exercise under equal exercise loads (65% 1RM) may provide an indication of the appropriate rest interval between sets that is applicable to muscle endurance or muscle hypertrophy. Furthermore, considering that the 65% 1RM exercise intensity presented in this study is the maximum load for muscular endurance training with an aerobic component [20] and the minimum load for hypertrophic training [9], differences in exercise performance may be seen depending on the rest interval conditions during resistance training at the same exercise intensity. Therefore, it would be meaningful to investigate the level of metabolic stress caused by the manipulation of rest intervals between sets during

65% 1RM resistance exercise, using heart rate as a physiological measurement variable, and to identify the significance of rest interval conditions to suggest the optimal application of rest intervals between sets. Therefore, this study aims to present more objectively the exercise performance level (repeated number) and physiological variables (heart rate and heart rate recovery rate (%)) according to the rest interval conditions between seven sets during resistance exercise at the same intensity (65% 1RM).

2. Materials and Methods

2.1. Research Process

1. Subject

This study aimed to determine the performance levels (reps) and physiological responses (heart rate, heart rate recovery (%)) of 7 sets of a 65% 1RM bench press exercise under 6 different rest interval conditions. To determine the appropriate sample size for this study, G-power software was used to calculate the number of subjects required for a repeated measures analysis of variance, and the required sample size was calculated to be 18 subjects. However, this study was conducted in 2016; since the G-power software program did not exist at the time, 11 subjects had been selected as participants in the study with IRB approval (DKU-2016-05-003). However, 3 subjects dropped out of the study due to personal reasons, so that 8 subjects participated in the experiment. Therefore, it cannot be overlooked that the validity level and effect size reliability of the statistical results presented in this study may be limited. The subjects of this study comprised 8 students who had more than 6 months of resistance exercise experience while attending C university. After fully understanding and recognizing the explanation regarding the purpose of the study before the experiment, the consent form was signed. The physical characteristics of the subjects are shown in Table 1.

Table 1. Physical characteristics.

Subject	Age (Year)	Weight (kg)	Height (cm)	Body Fat (%)
N = 8	23.33 ± 2.52	76.47 ± 7.12	178.07 ± 2.75	14.01 ± 4.21

2. Experimental design and procedure

In order to determine the squat exercise weight to be applied in this research, the study by the authors of [21] was referenced. One week before the experiment, the subjects' maximum weight for one repetition of bench press exercises was measured, and the 65% 1RM was calculated based on this measurement. Experiments were conducted by random assignment according to 6 rest interval conditions (30 s, 1, 2, 3, 4, 5 min). The experiment was carried out with maximum effort for each set, and a second experiment was conducted in the same manner after one week. A total of six experiments were conducted in this way; the experimental design of the study is shown in Figures 1 and 2.

2.2. Measuring Instrument and Method

(1) Repetition

The number of repetitions was controlled by the subject performing the bench press, with 1 s for the descent and 1 s for the ascent, based on each set's maximum repetition; this was counted as 1 repetition. In addition, if the repetition was not completed within the allotted time, or if either segment was timed out, the set was terminated and the number of repetitions completed at that point was measured and recorded. The bench press equipment used a 2.2 m, 20 kg elastic shaft (bar), and a 40 mm × 450 mm disc was used to match the subject's 65% 1RM exercise load.

Subject	8 men with more than 6 months of resistance training experience		
Experiment	65%1RM Bench Press	Rest	Set
		① 30 sec	7 sets-All Out
		② 1 min	7 sets-All Out
		③ 2 min	7 sets-All Out
		④ 3 min	7 sets-All Out
		⑤ 4 min	7 sets-All Out
		⑥ 5 min	7 sets-All Out
Measurement	Repetition	Heart Rate	
	Each set	Immediately after each set exercise	Immediately after each set Rest
Data process	SPSS 26.0 two-way ANOVA Contrast(Repeat)		

Figure 1. Experimental design of the research.

	30 sec		1min		2min		3min		4min		5min	
	●	○	●	○	●	○	●	○	●	○	●	○
	□		□		□		□		□		□	

● After exercise Heart rate ○ After Rest Heart rate □ Repetition

Figure 2. Experimental design of the measurement process.

(2) Heart Rate

The subject's heart rate was measured in a chair position, using a radio heart-rate-measuring device (Polar S610i), and each was measured 7 times immediately after each set of exercises and after the rest time, according to 6 rest interval conditions (30 s, 1 min, 2 min, 3 min, 4 min, and 5 min).

(3) Data processing

Data were processed via a two-way repeated measures ANOVA, using the SPSS 26.0 statistical program. The differences between the conditions were examined using the post-comparison (contrast: repeat) method if there was a statistically significant difference between the number of repetitions for each set, according to the 6 rest conditions and the heart rate just after exercise and after a rest duration. The significance level was set to $p = 0.01$.

3. Results

3.1. Repetition

The repetition results for the six rest intervals condition and the seven sets condition are detailed below.

As shown in Tables 2 and 3 and in Figures 3 and 4, the exercise performance level (the number of repetitions) in the rest interval condition showed a significant difference ($p < 0.000$) with a high effect size ($ES \geq 0.70$). The number of reps over the set progression was also statistically significant ($p < 0.000$), with a very high effect size ($ES \geq 0.64$). The interaction effect between the rest interval condition and sets was also statistically significant ($p < 0.000$), with a very high effect size ($ES \geq 0.60$). Post-comparisons showed that the number of reps according to rest interval conditions significantly decreased in the 30-s and 1-, 2-, and 3-min rest interval conditions, and similarly decreased in the 4-min and 5-min rest interval conditions. Furthermore, as the sets progressed, the number of reps decreased significantly to two sets in the 30-s rest interval condition, five sets in the 1-min rest interval condition, three to five sets in the 2-min rest interval condition, and three sets in the 4- and 5-min rest interval conditions.

Post-comparisons according to interaction effect showed that the number of reps decreased significantly by five sets in the 30-s and 1-min rest interval conditions, by three to five sets in the 2-min conditions, and by three sets in the 4- and 5-min conditions. Furthermore, after a significant decrease in the number of reps according to the rest interval condition, there was a tendency to maintain the same level of exercise performance (number of reps).

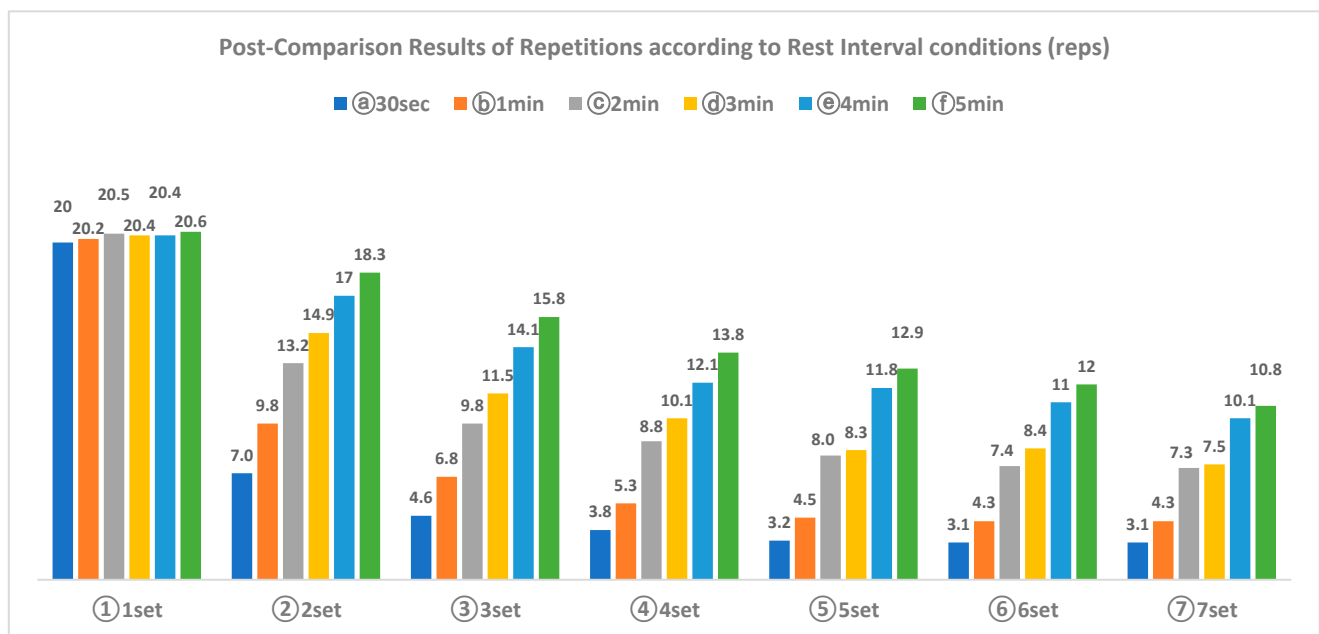
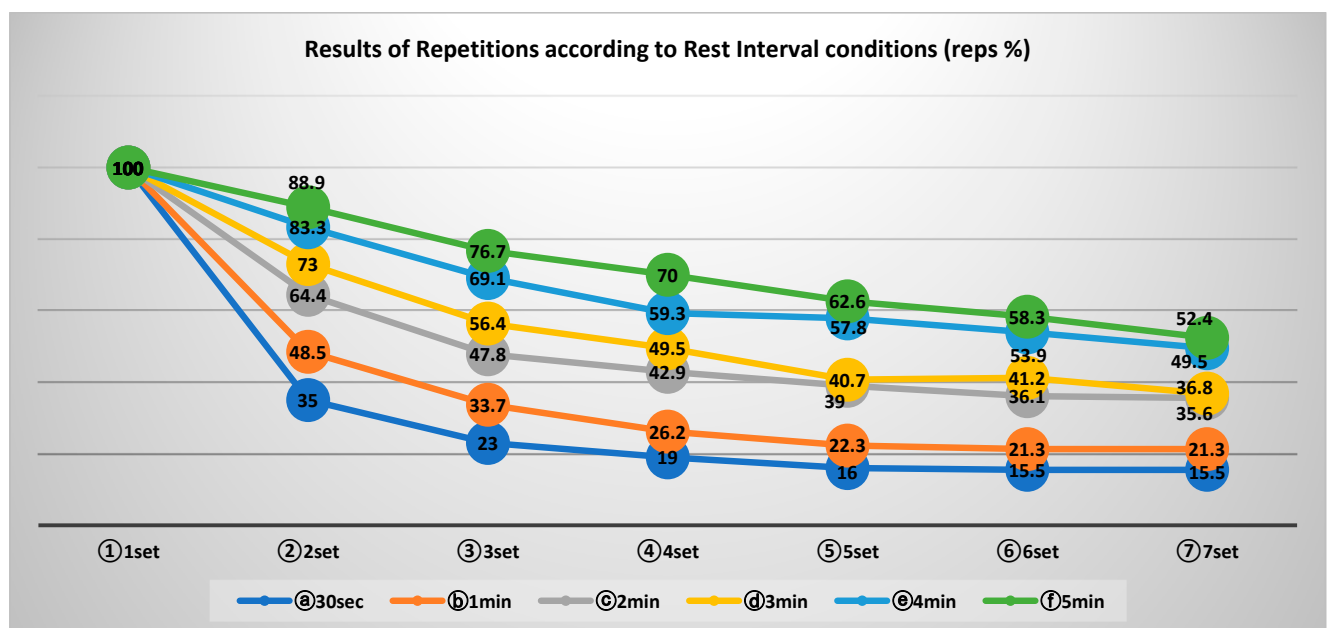
Table 2. Post-comparison results of repetitions, according to the rest interval conditions (in reps).

Rest Interval	① 1 Set	② 2 Set	③ 3 Set	④ 4 Set	⑤ 5 Set	⑥ 6 Set	⑦ 7 Set		ES	p	Contrast
① 30 s	20.0	7.0	4.6	3.8	3.2	3.1	3.1	Rest Interval (RI)	0.70	0.000 ***	① < ② < ③ < ④ = ⑤ = ⑥
② 1 min	± 1.5	± 2.5	± 1.4	± 1.7	± 1.4	± 1.2	± 1.5				
③ 2 min	20.2	9.8	6.8	5.3	4.5	4.3	4.3				
④ 3 min	± 1.3	± 2.0	± 1.6	± 1.5	± 1.1	± 1.3	± 1.0	Sets (S)	0.64	0.000 ***	① = ② > ③ = ④ > ⑤ > ⑥ > ⑦
⑤ 4 min	20.5	13.2	9.8	8.8	8.0	7.4	7.3				
⑥ 5 min	± 1.0	± 2.4	± 2.8	± 2.4	± 1.8	± 2.3	± 2.0				
⑦ 30 s	20.4	14.9	11.5	10.1	8.3	8.4	7.5	(RI) × (S)	0.60	0.000 ***	
⑧ 1 min	± 1.5	± 2.9	± 3.0	± 3.1	± 1.4	± 2.6	± 2.8				
⑨ 2 min	20.4	17.0	14.1	12.1	11.8	11.0	10.1				
⑩ 3 min	± 1.4	± 3.3	± 3.0	± 3.6	± 3.2	± 3.4	± 3.2				
⑪ 4 min	20.6	18.3	15.8	13.8	12.9	12.0	10.8				
⑫ 5 min	± 1.4	± 2.0	± 3.8	± 3.8	± 3.1	± 3.0	± 3.2				

(M ± SD), *** $p < 0.001$. ES: effect size range; f: small ≥ 0.1 , medium ≥ 0.25 , large ≥ 0.4 .

Table 3. Mean and standard deviation of the number of repetitions, shown by rest interval (M $\pm$ SD).

Rest Interval	① 1 Set	② 2 Set	③ 3 Set	④ 4 Set	⑤ 5 Set	⑥ 6 Set	⑦ 7 Set
Ⓐ 30 s	20.0 $\pm$ 1.5	7.0 $\pm$ 2.5	4.6 $\pm$ 1.4	3.8 $\pm$ 1.7	3.2 $\pm$ 1.4	3.1 $\pm$ 1.2	3.1 $\pm$ 1.5
Ⓑ 1 min	20.2 $\pm$ 1.3	9.8 $\pm$ 2.0	6.8 $\pm$ 1.6	5.3 $\pm$ 1.5	4.5 $\pm$ 1.1	4.3 $\pm$ 1.3	4.3 $\pm$ 1.0
Ⓒ 2 min	20.5 $\pm$ 1.0	13.2 $\pm$ 2.4	9.8 $\pm$ 2.8	8.8 $\pm$ 2.4	8.0 $\pm$ 1.8	7.4 $\pm$ 2.3	7.3 $\pm$ 2.0
Ⓓ 3 min	20.4 $\pm$ 1.5	14.9 $\pm$ 2.9	11.5 $\pm$ 3.0	10.1 $\pm$ 3.1	8.3 $\pm$ 1.4	8.4 $\pm$ 2.6	7.5 $\pm$ 2.8
Ⓔ 4 min	20.4 $\pm$ 1.4	17.0 $\pm$ 3.3	14.1 $\pm$ 3.0	12.1 $\pm$ 3.6	11.8 $\pm$ 3.2	11.0 $\pm$ 3.4	10.1 $\pm$ 3.2
Ⓕ 5 min	20.6 $\pm$ 1.4	18.3 $\pm$ 2.0	15.8 $\pm$ 3.8	13.8 $\pm$ 3.8	12.9 $\pm$ 3.1	12.0 $\pm$ 3.0	10.8 $\pm$ 3.2

**Figure 3.** Post-comparison results of repetitions, shown according to rest interval conditions (reps).**Figure 4.** Results of repetitions, shown according to rest interval conditions (reps %).

3.2. Heart Rate

3.2.1. Heart Rate Immediately after Exercise

According to the rest intervals for six conditions and seven sets, the change in heart rate immediately following exercise is the same as that shown in Table 4. The heart rate recorded after exercise, compared according to the rest interval conditions, did not show a statistically significant difference. However, the heart rate recorded after exercise, compared according to the set, showed statistical significance ($p < 0.005$). There was no statistically significant difference in the interaction effect between sets and rest intervals. As shown in Figure 5, the short rest interval conditions (30 s and 1 min) showed a heart rate level of 140 beats/min or higher immediately after exercise as the set progressed, and the 1-min rest interval condition was highest for all sets. The 2-min rest interval condition showed a constant heart rate level as the set progressed, while the 3-, 4-, and 5-min rest interval conditions were higher than at the beginning of the set as the set progressed toward the end of the set. This means that the number of sets affects the physiological response (heart rate) immediately after exercise ($ES \geq 0.41$). The post-comparison results showed that the heart rate was similar in the 30-s and 1-min rest interval conditions, was maintained or increased in the 2- and 3-min rest interval conditions, and continued to increase in the 4- and 5-min rest interval conditions. There was no statistical significance in the interaction effect between the set rest interval and the set. According to the post-comparison of heart rates recorded immediately after exercise according to set, the heart rate was maintained similarly in the 30-s and 1-min rest intervals, was maintained or increased in the 2- and 3-min rest intervals, and showed a tendency to increase continuously in the 4- and 5-min rest intervals.

Table 4. Post-comparison results after exercise between sets, shown according to rest interval (beats/min).

Rest Interval	Pre-Exercise	① 1 Set	② 2 Set	③ 3 Set	④ 4 Set	⑤ 5 Set	⑥ 6 Set	⑦ 7 Set		ES	<i>p</i>	Contrast
① 30 s	91 ± 15.2	141.8 ± 14.9	141.8 ± 14.9	143.3 ± 14.0	142.3 ± 13.6	142.4 ± 13.2	141.9 ± 11.6	142.3 ± 11.0	Rest Interval (RI)	0.352		
② 1 min	93 ± 14.6	147.6 ± 28.2	147.6 ± 28.2	146.6 ± 25.4	144.8 ± 22.6	141.0 ± 24.3	142.9 ± 22.4	142.8 ± 22.8				
③ 2 min	88 ± 16.9	135.9 ± 30.0	135.9 ± 30.0	135.3 ± 27.5	136.1 ± 22.7	137.1 ± 19.7	135.3 ± 23.3	136.8 ± 22.0	Sets (S)	0.41	0.005 *	① = ② < ③ < ④ = ⑤ < ⑥ < ⑦
④ 3 min	89 ± 15.2	135.1 ± 22.6	135.1 ± 22.6	138.1 ± 19.1	140.4 ± 20.0	140.8 ± 16.6	140.1 ± 18.2	140.4 ± 17.6				
⑤ 4 min	89 ± 13.8	132.6 ± 22.8	132.6 ± 22.8	141.6 ± 15.6	141.9 ± 14.6	143.0 ± 11.8	145.5 ± 11.3	143.8 ± 10.7	(RI) × (S)	0.982		
⑥ 5 min	87 ± 15.5	130.3 ± 17.5	130.3 ± 17.5	140.8 ± 16.1	140.5 ± 17.8	141.8 ± 16.7	142.6 ± 12.9	143.5 ± 19.0				

(M ± SD), * $p < 0.05$. ES: effect size range; f: small ≥ 0.1 , medium ≥ 0.25 , large ≥ 0.4 .

3.2.2. Heart Rate Immediately after the Rest

The results for the change in heart rate after rest according to the rest interval for six conditions and seven sets are the same as that shown in Table 5. The heart rate after rest according to the rest interval condition showed statistical significance ($p < 0.020$), while the heart rate after rest according to the set progression showed a significant difference ($p < 0.000$). There was no interaction effect seen according to the rest interval condition and set progress. As shown in Table 5 and Figure 6, the resting interval conditions and the heart rate levels after rest were affected by both the rest interval conditions and the sets. In addition, the change in heart rate immediately after rest was found to be higher in relation to the set number ($ES \geq 0.54$) rather than the rest interval condition ($ES \geq 0.39$). The post-comparison results showed that the heart rate recorded after resting according to the resting interval conditions was significantly different in the 30-s and 1-min rest interval condition and the 4- and 5-min rest interval conditions. After rest, the heart rate showed a

significant difference in sets 1, 2, 6, and 7, and there was no interaction effect between the rest interval conditions and sets.

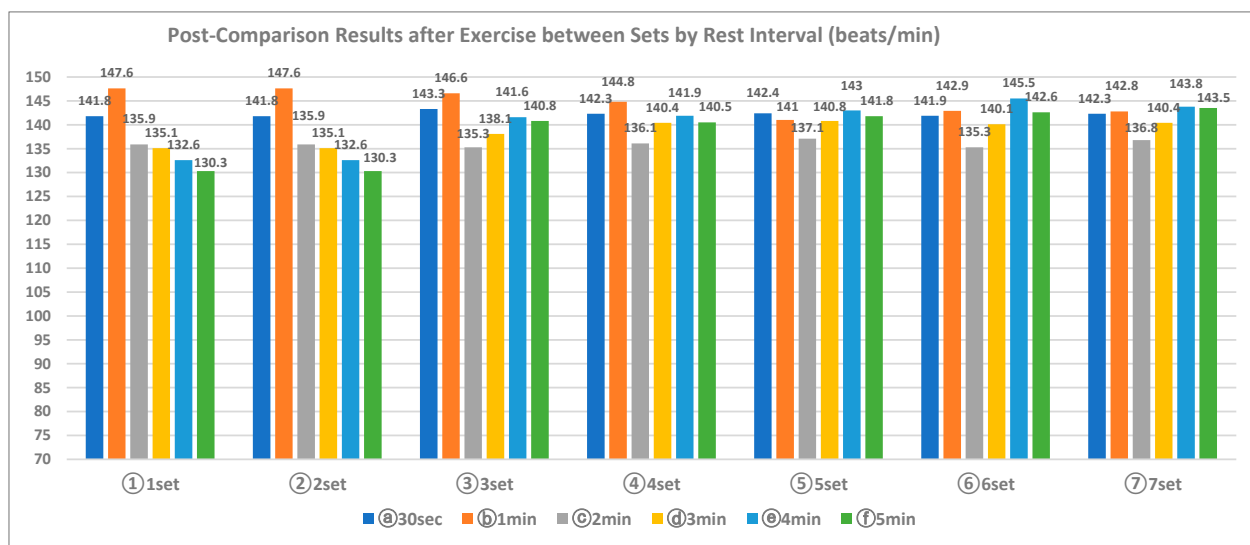


Figure 5. Post-comparison results after exercise between sets, shown in beats/min.

Table 5. Post-comparison results after rest between sets, shown according to rest interval (beats/min).

Rest Interval	① 1 Set	② 2 Set	③ 3 Set	④ 4 Set	⑤ 5 Set	⑥ 6 Set	⑦ 7 Set		ES	p	Contrast
a	117.5	123.5	124.1	121.1	122.5	123.5	119.8	Rest Interval (RI)	0.39	0.020 **	a, b > c > d, e > f
30 s	± 18.7	± 18.1	± 16.5	± 16.6	± 15.4	± 18.5	± 15.5				
b	113.0	115.0	115.9	112.8	113.3	115.1	108.9				
1 min	± 20.0	± 19.5	± 17.7	± 17.2	± 16.3	± 16.9	± 15.3	Sets (S)	0.54	0.000 ***	① < ② = ③ = ④ = ⑤ = ⑥ > ⑦
c	92.9	95.4	97.6	99.1	98.3	100.5	96.1				
2 min	± 19.8	± 21.3	± 21.5	± 19.8	± 18.4	± 20.5	± 18.2				
d	87.9	93.0	96.3	101.8	100.3	99.3	99.6	(RI) × (S)	0.51	0.540	
3 min	± 15.2	± 15.0	± 15.5	± 13.1	± 12.5	± 13.5	± 11.2				
e	88.5	94.0	99.0	100.0	102.6	101.8	99.1				
4 min	± 15.0	± 15.3	± 12.9	± 11.6	± 8.6	± 10.9	± 10.7				
f	83.0	88.6	90.4	92.8	94.0	94.4	87.9				
5 min	± 14.6	± 13.7	± 15.2	± 17.4	± 16.2	± 17.6	± 13.0				

(M ± SD), ** $p < 0.01$, *** $p < 0.001$; Effect size Range (ES) f: Small ≥ 0.1 , Medium ≥ 0.25 , Large ≥ 0.4 .

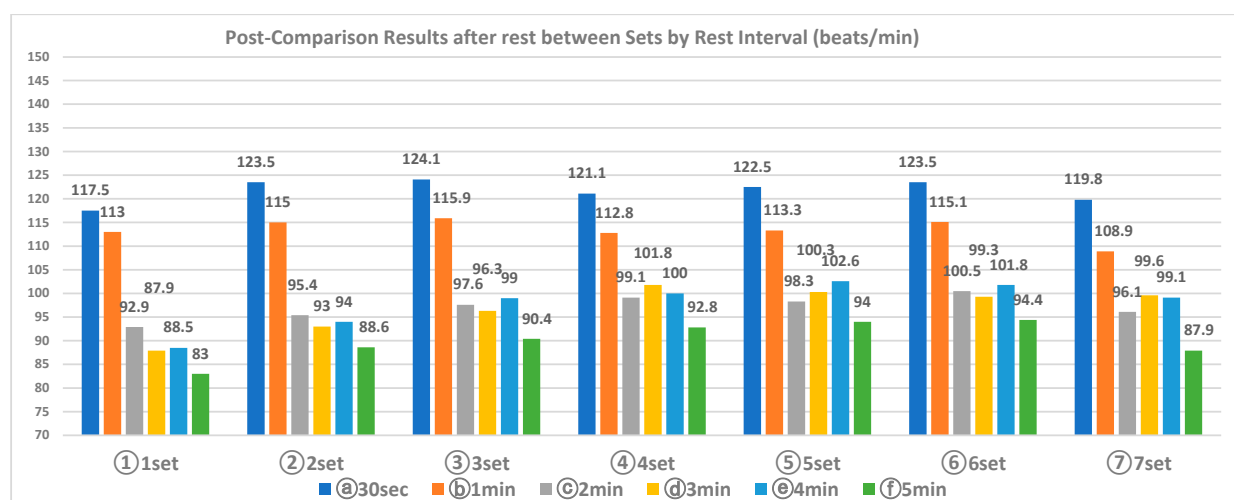


Figure 6. Post-comparison results after the rests between sets, shown in beats/min.

3.2.3. Heart Rate Recovery Rate (%)

The result of the change of heart rate recovery rate according to the rest interval 6 conditions and 7 sets are the same as in Table 6. The heart rate recovery rate (%) was calculated by subtracting the heart rate after rest from the heart rate after exercise, multiplying it by 100, and dividing it into the heart rate after rest. The relationship between heart rate recovery rate and exercise performance ability was examined. The Heart rate recovery rate (%) by rest interval condition showed a statistically significant difference between sets 1 and 2 and sets 6 and 7 ($p < 0.039$), and heart rate recovery by set progression also showed a statistically significant difference between sets 1 and 2 and sets 6 and 7 ($p < 0.026$). The interaction effect between set and rest interval condition also showed a statistically significant ($p < 0.000$) difference. As shown in Table 6 and Figures 7 and 8, the rest interval condition and the heart rate recovery rate (%) according to the set progression were found to have an effect on both the rest interval condition ($ES \geq 0.37$) and the set ($ES \geq 0.37$). However, the heart rate recovery rate (%) was found to be due to a larger interaction effect size ($ES \geq 0.49$) by the rest interval condition and the set progress.

Table 6. Post-comparison of after-exercise and rests between sets, shown by rest interval (%).

Rest Interval	① 1 Set	② 2 Set	③ 3 Set	④ 4 Set	⑤ 5 Set	⑥ 6 Set	⑦ 7 Set	(M $\pm$ SD)		ES	<i>p</i>	Contrast
Ⓐ 30 s	20.7	14.8	15.5	17.5	16.2	14.9	18.8	16.9 $\pm$ 2.2	Rest Interval (RI)	0.37	0.039 **	Ⓐ < Ⓑ < Ⓒ < Ⓓ Ⓔ Ⓕ
Ⓑ 1 min	30.6	28.3	26.5	28.4	24.4	24.2	31.1	27.7 $\pm$ 2.8				
Ⓒ 2 min	46.3	42.5	38.6	37.3	39.5	34.6	42.4	40.2 $\pm$ 3.9	Heart Rate Recovery (HRR)	0.37	0.026 **	① < ② = ③ = ④ = ⑤ = ⑥ < ⑦
Ⓓ 3 min	53.7	45.3	43.4	37.9	40.4	41.1	41.0	43.2 $\pm$ 5.2				
Ⓔ 4 min	49.8	41.1	43.0	41.9	39.4	42.9	45.1	43.3 $\pm$ 3.4	(RI) $\times$ (HRR)	0.49	0.000 ***	
Ⓕ 5 min	57.0	47.1	55.8	51.4	50.9	51.1	58.7	53.1 $\pm$ 4.1				

(M $\pm$ SD), ** $p < 0.01$, *** $p < 0.001$. ES: effect size range; f: small ≥ 0.1 , medium ≥ 0.25 , large ≥ 0.4 .

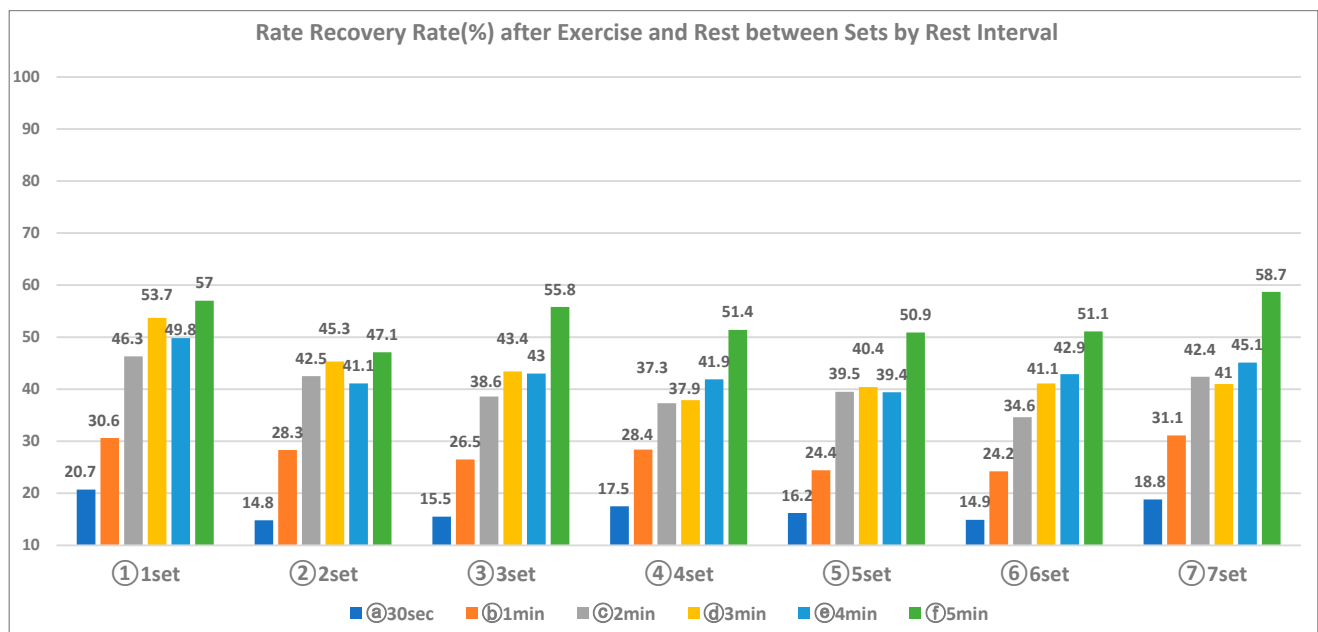


Figure 7. Heart rate recovery rates (%) after exercise and rests between sets, shown by rest interval.

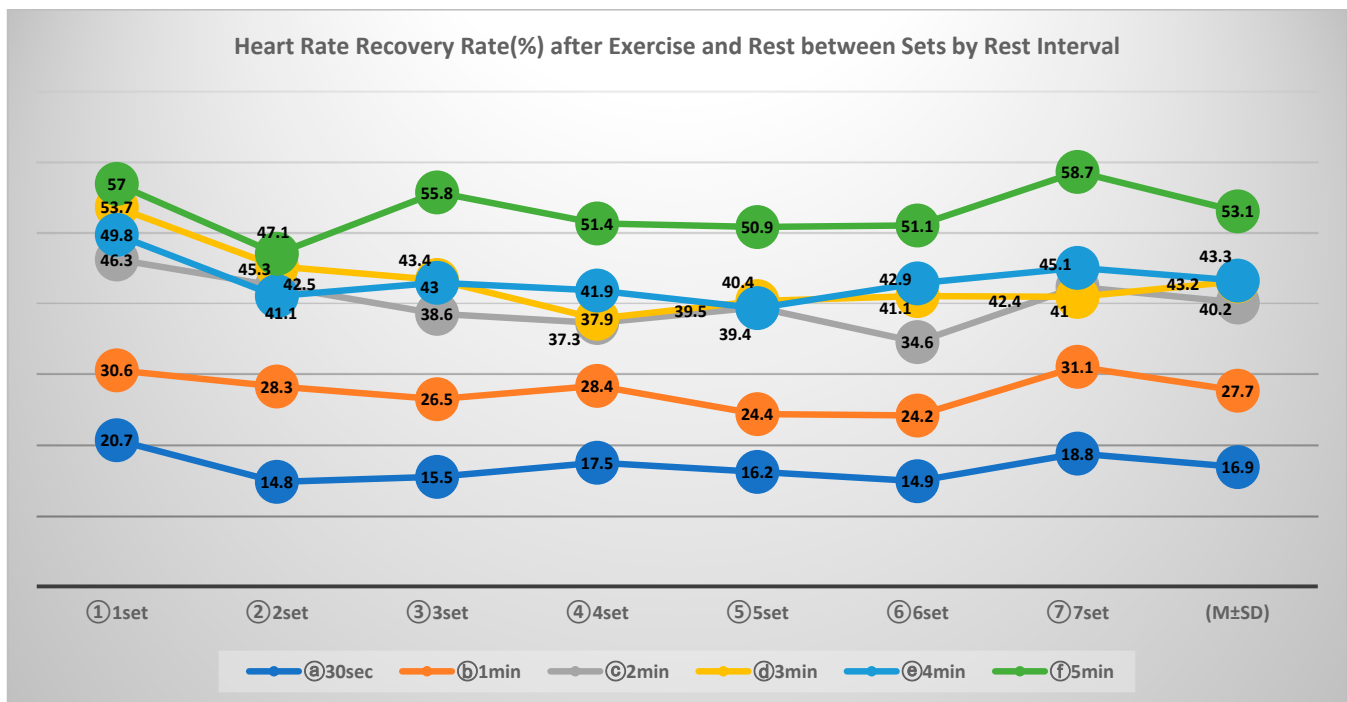


Figure 8. Heart rate recovery rate (%) after exercise and rests between sets, shown by rest interval.

4. Discussion

4.1. Changes in the Number of Repetitions for Each Set of Rest Interval Conditions

The number of repetitions and the speed of performance during resistance exercises show a strong inverse correlation [22]. The exercise performance is relatively fast in terms of low-intensity load compared to high-intensity load, but as the number of repetitions increases, the metabolic stress also increases, and the speed decreases [9]. When the rest interval conditions between sets are performed at 75% of the athlete's maximum bench press weight, previous studies on the number of repetitions according to exercise intensity and rest interval conditions [23] reported that the number of repetitions from two sets after 1 set decreased due to an increase in metabolic stress when the rest interval conditions were performed at 1, 3, and 5 min. In a previous study [24], it was reported that it is impossible to continue with 5 sets at 15RM when the rest intervals between sets are fixed at 30 s, 1 min, and 2 min during resistance exercise. The results of this study were consistent with previous studies, wherein the short rest interval condition results (30-s and 1-, 2-, and 3-min rest intervals) were lower than for the long rest interval conditions (4- and 5-min rest intervals).

However, considering the fact that there are no previous studies that have suggested six rest interval conditions during resistance training, the change and ratio of the number of repetitions shown in Tables 2 and 3 and in Figures 3 and 4 are judged to indicate the difference in exercise performance and exercise amount between rest interval conditions during 65% 1RM resistance training. In addition, the short rest-interval condition performance was due to the lack of time allowed for physiological recovery, such as for energy re-compensation [25,26] and oxygen transfer in the muscle, compared to the long rest interval conditions after performing the sets. It is thought that this reduction in energy utilization ability and the accumulation of metabolic stress caused by this pattern decreased the number of repetitions significantly as the sets progressed. As a result of post-comparison according to sets and set intervals, the number of repetitions according to set interval conditions decreased statistically significantly from 30 s to 1, 2, and 3 min, while the 4- and 5-min conditions showed similar levels. This is judged to indicate the level of energy replenishment [25,26], as well as the level of metabolic stress [27–29] for each rest interval during resistance exercise at 65% 1RM intensity. Therefore, it was found

that energy replenishment through physiological recovery was relatively higher in the long rest interval conditions (4- and 5-min rest intervals) compared to the short rest interval conditions. In addition, it is believed that this is because the shorter rest intervals had less effect on the exertion and reduction of mechanical tension [18] due to the metabolic stress caused by exercise performance.

Therefore, it is thought that the decrease in the number of repetitions was different as the sets progressed. This suggests that the performance of sets with short rest intervals between the sets can cause high metabolic stress levels, which can affect muscle endurance improvement. However, based on the assumption that incomplete recovery and performance in the next exercise performance are prerequisites for endurance training improvement, the 30-s and 1-min rest interval conditions yield low mechanical tension efficiency due to metabolic stress [27–32] is low. In this case, there is a limit to the expected muscle endurance improvement. Therefore, it is thought that a 2–3-min rest interval between sets during a 65% 1RM bench press exercise can be suggested for muscular endurance training.

On the other hand, there was no difference in muscle size between the scenarios in the study by the authors of [6] on adaptation to muscular hypertrophy, which examined two exercise intensity conditions under 60% 1RM (below 60% 1RM) and over 60% 1RM (above 60% 1RM). This suggests that exercise load is not a factor that determines an increase in muscle mass, and also that the effective factors for improving muscle hypertrophy are the failure of muscle contraction through maximum effort and the number of repetitions.

Therefore, the high number of repetitions of each set in the relatively long-term rest time conditions (4 and 5 min) examined in this study is thought to be consistent with previous studies, and it is considered likely that this can be proposed as a suitable rest interval for a muscle hypertrophy improvement program using 65% 1RM intensity.

It has been concluded that the application of rest intervals between sets during resistance exercise using 65% 1RM equalized loads can be used to train muscle hypertrophy and improve endurance. Furthermore, it is believed that the rest intervals between sets and the number of sets may support the argument by the authors of [32] that exercise intensity is an important exercise intensity factor in resistance exercise programs.

4.2. Changes in Heart Rate and the Heart Rate Recovery Rate (%) Immediately after Exercise and after Rest for Each Set of Rest Interval Conditions

The strength of muscle contraction affects the size and speed of heart rate increase, while an increase in exercise intensity affects the heart rate and stroke volume; the higher the exercise intensity, the stronger the heart rate response [12]. In addition, heart rate and cardiac output respond differently according to the nutrient and oxygen demand of cells in the environment of various exercise conditions [33]. According to the study's rest interval conditions in between sets, the heart rate was not statistically significant immediately following exercise, and there was no interaction impact. This result is thought to be because the heart rate was measured immediately after the exercise was performed at the maximum effort level, using the same exercise intensity (65% 1RM). However, the heart rate recorded after exercise according to the set showed statistical significance ($p < 0.005$).

The 2- and 3-min rest interval conditions were lower than the short rest interval condition after two-set, remained slightly higher or similar to the 4- and 5-min long rest interval condition, and gradually increased to a level similar to the short rest interval condition after three-set. This is because the heart rate was recorded immediately after exercise after the maximum repetition (effort) performance from the first set, so it is thought that there is no significant difference between all rest interval conditions. This suggests a level of energy recovery due to the difference in rest intervals between sets that allows for greater energy recovery than the relatively short rest interval condition, and the subsequent increase in metabolic stress due to the relatively greater workload (sets $\times$ reps) than the short rest interval condition may also have contributed to the gradual increase in heart rate as the sets progressed. This suggests that heart rate (contraction frequency) does not increase during the 65% 1RM bench press exercise and that the increase in stroke volume

begins at the 2-min level. However, it is worth noting that this response of no increase in heart rate (contraction frequency) and an increase in stroke volume occurred across rest interval conditions and set progression, but there were no significant differences in maximum heart rate levels. This suggests that manipulation of rest intervals between sets during equal-intensity resistance exercise has a direct effect on physiological response levels and may modulate metabolic stress levels. In addition, heart rates after exercise with the 2- and 3-min rest interval conditions were maintained or increased, and the heart rates after exercise with 4- and 5-min rest interval conditions gradually increased. This suggests that heart rate (contraction frequency) does not increase during the 65% 1RM bench press exercise and that the increase in stroke volume begins at the 2-min level. However, it is worth noting that this response of no increase in heart rate (contraction frequency) and an increase in stroke volume occurred across rest interval conditions and set progression, but there were no significant differences in maximum heart rate levels. After that point, it is thought that the heart rate increased immediately after exercise due to the increase in the number of repetitions and the increase in accumulated metabolic stress.

Conversely, there was a significant difference 'before rest' and 'after rest' is right, and there was a significant difference in the rest interval condition and the interaction effect between the sets. This is thought to indicate high metabolic stress levels and low physiological recovery levels in relatively short rest interval conditions. As the set progressed at the same time, the ratio of energy required for recovery was higher than that with long rest interval conditions due to the energy being used for muscle contraction [25,26].

The average heart rate recovery rate (%) according to rest interval condition was $16.9 \pm 2.2\%$ in the 30-s rest interval condition, $27.7 \pm 2.83\%$ in the 1-min rest interval condition, $40.2 \pm 3.9\%$ in the 2-min rest interval condition, $43.2 \pm 5.2\%$ in the 3-min rest interval condition, $43.3 \pm 3.4\%$ in the 4-min rest interval condition, and $53.1 \pm 4.1\%$ in the 5-min rest interval condition, while the heart rate recovery rate in the relatively long rest interval (3, 4, and 5 min) conditions was higher than the short rest interval (30 s, 1 min, and 2 min) conditions. Figures 7 and 8 show the percentage of heart rate recovery (%) and the percentage of reps (%) between sets, by rest interval condition and set, after performing 1 set of exercises in each condition. The percentage of reps between sets for the 30-s rest interval condition was 35%, 23%, 19%, 16%, 15.5%, and 15.5%. The percentage for the 1-min rest interval condition was 48.5%, 33.7%, 26.2%, 22.3%, 21.3%, and 21.3%; that for the 2-min rest interval condition was 64.4%, 47.8%, 42.9%, 39%, 36.1%, and 35.6%; that for the 3-min rest interval condition was 73%, 56.4%, 49.5%, 40.7%, 41.2%, and 36.8%; that for the 4-min rest interval condition had 83.3%, 69.1%, 59.3%, 57.8%, 53.9, and 49.5%; finally, that for the 5-min rest interval condition had 88.9%, 76.7%, 70%, 62.6%, 58.3%, and 52.4%. The percentage of heart rate recovery (%) during set progression across the six rest interval conditions also increased in the longer rest interval conditions, as did the percentage for exercise performance (reps) level. Afterward, as the set progressed, the ratio of the number of repetitions increased as the heart rate recovery ratio between the rest interval conditions increased. This difference can be explained by a previous study which reported that the relatively long rest interval between sets during resistance exercise can allow a great deal of exercise [28] because there is enough time for the body to supplement its energy compared to the short rest interval; this is considered to indirectly imply the difference in metabolic stress between each rest interval condition. A decrease in relative muscle strength compared to absolute muscle strength results from the short rest interval conditions' low heart rate recovery rate, which also means that metabolic stress accumulation [25,26] is relatively high as the set progresses. This is different from the results for relatively long rest interval conditions, which are thought to have decreased exercise performance (in terms of the number of repetitions) from the start of the set.

5. Conclusions

In this study, eight students who had more than 6 months of resistance exercise experience at C university were selected and the number of repetitions, heart rate (after

exercise, after rest), and heart rate recovery rate (%) according to six rest interval conditions were examined when performing 65% 1RM bench press exercises.

First, the lower heart rate recovery rate (%) seen with the shorter rest interval conditions compared to the long rest interval conditions showed that the rate of energy used for physiological recovery was higher than the rate of energy available for the next set; therefore, the decrease in the number of repetitions was higher as the sets progressed. Hence, it is considered likely that applying short rest interval conditions (30 s and 1 min) with a low heart rate recovery rate (%) to the muscular endurance training program will have limitations in terms of volume (number of repetitions) and energy use.

Second, considering that incomplete recovery between sets during resistance training is a prerequisite for muscle endurance improvement, it is thought that the 2- to 3-min rest interval conditions during the 65% 1RM bench press resistance training conducted in this study can be effective in improving muscle endurance. In addition, the long rest intervals (4 and 5 min), which demonstrated the highest number of repetitions with a relatively high energy recovery level, are considered to be most effective when applied to the muscle hypertrophy exercise program, which is positively correlated with exercise volume (volume load or the dose–response relationship). However, it is judged that a long-term resistance training program applying an inter-set rest interval (2, 3, 4, and 5 min) under a load intensity of 65% 1RM is likely to affect all muscle hypertrophy improvements.

Finally, the sample size suitable for this study was calculated as 18 subjects, but considering the fact that the number of subjects was limited to 8, it is thought that the validity and effect size reliability of the statistical results from this study may be limited. In addition, considering that this study is a pilot study, it may be possible to identify the transition of one-time physiological response and exercise performance level during resistance exercise. However, additional studies regarding the number of statistically valid subjects, training items, training period, gender, age, and exercise items will be helpful in clarifying the actual effects of the results presented in this study.

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