Effect of Static Recovery and Dynamic Recovery on the Cardiopulmonary Variables, Lower Extremity Muscle Activity after Progressive Resistance Exercise to Maximal Point

This study was to examine on the respiratory variables, heart rate and muscle activity between the static recovery and dynamic recovery after progressive resistance exercise to maximal point. Subjects were 15 students enrolled in N University. All were tested two times (static recovery and dynamic recovery) and were requested to perform a walking on a treadmill after progressive resistance exercise to maximal point. Electromyography (EMG) was used to monitor the muscle activity (TA: Tibialis Anterior, MG: Medial Gastrocnemius) during gait. CPEX-1 was used to measure the respiratory variables and heart rate. The dynamic recovery group was shown the significant lower heart rate than that of static recovery group at during gait. Respiratory rate showed statistically a significant difference. Electromyography (RMS, root mean square) showed a non–significant difference. But the dynamic recovery group of muscle activity was found highly in TA and MG. This study indicated that the dynamic recovery method evidenced more faster than the static recovery method. And this type of dynamic rest by walking can be a help of recovery after exercise.

Key words: Heart Rate: Muscle Activity: Recovery: Respiratory

INTRODUCTION

The lengthened leisure hours in present–day life give the general public more opportunities for sporting activities. These days the sporting activities are regarded not merely as a measure releasing stress but as a favorite pastime by a lot of people. According to this trend, the sports during leisure hours are being segmental: more expertly in modern society.

As the sporting activities in leisure hours should give people the strength to go on, the study on the proper way how to smoothly return to daily life, recovering from the fatigue caused by the sporting activities and the outcome of this study needs to be brought into practice for the sake of the general public.

The individual capability of exercise and the extent of personal fatigue have been regarded as an important factor of recovery. Diverse researches to enhance the athlete’s competency have been in progress, focusing on the way how to hold back the exercise fatigue and overcome the tiredness(1, 2). In the course of progress, the diverse researches mentioned above have introduced the following theories, ① That the athlete’s breath control on the actual spot is effective to steady the heavy breathing after exercise(3), ② That a high concentration oxygen breathing, additionally given after high intensity exercise, intensity exercise, makes the recuperative power strengthened(4). On the matter of how to find the best way of recovery both the passive way through ample relaxation or sleep and the active way through an adequate exercise were tried in the preceding researches(5). Also researches on how the physiological response changes according to the recovery method or the recovery exercise type have been progressed till today(6, 7, 8).

Since 1930s, it was continuously reported that the dynamic relaxation in the removal of lactic acid, accumulated through exercise(9, 10, 11). But the approach
in the past researches was merely based on the respective single element of the lactate threshold or maximal oxygen up take. Thus, concerning the theme of comparison recovery, more indepth approach through heart–rate and muscle activities is required to be attempted now. The progressive resistance exercise to maximal point test is generally being used to analyze and assess the subject’s physical fitness, focusing on the cardiopulmonary function. In each course of progressive resistance exercise to maximal point test where the intensity is gradually added by the pre-fixed ratio, the motor ability is to be thoroughly analyzed, through observing the changes in the physio–biochemistry variables like respiratory gas variable and blood variable(12). The heart rate is an index that indicates the load intensity on the heart and the normal and quick recovery of heart rate after a continual exercise reflects the extent of motor ability for next exercise(13, 14). EMG(Electromyograph) which is used to study the features of muscular activity, is known as the minute and complicated random signals and the random signals are the spastic–temporal synthesis among various action potentials that are made by the stimulation on motor unit at the time of muscle activity(15, 16). It was reported that RMS(root mean square) appeared in EMG showed the number of vitalized motor units of muscle and the proportion of mobilization. The same report also mentioned that we can compare the muscle fatigue through RMS(17, 18, 19).

The exercise protocol for exercise tolerance test should be prudently selected, taking the level of physical strength, the age and the gender into consideration, otherwise the competence in aerobic exercise might be overrated or underestimated(20). This research aims to examine what influence is given on the cardiorespiratory variable and the muscle activities of lower limbs by the dynamic relaxation and static relaxation often progressive resistance exercise to maximal point. The primary purpose of this research is to investigate the way how a normal person recovers effectively after he exercises to the extent that his daily life may not be obstructed, Accordingly, targeting the males in their early 20s, a comparison between the dynamic relaxation and the static relaxation was implemented and the focus of this comparison was the heart rate, respiratory function and muscle activity in the stage of relaxation after progressive resistance exercise to maximal point.

**MATERIALS AND METHODS**

**Subjects**

The subjects, selected for this experiment were composed of 15 male students in their twenties who were attending N university in the province of ChungNam. None of them have had the history of musculoskeletal disease and cardiopulmonary disease and have engaged in specific sports activities for the recent 6 months. All subjects in this experiment have signed the written consents, upon hearing an explanation of the purpose and the method of this experiment. Among them only volunteers participated and the physical features of the subjects are shown as Table 1.

<table>
<thead>
<tr>
<th>Table 1, Physcial properties of subjects</th>
<th>Age(yr)</th>
<th>Height(cm)</th>
<th>Weight(kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean±SD</td>
<td>Mean±SD</td>
<td>Mean±SD</td>
</tr>
<tr>
<td>Experimental group(n=15)</td>
<td>21.93±1.83</td>
<td>176.67±6.72</td>
<td>67.13±8.79</td>
</tr>
</tbody>
</table>

**Experimental Method and Measurement Variable**

The measurement in this experiment was implemented two times per person with the time interval of one week, and excessive exercise was prohibited, one day previous to the measurement. On the day of measurement, the meal had to be completed 3 hours prior to the commencement.

**The measurement of the variables before exercise (the first time measurement)**

The respiratory gas analyzer was connected with the treadmill for measurement of variables, and the speed of ordinary pace, 3km per hour was set on the treadmill. The respiratory gas and heart rate during walking was measured. Also the analysis of RMS through EMG was conducted in order to measure the lower limbs, activity during walking. The oxygen uptake(ventilation of oxygen, VO₂), the carbon dioxide uptake(ventilation of CO₂, VCO₂), tidal volume, heart rate and the RMS value in EMG were used as measurement variables.

At time of electromyography examination, surface electrodes were used for gauging and the analysis of EMG was conducted, using the RMS value, obtained from tibialis anterior and medial gastrocnemius of both legs. Subjects performed three maximal voluntary contractions(MVO) in muscular testing position.
of each muscle to obtain a reference value for RMS normalization, EMG force output was sampled with a 1000Hz, band-pass filtered at 20–500Hz. The physical parts for electrodes, attachment were shaved and cleaned up with alcohol in order to prevent any measuring mistake and, afterwards, two electrodes were attached to the belly of the muscle.

**Progressive resistance exercise**

In conformity with the objective of this research, the progressive resistance exercise was implemented on a treadmill that was connected to the respiratory gas analyzer(CPEX–1). As the method of TR–3, a modification of Bruce protocol which is so-called an inclined treadmill protocol, was suggested by the analyzer, CPEX–1, the researcher adopted the TR–3 slope method, considering that all of the subjects are males in their early twenties.

Admitting that the threshold value of the respective individual is not same, the subjects were asked to stop exercising both when the maximal heart rate was over 180 beats per minute and when the figure of respiratory exchange ratio was over 1.0, which means VCO$_2$ became bigger than VO$_2$. Also when the subject appealed to the researcher to stop immediately, having felt utterly exhausted, the exercise was ceased. Having the subjects undergo the progressive resistance exercise, the researcher measured the maximal value by stages. The exercise intensity during dynamic recovery was set at 40% of static recovery's, in terms of VO$_2$ max and the intensity of the respective individual was not standardized, considering the difference by individual(21, 22).

**The recovery test, based on recovery method**

Resting on a chair for 6 minutes was adopted as a method of statistic relaxation and walking on a treadmill for 6 minutes under the condition of VO$_2$ max 40% was set as a method of dynamic relaxation.

**Normal gait after exercise(the 2nd time measurement)**

Same as the 1st time measurement, above.

**Measurement Scale**

The experimental apparatus in this research is introduced in Table 2 and Figure 1, 2.

**Table 2. Experimental apparatus**

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Product</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wireless electrode EMG system</td>
<td>Free EMG</td>
<td>Italy/BTS</td>
</tr>
<tr>
<td>Respiratory gas analyzing system</td>
<td>CPEX–1</td>
<td>Japan/IRS</td>
</tr>
</tbody>
</table>

![Fig. 1. Wireless electrode EMG system](image1.jpg)

![Fig. 2. Respiratory gas analyzing system](image2.jpg)

**Data Analysis**

In this research, the statistic program of SPSS 12.0 was used for data analysis. In order to have the muscle activity pre and post static relaxation be compared with that pre and post dynamic relaxation, this research adopted the means of related t–test. The related t–test was also used in order to have the respiratory gas figures pre and post dynamic relaxation, after progressive resistance exercise to maximal point(complain to fatigue). And the significance level of 5% was set in this test.

**RESULTS**

The Comparison of Muscle Activity between Static Relaxation and Dynamic Relaxation, after the Progressive Resistance Exercise to Maximal Point.

The muscle activity which varies according to the
method of relaxation, was measured through the RMS value of the 4 muscles of right and left tibialis anterior and right and left medial gastrocnemius. The result of measurement is shown in Table 3. The muscle activity difference between static relaxation and dynamic relaxation was not statistically significant.

**Table 3.** Comparison of muscle activity between static relaxation and dynamic relaxation after progressive resistance exercise to maximal point

<table>
<thead>
<tr>
<th>Variable</th>
<th>Static relaxation</th>
<th>Dynamic relaxation</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right tibialis anterior</td>
<td>0.029 ± 0.20</td>
<td>0.126 ± 0.18</td>
<td>-1.672</td>
<td>.117</td>
</tr>
<tr>
<td>Left tibialis anterior</td>
<td>-0.056 ± 0.23</td>
<td>0.060 ± 0.17</td>
<td>-1.941</td>
<td>.073</td>
</tr>
<tr>
<td>Right medial gastrocnemius</td>
<td>0.019 ± 0.23</td>
<td>0.174 ± 0.22</td>
<td>-1.765</td>
<td>.099</td>
</tr>
<tr>
<td>Left medial gastrocnemius</td>
<td>-0.023 ± 0.16</td>
<td>0.047 ± 0.28</td>
<td>-0.935</td>
<td>.366</td>
</tr>
</tbody>
</table>

The Comparison of Respiratory Gas Figure between Static Relaxation and Dynamic Relaxation after Progressive Resistance Exercise to Maximal Point.

The Comparison result with regard to the respiratory gas figure is shown in Table 4. Talking on the matter of respiratory gas after progressive resistance exercise to maximal point, VO₂ and VCO₂ with dynamic relaxation showed higher statistic significance than that with static relaxation (P<0.01). On the other hand, the heart rate under the condition of dynamic relaxation showed lower statistic significance (P<0.05), and as for total lung capacity, there was no significant difference between the two kinds of relaxation.

**Table 4.** Comparison of muscle activity between static relaxation and dynamic relaxation after progressive resistance exercise to maximal point

<table>
<thead>
<tr>
<th>Variable</th>
<th>Static relaxation</th>
<th>Dynamic relaxation</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VO₂ (ml/min)</td>
<td>-54.07±205.15</td>
<td>188.33±176.27</td>
<td>-3.475</td>
<td>.004**</td>
</tr>
<tr>
<td>VCO₂ (ml/min)</td>
<td>-27.00±133.69</td>
<td>124.00±119.91</td>
<td>-3.052</td>
<td>.006**</td>
</tr>
<tr>
<td>Heart Rate(beats/min)</td>
<td>51.13±38.75</td>
<td>22.33±20.94</td>
<td>2.465</td>
<td>.027*</td>
</tr>
<tr>
<td>Total Lung Capacity(ml/min)</td>
<td>361.40±380.33</td>
<td>172.07±255.47</td>
<td>1.806</td>
<td>.093</td>
</tr>
</tbody>
</table>

*: p<.05 **: p<.01

**DISCUSSION**

This research aims to examine which one out of the two methods of relaxation is more effective in recovery, after progressive resistance exercise to maximal point. The purpose of this research is also to give assistance in maintaining and enhancing motor performance capacity through deducing the efficient recovery way.

The preceding researches have reported that the recovery through exercise had more positive effects in getting rid of the fatigue than the recovery through a calm rest(23, 3, 10, 21). In order to give an established significance to the precedent researches and to check if there is any additional change among the variables, the researches intended to confirm the effects of dynamic recovery, upon using the respiratory gas analyzer(CPEX-1) and wireless electrode EMG system(Free EMG).

The heart rate, indicating the contraction frequency of heart, can be set as an index which shows the intensity of heart load(7, 24). It is a normal reaction that the heart rate goes up as the exercise gets more intensified(25). The quick normalization of heart rate after an intense exercise signifies that one is ready to perform the next exercise, and the state of each individual's heart function and the limit of heart's
endurance and be judged objectively from this(5).

This experiment, implemented on the basis of the previous studies on heart rate, brought a result that the group of dynamic relaxation showed lower heart rate than the group of static way in the stage of recovery next to exercise. From this, we can notice that the experimental group of dynamic relaxation shows more stabilized situation where one’s heart rate gets back to the almost original state(5, 37). As a result of this research on heart rate, it can be concluded that the dynamic relaxation influenced more positively than static relaxation. This conclusion seems to reinforce the precedent research of Huh and Park that the recovery of heart rate with the dynamic relaxation group shows more significant efficiency(27).

The change of VO2 and VCO2 that comes into being because of exercise if connected with the vitalization of metabolism(28, 29). The immediate increase of VO2 upon commencing exercise, is a rapid respiratory compensation in the system(body). The progressive resistance exercise to maximal point results in the increase of pH concentration, lactic acid and the body heat and these makes increases such a compensatory action as above take place(30). In order to provide the necessary energy for restoring the body to the status quo ante and also to supplement the consumed portion of energy storage, the oxygen uptake(VO2) increases for a certain short period of time in the step of relaxation after exercising(31).

Related to such studies on respiratory gas as above, this research brought a result that the treadmill walking as a means of dynamic relaxation rather showed the increase of oxygen uptake(VO2) than the static relaxation after progressive resistance exercise to maximal point. As shown in this research, the higher oxygen uptake(VO2) with the method of dynamic relaxation confirms that the dynamic relaxation supplies the oxygen required for the body to recover more adequately than the static relaxation. We can say that the existing theories enumerated below, were revalidated by the result of this study. 1) The higher VO2 can improve aerobic capacity more efficiently than the lower VO2. 2) The higher VO2 can vitalize oxygen transportability and thus remove the body wastes rapidly for fatigue recovery.

The research method that examines the change of motor unit activity on function, analyzing the signals of surface electromyography, has been continuously used since long time ago(32, 24).

As per the measurement value by electromyography with this research, there was no significant statistical difference between the two types of relaxation but the group of dynamic relaxation showed higher RMS value when the comparison of numerical change was implemented between them. The precedent researches reported that the RMS value had reduced upon causing the muscle fatigue on quadriceps femoris muscle(32, 34). The precedent researches maintained that RMS value reduced with the increase of muscle fatigue and this research proved that the group of dynamic relaxation showed a higher RMS value than the group of static relaxation. From this, we can conjecture that the dynamic relaxation is more effective in the recovery of muscle fatigue, even though the statistical significance was not verified.

Besides, Astrand et al, have reported that the muscle vitality is increased if the blood temperature is high because the high temperature makes more oxygen can be delivered to the muscle on function through blood(24). Accordingly, the higher RMS value with dynamic group can be interpreted as the muscle activity with dynamic group was enhanced for a rapid recovery through the increased VO2. However, the numerical value of muscle activity did not bring out any statistically significant results despite of the higher RMS value with dynamic group. The researcher would like to contend it was because the duration of relaxation, set in this research was proper for the recovery of respiratory gas variable, but not proper more or less for the recovery of muscle activity. Han and Kwak(19) have expressed that RMS value would decrease due to the muscle fatigue and would increase after relaxing. So if we revise the duration of relaxation, following the above opinion by Han and Kwak, we might more clearly define the correlation between the fatigue from exercising and the motor unit mobilization and the difference of muscle activity between the two methods would also be clearly defined.

Therefore, in future researches, exploration for a relaxing method with more diverse variables should be attempted. The researcher considers that a more systematic relaxation method which shorten the recovery time needs to be developed and all the protocols on relaxation method, including the one in this research would be compared for the development.

**CONCLUSION**

Aiming at investigating the effect of static and dynamic recovery on the cardiopulmonary variables and also on the muscle activity of lower limbs, after
progressive resistance exercise to maximal point, this research was performed two times with the interval of one week.

The boy students attending N university were recruited as subjects in this research. In this research, the muscle activity of lower limbs during dynamic and static recovery after progressive resistiv-
ance exercise to maximal point on a treadmill was gauged and the heart rate and total lung capacity during dynamic recovery and static recovery were analyzed through CPEX-1, the respiratory gas ana-
lyzer. As a result, the following outcome was obtained through this research: after progressive resistance exercise to maximal point, the dynamic recovery more quickly stabilizes the heart rate and brings about the more increased VO₂ than static recovery.

Accordingly the dynamic recovery is considered to be of more assistance in maintaining and enhancing the motor performance capacity than the static recovery.

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