Effect of Individual Difference in Maximal Strength and Number of Repetitions at Relative Intensity on Muscle Oxygenation During Knee Extension Exercise

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The purpose of this study was to investigate muscle oxygenation during intense dynamic knee extension exercise, after a classification into four groups based on the relative merit of one repetition maximum (1RM) and the total number of repetitions loaded at 90%, 70% and 50% of 1RM ($N_{\text{total}}$). Thirty six male university undergraduate and graduate students with experience in various sports participated in the study. Subjects performed knee extension exercise at 1RM and a number of repetitions loaded at 90%, 70% and 50% of 1RM. Subjects were divided into four groups based on the results of 1RM and $N_{\text{total}}$ (SN group : 1RM-high / $N_{\text{total}}$-high, Sn group : 1RM-high / $N_{\text{total}}$-low, sN group : 1RM-low / $N_{\text{total}}$-high, sn group : 1RM-low / $N_{\text{total}}$-low). Muscle oxygenation on the vastus lateralis muscle was measured during the repetition exercises. The minimum value and rate of decrease at onset of repetition exercise (4-9 seconds after the start of exercise) were calculated to estimate muscle oxygenation. The major findings were: (1) The relative merit of 1RM and number of repetitions at relative intensity affected the muscle oxygenation during repetition exercise. (2) A significant negative correlation between $N_{\text{total}}$ and rate of decrease of muscle oxygenation was observed with loads at 70% and 50% 1RM, but not at 90% 1RM. These results suggest that it is important to focus on the improvement of aerobic capacity in resistance training to increase the number of repetitions at relative intensity.

Keywords: 1RM, near infrared spectroscopy (NIRS), oxygenated hemoglobin/myoglobin (oxy-Hb/Mb)

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Masuhara (2000) examination of the relationship between oxy-Hb/Mb dynamics and the duration of dynamic knee extension exercise suggested the possible influence of the lowered oxy-Hb/Mb with increased exercise intensity (10-30% MVC) on the shortening the exercise period. It was also reported that such changes in the oxy-Hb/Mb dynamic were primarily the result of the involvement of an increase in intramuscular pressure along with increased exercise intensity and subsequent incidental blood flow limitation and decrease of oxygen supply in active muscle (Barnes, 1980; Sadamoto, et al., 1983; Ballard, et al., 1998).

The number of repetitions in each %1RM was found to have a significant negative correlation with 1RM (Berger, 1970; Caroson and McCraw, 1971), suggesting the possibility that even for the same %1RM, the more 1RM the person has, the fewer the number of repetitions. Because the characteristic of the load used for resistance training is determined by the combination of 1RM and the number of repetitions in each %1RM (Fleck and Kraemer, 1987), it is important to understand the possibility that the number of repetitions in each %1RM significantly decreases along with an increase of 1RM by training. It was reported that such individual differences in the number of repetitions among individuals tend to be found in %1RM of the lower intensity area. It is suggested that these results are influenced by blood flow limitation via an increase in intramuscular pressure during exercise, muscle fiber type composition and the recruitment patterns of muscle fiber (Maughan, et al., 1986; Robergs, et al., 1991; Hickson, et al., 1994).

As mentioned above, 1RM, the number of repetitions in each %1RM and oxy-Hb/Mb dynamics during repetitive exercise are considered to be related to one another. Although the relationship between loading intensity and oxy-Hb/Mb dynamics has been examined, no studies that also examine the influence by 1RM have been reported. Moreover, in spite of the possibility of energy supply by O₂ system involvement in resistance training, there are very few studies that examine oxy-Hb/Mb dynamics targeting loads between high and moderate intensity that are used for training (Tamaki, et al., 1994; Hoffman, et al., 2003). Examining oxy-Hb/Mb dynamics with potential influence on the number of repetitions and the levels of 1RM will be useful basic findings for the clarification of the cause of the decrease in the number of repetitions along with the increase of 1RM.

The purpose of this study was to investigate oxy-Hb/Mb dynamics in active muscles for 3 types of %1RM (90%, 70%, 50%1RM) after a classification into four groups based on levels of 1RM and the number of repetitions in %1RM. A method similar to that employed in authors’ previous study (Ikeda & Takamatsu, 2005) was used for grouping subjects.

2. Method

2.1. Subjects

Subjects were 36 male university undergraduate and graduate school students who had various athletic experience (Age: 24.0±2.2 years, Height: 173.1±5.7cm, Weight: 70.2±10.0kg). We obtained consent from all subjects after explaining the purpose of this study and safety considerations prior to the start of this experiment.

2.2. Experiment protocol

All subjects warmed-up and stretched sufficiently prior to exercise via bicycle pedaling exercise (1.5kp, 60rpm, 5 minutes) after thigh girth measurement was performed. Then, one repetition maximum of dynamic knee extension exercise (1RM) and the number of repetitions loaded at 90%, 70% and 50% of 1RM (N₉₀, N₇₀, N₅₀) of right leg in a chair-sitting position were measured. The attempts in N₉₀ and N₇₀ were randomized; however, N₅₀ was scheduled as the final attempt in consideration of N₅₀ being exercise producing a high level of fatigue. Simultaneously, the change of oxy-Hb/Mb in active muscles was observed by NIRS device during repetitive exercise. Measurement at each %1RM was performed at intervals of not less than 30minutes and confirming a return of the oxy-Hb/Mb level to the value at rest (baseline value).

2.3. Measurement items and methods

2.3.1. Thigh girth

A steel measure was used to measure thigh girth. After identifying the greater trochanter and the lateral intercondylar tubercle of the right femoral region, the girth of the region at a level 50% distal to the greater trochanter was measured twice, and the average value was obtained.
2.3.2. Maximum dynamic knee extension exercise

The muscular strength measurement machine used in authors’ previous study (Ikeda & Takamatsu, 2005) was used to measure 1RM. The range of motion was from 90° in a flexion position to 0° in an extension position when the anatomical extension position of the knee joint in a chair sitting position was regarded as 0°, and the exercise provided the same level of load over the entire range of motion. Two places in the lumbar and femoral regions were fixed by the special belt during exercise. To avoid the influence of upper body muscles, the subjects were instructed to cross their arms in front of their chests, and fixed the upper bodies on the backrest of the chair. If the subject could hold up one weight, they were allowed to attempt the next weight. The weight was increased by 2.5kg for each time successive attempt. Each subject was allowed to determine the first weight in order to prevent the number of attempts from the first attempt from exceeding 5 times. 1RM was regarded as the maximum weight at which the specified movements could be performed.

2.3.3. Number of repetitions in each %1RM

The number of repetitions (N_{90}, N_{70}, N_{50}) utilizing loading intensity at 90%, 70% and 50% of 1RM by repeating the exercise until reaching the all-out point was measured. The measurement machine that was used was the same as for the 1RM measurement. The speed of the repetitive exercise was set at once every two seconds (1 second for the concentric phase and 1 second for the eccentric phase), and subjects repeated this until such time that they could not maintain the speed or not extent to 0° of the knee joint extension position. Determination of all-out was made when subjects were no longer able to perform the attempts under the required conditions twice in succession. The minimum unit of loading intensity was set at 1.25kg. The total number of repetitions of N_{90}, N_{70} and N_{50} (N_{total}) used in authors’ previous study (Ikeda & Takamatsu, 2005) was calculated and used as an indicator for the comprehensive evaluation of the number of repetitions in 3 types of %1RM.

2.3.4. Grouping subjects on the basis of the level of 1RM and N_{total}

The relationship between 1RM and N_{total} is shown in Figure 1. The vertical dotted line in the figure indicates the average value of 1RM (57.3kg), and the diagonal dotted line indicates the exponential function approximation of N_{total}. Although a significant negative correlation was found in the relationship between 1RM and N_{total}, it showed the greatest conformity to the exponential function after checking both values with various regression functions. Therefore, this exponential function was adopted in this study. All subjects were separated into 4 groups according to the two above-mentioned dotted lines.

SN group: Group showing high values in both 1RM and N_{total} (n=9)
Sn group: Group showing high values in 1RM and low values in N_{total} (n=8)
sN group: Group showing low values in 1RM and high values in N_{total} (n=7)
sn group: Group showing low values both in 1RM and N_{total} (n=12)

2.3.5. Oxy-Hb/Mb change in active muscles

A laser tissue blood oxygen monitor (BOM-L1TR, Omega Wave, Japan) was used for the measurement of oxy-Hb/Mb during repetitive exercise in 3 types of 1RM. This measurement device, based on near infrared spectroscopy (NIRS), is known as a noninvasive technique for evaluating oxygenation of skeletal muscles by the different light absorption characteristics of Hb/Mb (Kawaguchi et al., 2001; Shibuya et al., 2004).

The validity of the measurement of Hb/Mb dynamics in muscles by NIRS device was confirmed in a previous study (Mancini et al., 1994; Delcanho et al., 1996). The distance between the light source and the optical detector of the NIRS device was set at 30mm, and fixed on a rubber sheet. After identifying the greater trochanter and lateral intercondylar tubercle of the right leg, the above-mentioned rubber sheet was fixed to the vastus lateralis muscle of the region that was 50% distal to the greater trochanter. After all the exercises were finished, a cuff belt was fixed on the femoral base which maintained a continuous pressure of greater than 300mmHg (arteriovenous ischemia) for longer than 10 minutes or until the oxy-Hb/Mb reduction stabilized in order to measure the maximum deoxygenation value of oxy-Hb/Mb. Measurement data was sampled at 10Hz, and the average value of each second was used for the analysis.

The relative oxy-Hb/Mb (% oxy-Hb/Mb) during each exercise was calculated as the relative value for oxy-Hb/Mb resting value and the maximum
Ikeda, T. and Takamatsu, K.

deoxygenation value obtained during ischemia (Chance et al., 1992). The lowest value and the rate of decrease at the initial stage of exercise (4-9 seconds after starting exercise) were calculated in order to evaluate the oxy-Hb/Mb dynamics during the exercise. The rate of decrease of oxy-Hb/Mb at the onset of exercise was reported to reflect aerobic capacity in the active muscles (Hamaoka et al., 1997). Considering the influence of the inflow of blood into muscles immediately after the start of exercise (Sako et al., 2001), the period of 4-9 seconds after the start of exercise was used for analysis.

2.4. Statistical processing

All measurement values were indicated in average value ± standard value. One-way analysis of variance was used for verification of average value differences of measurement items between 3 types of loading intensity. Moreover, when the F value is significant, multiple comparison by Scheffé’s method was carried out. The relation of 1RM and N<sub>total</sub> to each parameter was analyzed by Pearson’s correlation. Statistical significance was determined to be a risk rate of 5%.

3. Results

3.1. Examining by data for all subjects

The average value and standard deviation of 1RM and N<sub>total</sub> for all the subjects were 57.3±10.2kg and 53.4±13.8 times, respectively. A significant negative correlation was found between 1RM and N<sub>total</sub> (r = -0.499, P < 0.01). The average values and standard deviations for N<sub>90</sub>, N<sub>70</sub> and N<sub>50</sub> were 7.1±2.1 times, 16.4±3.1 times and 29.1±8.5 times. The number of repetitions was found to increase significantly along with a decrease in loading intensity (P < 0.01).
Table 1 Characteristics of subjects in each group.

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (yrs)</th>
<th>Height (cm)</th>
<th>Body Mass (kg)</th>
<th>Thigh girth (cm)</th>
<th>1RM (kg)</th>
<th>N_{total} (times)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SN</td>
<td>23.8 ± 1.7</td>
<td>176.7 ± 3.5</td>
<td>78.6 ± 13.2</td>
<td>55.9 ± 4.3</td>
<td>66.1 ± 8.5</td>
<td>51.7 ± 10.4</td>
</tr>
<tr>
<td>Sn</td>
<td>24.0 ± 2.6</td>
<td>172.1 ± 6.4</td>
<td>73.4 ± 7.8</td>
<td>56.0 ± 2.3</td>
<td>65.3 ± 7.1</td>
<td>42.4 ± 5.6</td>
</tr>
<tr>
<td>sN</td>
<td>24.4 ± 3.1</td>
<td>170.4 ± 4.2</td>
<td>63.3 ± 3.5</td>
<td>51.7 ± 1.6</td>
<td>49.6 ± 5.9</td>
<td>75.7 ± 11.2</td>
</tr>
<tr>
<td>sn</td>
<td>23.9 ± 1.7</td>
<td>172.5 ± 6.4</td>
<td>65.7 ± 4.8</td>
<td>52.3 ± 2.5</td>
<td>49.8 ± 4.2</td>
<td>49.2 ± 3.1</td>
</tr>
</tbody>
</table>

Table 2 Minimum value and rate of decrease of oxy-Hb/Mb during knee extension exercise loaded at 90%, 70% and 50% of 1RM.

<table>
<thead>
<tr>
<th>Group</th>
<th>Oxy-Hb/Mb during exercise</th>
<th>Minimum (%)</th>
<th>Rate of decrease (% / sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SN</td>
<td>N_{90} 51.7 ± 10.6</td>
<td>5.2 ± 1.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>N_{70} 47.7 ± 8.2</td>
<td>3.4 ± 1.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>N_{50} 46.8 ± 5.9</td>
<td>2.0 ± 1.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Difference NS</td>
<td>50 ± 70 &lt; 90</td>
<td></td>
</tr>
<tr>
<td>Sn</td>
<td>N_{90} 57.0 ± 12.2</td>
<td>6.5 ± 1.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>N_{70} 46.9 ± 4.1</td>
<td>4.1 ± 1.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>N_{50} 44.3 ± 10.1</td>
<td>2.6 ± 1.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Difference 50 ± 70 &lt; 90</td>
<td>50 ± 70 &lt; 90</td>
<td></td>
</tr>
<tr>
<td>sN</td>
<td>N_{90} 44.2 ± 7.4</td>
<td>5.3 ± 2.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>N_{70} 46.4 ± 5.9</td>
<td>1.9 ± 1.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>N_{50} 50.0 ± 5.7</td>
<td>0.2 ± 1.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Difference 90 ± 70 &lt; 50</td>
<td>50 ± 70 &lt; 90</td>
<td></td>
</tr>
<tr>
<td>Sn</td>
<td>N_{90} 52.1 ± 5.1</td>
<td>7.2 ± 1.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>N_{70} 45.5 ± 4.3</td>
<td>3.6 ± 1.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>N_{50} 50.2 ± 6.5</td>
<td>2.0 ± 1.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Difference 70 ± 50 &lt; 90</td>
<td>50 ± 70 &lt; 90</td>
<td></td>
</tr>
</tbody>
</table>

1. Values are means ± SD
2. <; P < 0.05

3.2. Comparison among 4 groups

The physical characteristics of subjects in the 4 groups are shown in Table 1. The body weight was significantly heavier in the SN group than in the sn and sN groups, 1RM was significantly higher in the SN and Sn groups than in the se and sN groups, and the N_{total} was significantly larger in the sN group than in the SN, sn and Sn groups. Average value and standard deviation of N_{90}, N_{70} and N_{50} in each group were as follows: SN group: N_{90} 6.3 ± 1.9 times, N_{70} 15.9 ± 2.9 times, N_{50} 29.4 ± 6.1 times; the Sn group: N_{90} 5.8 ± 2.0 times, N_{70} 14.0 ± 2.2 times, N_{50} 22.6 ± 2.4 times; the sN group N_{90} 9.1 ± 2.1 times, N_{70} 20.4 ± 3.0 times, N_{50} 41.9 ± 9.4 times; and the sn group: N_{90} 7.3 ± 1.4 times, N_{70} 16.0 ± 1.5 times, N_{50} 25.8 ± 2.2 times.

The lowest value and the rate of decrease of oxy-Hb/Mb during exercise in 4 groups are shown in Table 2. The lowest value of oxy-Hb/Mb did not show any significant differences in any of the N_{90}, N_{70} and N_{50} attempts among the 4 groups. The attempts that showed the lowest oxy-Hb/Mb values were N_{50} in the SN and Sn groups, N_{90} in the sN group and N_{70} in the sn group, confirming that this differed in each group. The rate of decrease of oxy-Hb/Mb during exercise in N_{50} showed significantly high values in the SN group compared with the sN group. An examining of the differences in the rate of decrease of oxy-Hb/Mb among the attempts in each group showed a tendency for the rate of decrease of oxy-Hb/Mb to exhibit low values according to the decrease in loading intensity in all groups.

Correlation coefficients of 1RM and N_{total} with each parameter are shown in Table 3. Significantly positive correlations were found between 1RM and thigh girth (P < 0.01), 1RM per thigh girth (P < 0.01), the lowest oxy-Hb/Mb values (N_{90}, P < 0.05) and the rate of decrease of oxy-Hb/Mb (N_{70}, P < 0.05). Significantly negative correlations were found
between N\text{total} and 1RM (P < 0.01), thigh girth (P < 0.01), the lowest oxy-Hb/Mb values (N\text{90}, P < 0.01) and the rate of decrease of oxy-Hb/Mb (N\text{70}, P < 0.005 / N\text{50}, P < 0.01).

### 4. Discussion

The major findings obtained in this study are as follows: There is a possibility that levels of 1RM and N\text{total} affect the oxy-Hb/Mb dynamics in dynamic knee extension exercise of 3 types of %1RM (90%, 70% and 50%1RM); There is also a possibility that the levels of aerobic metabolic capacity affect individual differences in the number of repetitions seen in N\text{70} and N\text{50}.

No significant differences were found in the lowest oxy-Hb/Mb values among the 4 groups for any of the N\text{90}, N\text{70} and N\text{50} attempts (Table 2). Many previous studies have shown that along with an increase in %1RM, intramuscular pressure generally increases and a corresponding limitation of blood flow becomes greater (Barnes, 1980; Sadamoto et al., 1983; Kagaya, 1994; Ballard et al., 1998). All results of these previous studies suggest that the loading intensity at which the blood flow starts to become a limitation during dynamic exercise is between 20-50% MVC, and because it is difficult to maintain sufficient blood flow at a loading intensity of greater than 20-50% MVC, it affects the continuation of exercise. It also suggests that there is a possibility that the levels of oxygen consumption ability in regional muscle affect the lowest oxy-Hb/Mb values during exercise. However, the impact of the limitation of blood flow due to the increase of intramuscular pressure becomes significant, suggesting the possibility that because the above-mentioned differences in oxygen consumption ability were reduced, no differences were found in the lowest values of oxy-Hb/Mb.

A significant positive correlation was found between the lowest oxy-Hb/Mb values in N\text{90} and 1RM for all subjects (Table 3). It was suggested that completion of the exercise before maximal deoxygenation of oxy-Hb/Mb affected the correlation because there was a significant negative correlation between N\text{90} and 1RM (r = -0.576, P < 0.01), and N\text{90} was an exercise with relatively low number of repetitions (7.1±2.1 times).

Next, the rate of decrease of oxy-Hb/Mb in the onset of exercise was examined. The rate of decrease showed a tendency toward low values according to a decrease in loading intensity, and sN group showed significantly low values in N\text{50} compared with Sn group (Table 2). Furthermore, no significant correlation between N\text{total} and the rate of decrease of oxy-Hb/Mb was seen in N\text{90}. However, a significant negative correlation was found in N\text{70} and N\text{50} (Table 3). These results revealed that the oxy-Hb/Mb at the onset of exercise in N\text{70} and N\text{50} decreased more slowly in subjects whose N\text{total} was larger. These results also suggest the possibility that the rate of decrease of oxy-Hb/Mb at the onset of exercise is more important than the lowest oxy-Hb/Mb values seen during exercise as a factor affecting the number of repetitions in exercise with relative high intensity. In this study, the reasons for these results were considered to be correlated with the 1RM and N\text{total} of each group as follows:

The first reason was the possible influence of the levels of 1RM. The rate of decrease of oxy-Hb/Mb was significant lower in the sN group than in the Sn group in N\text{50} (Table 2). Barnes (1980) found a

### Table 3 Correlation coefficients between 1RM, N\text{total} during knee extension exercise loaded at 90%, 70% and 50% of 1RM and each parameter.

<table>
<thead>
<tr>
<th></th>
<th>1RM</th>
<th>N\text{total}</th>
</tr>
</thead>
<tbody>
<tr>
<td>1RM</td>
<td>-0.461**</td>
<td></td>
</tr>
<tr>
<td>Thigh girth</td>
<td>0.797**</td>
<td>-0.439**</td>
</tr>
<tr>
<td>1RM / Girth</td>
<td>0.948**</td>
<td>-0.396*</td>
</tr>
<tr>
<td>Oxy-Hb/Mb</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum value</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N\text{90}</td>
<td>0.379*</td>
<td>-0.564**</td>
</tr>
<tr>
<td>N\text{70}</td>
<td>0.162</td>
<td>-0.104</td>
</tr>
<tr>
<td>N\text{50}</td>
<td>-0.209</td>
<td>0.163</td>
</tr>
<tr>
<td>Rate of decrease</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N\text{90}</td>
<td>0.030</td>
<td>-0.284</td>
</tr>
<tr>
<td>N\text{70}</td>
<td>0.336*</td>
<td>-0.355*</td>
</tr>
<tr>
<td>N\text{50}</td>
<td>0.301</td>
<td>-0.575**</td>
</tr>
</tbody>
</table>

1. n = 36
2. *P < 0.05, **P < 0.01
negative correlation between %1RM that cause blood flow ischaemia during exercise and the maximum muscular strength, and reported that blood flow starts to be interrupted at relatively lower intensities in subjects whose muscular strength is higher. This suggests that the sN group, which had a small 1RM, did not have much loading intensity when blood flow limitation occurred, while the Sn group, that had large 1RM, revealed a strong limitation of blood flow due to the large increase of intramuscular pressure from the onset of exercise.

Maximum muscle strength is well known to be proportionate to muscle cross-section area. Thigh girth was used as a representative indication of muscle cross-section area in this study. Although care must be taken with the use of thigh girth to assure it reflects muscle cross-section area properly because it contains fat tissue and bone tissue, the Sn group (56.0±2.3cm) had a tendency toward higher values compared with the sN group (51.7±1.6cm) (Table 1). Moreover, the vastus lateralis muscle, the object muscle, is a pennate muscle, and the pennation angle is known to increase along with muscle hypertrophy (Kawakami et al., 1993, 1995). It was reported that an increase of pennation angle causes an increase of muscle curvature (change of pennation angle) during muscle contraction, and affects the increase of intramuscular pressure (Kawakami et al., 1998). It is thought that these factors were combined and possibly affected the rate of decrease of oxy-Hb/Mb.

The second reason is that it is possible that the differences in the amount of blood flow to active muscles immediately after the initiation of exercise had an affect. It is thought that the sN and sn groups had a tendency toward lower values in 1RM and thigh girth (Table 1), and the impact of the limitation of blood flow due to the increase of intramuscular pressure was relatively small. A comparison of the rate of decrease of oxy-Hb/Mb between the 2 groups showed that the sN group showed lower values in all attempts of the 3 types of %1RM compared with the sn group. The rate of decrease of oxy-Hb/Mb was analyzed for the section of 4-9 seconds after the initiation of exercise in this study; however, a previous study utilizing dynamic knee extension exercise by Bangsbo et al. (2000) reported that muscle blood flow reaction became faster than the oxygen intake reaction at the onset of exercise. This suggests the high possibility the rate of decrease of oxy-Hb/Mb was strongly affected by the blood flow reaction in the sN and sn groups that were thought to be less affected by the limitation of blood flow due to the increase of intramuscular pressure.

Hamaoka et al. (1997) reported that there was a significant positive correlation between the rate of decrease of oxy-Hb/Mb and fiber composition (%ST+FTa), and the number of blood capillaries per fiber of gastrocnemius. Bae et al. (2000) reported that there was a significant positive correlation between the rate of decrease of oxy-Hb/Mb and the maximum oxygen uptake (VO_{2max}) by Wingate test. These suggest that it is possible that the greater the muscle aerobic metabolic capacity the subject has, the more oxygen consumption in active muscles at the onset of high to moderate intensity exercise becomes. The possibility is also suggested that the relative merits of aerobic metabolic capacity may have affected the rate of decrease of oxy-Hb/Mb in this study. However, considering that there was a significant negative correlation found between N_{total} and the rate of decrease of oxy-Hb/Mb in N_{70} and N_{50} (Table 3), it is suggested that the impact of the amount of blood flow was involved to a greater degree than the oxygen consumption of active muscles.

This study focused the discussion entirely on the findings of previous studies because direct measurement was not carried out in this study. It is thought to be essential to carry out a detailed examination correlated with muscle fiber composition and blood capillary distribution in addition to having an actual measurement of the amount of blood flow and oxygen uptake during exercise in order to clarify the factors effecting oxy-Hb/Mb dynamics. This study focused only on oxy-Hb/Mb dynamics; however, it is thought to be necessary to examine relationships with anaerobic metabolic capacity such as muscle energy store (MacDougall et al., 1977; Cadefau et al., 1990); muscle buffering capacity (Green et al., 1996); and the recruitment of the quadriceps muscle, the agonist muscle in knee extension exercise (Homma et al., 1998) because the involvement of these are thought to have a great impact.

In conclusion, it was suggested that the level of 1RM and N_{total} may affect oxy-Hb/Mb dynamics in dynamic knee extension exercise in 3 types of %1RM (90%, 70% and 50% 1RM), and aerobic metabolic capacity level is possibly involved in the individual difference in the number of repetitions seen in N_{70}.
and N_{50}. The authors' previous study (Ikeda & Takamatsu, 2005) utilizing the same grouping as the present study pointed out the importance of aiming for improving the number of repetitions for the sn and Sn groups that are inferior to N_{total} to effect a reasonable increase of 1RM. It was suggested that it is also potentially important to improve the aerobic metabolic capacity in addition to the anaerobic metabolic capacity during the resistance training when aiming for an improvement in the number of repetitions according to the individual training objectives.

References


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• Japan Society of Exercise and Sports Physiology
• The Japan Society of Sport Methodology
• Japan Society of Training Science for Exercise and Sport