Effects of muscle activity and number of resistance exercise repetitions on perceived exertion in tonic and phasic muscle of young Korean adults

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Abstract. [Purpose] The aim of this study was to examine the effects of muscle activity and the number of resistance exercise repetitions on perceived exertion in tonic and phasic muscles in young Korean adults. [Subjects] Janda’s classification system was used to divide 40 Korean males and females in their 20s into a tonic muscle group (10 males, 10 females) and phasic muscle group (10 males, 10 females). [Methods] Each participant performed resistance exercise at 70% of maximum exertion for a single repetition. Muscle activity and number of repetitions were measured according to the Borg Rating of Perceived Exertion scale, with fairly light, hard, and very hard rated as 11, 15, and 19, respectively. Multiple regression analysis was performed. [Results] As the number of tonic and phasic muscle repetitions for males and females and female phasic muscle activity increased, the perceived exertion increased. Perceived exertion increased as the number of tonic muscle repetitions and activity of gastrocnemius muscles in males and females and the hamstring in males increased. Increased activity of phasic muscles in males and females and rhomboid muscle activity in males was associated with significantly increased perceived exertion. [Conclusion] Muscle activity and number of repetitions affect perceived exertion. The perception of exertion differs by muscle type and can differ by gender. The influence of the number of repetitions exceeds that of muscle activity.

Key words: Tonic muscle, Phasic muscle, Perceived exertion

INTRODUCTION

The Rating of Perceived Exertion (RPE) refers to the degree of perception involving a combination of local sensations comprising the circulatory and respiratory systems, metabolic system, skeletal muscles, and the peripheral nervous system1). RPE is significantly related to oxygen uptake measurement and the amount of exertion2), and so it is used to assess and regulate the intensity of physical activity3). The Borg Scale is a subjective assessment of exercise intensity. Nonetheless, it provides valuable information concerning RPE4).

RPE is an area of active interest for psychologists and physiologists concerning physical activity and sports5). Information about how individuals perceive their performance may be more important than knowing their actual performance. Subjective perceptual ratings of effort expenditure can be employed as effective predictors of maximal performance.

Physiological, physical, and psychological responses and perceptive changes caused by RPE have been studied6). RPE is related to the muscle soreness and stiffness after a marathon7) and is increased during shorter, rather than longer, rest intervals8). The data support the view that RPE is an indicator for muscle recovery when resistance training is done. Additionally, the order of exercise does not affect the total VO2, but does affect RPE9). Results from examination of physical strain associated with high intensity exercise indicate the value of RPE in measuring an individual’s maximum number of repetitions and actual relative volume. Furthermore, perceived respiratory exertion was shown to not be related to respiratory power output in a previous study but rather to be related to the perceived exertion of the legs, which is related to muscle metabolic conditions10).

Tonic and phasic muscles are usually classified according to the phylogenetic development criteria of Janda11). Muscles are functionally classified as tonic or phasic. The tonic system is phylogenetically older and dominant and consists of the flexors. These muscles are activated in flexor synergies and involved in repetitive or rhythmic activity12).
The phasic system emerges shortly after birth and consists of the extensors. These muscles emerge in extensor synergies and work eccentrically against the force of gravity.

This study was undertaken to investigate the results of isotonic resistance exercise based on the Janda classification and theoretical background. Many prior studies have focused on the relationship between RPE and muscle activity, RPE and number of repetitions, and RPE and energy consumption. However, little is known about the effects of multiple repetitions on muscle activity and RPE during resistance training.

This study investigated the effects of the activity of phasic and tonic muscles and the number of repetitions on RPE during isotonic resistance exercise in young Korean adults.

### SUBJECTS AND METHODS

#### Subjects

The subjects of this study consisted of 20 males and 20 females with average ages of 21.27 ± 1.75 years and 21.09 ± 1.97 years, respectively. Their average heights were 176.84 ± 4.80 cm and 164.36 ± 6.17 cm, respectively, and their average weights were 71.57 ± 13.34 kg and 59.91 ± 9.17 kg, respectively. Their average VO\textsubscript{2max} values were 46.71 ± 7.19 mL/kg/min and 34.15 ± 4.05 mL/kg/min, respectively.

The participants were university students in whom a physician examination had not detected any problems in the upper and lower limbs and muscular skeletal system. None of the participants were engaging in a regular muscle strengthening routine, and none had any contractures in the upper and lower limbs or spinal column that limited any movements necessary for the current study. All participants were instructed about the potential risks and experimental design and provided informed consent for participation, with the knowledge that they could withdraw at any time. The study was approved by the Institutional Review Board of Yongin University.

Muscles were divided according to the Janda classification. Tonic muscles included the iliopsoas, hamstring, gastrocnemius, and pectoralis major muscle. Phasic muscles included the gluteus maximus, quadriceps, tibialis anterior, and rhomboid muscles. Each participant had their maximal dynamic strength (1RM) measured and completed practice trials to become familiar with the isotonic resistance exercise used.

#### Exercise equipment and electrode attachment area depending on muscle type

| Muscle type   | Muscle                  | Exercise method        | Electrode placements                                                                 |
|---------------|-------------------------|------------------------|--------------------------------------------------------------------------------------|
| Tonic muscle  | Pectoralis major        | Chest press            | On the chest wall at an oblique angle toward the clavicle, approximately 2 cm below   |
|               |                         |                        | the clavicle, just medial to the axillary fold.                                       |
|               | Hamstring               | Seated leg curls       | Two electrodes 3 to 4 cm apart placed parallel to the muscle in the center of the back |
|               |                         |                        | of the thigh, approximately half the distance from the gluteal fold to the back of   |
|               |                         |                        | the leg.                                                                             |
|               | Iliopsoas               | Leg raise machine      | Locate the femoral pulse. Go lateral to this, yet medial to the quadriceps femoris    |
|               |                         |                        | and inferior to the inguinal ligament.                                                |
|               | Gastrocnemius           | Donkey calf raises     | Active electrodes are placed 2 cm apart, running parallel to the muscle fibers, just  |
|               |                         |                        | distal to the knee and 2 cm medial or lateral to midline.                            |
|               | Lower trapezius         | Lat pulldown machine   | Place the electrodes on an oblique angle, approximately 5 cm down from the scapular   |
|               |                         |                        | spine. The two active electrodes (2 cm apart) are placed next to the medial edge of   |
|               | Quadriceps (rectus femoris) | Seated leg press machine | the scapula at a 55-degree oblique angle.                                            |
|               | Upper gluteus maximus   | Smith machine          | Place the electrodes on the center of the anterior surface of the thigh, approximately |
|               |                         |                        | half the distance between the knee and the iliac spine. The two active electrodes are |
|               | Tibialis anterior       | Power leg press        | Two active electrodes (3 cm apart) are placed half the distance between the trochanter |
| Phasic muscle |                         |                        | (hip) and the sacral vertebrae in the middle of the muscle on an oblique angle at the |
|               |                         |                        | level of the trochanter or slightly above.                                            |
|               |                         |                        | Two active electrodes, 2 cm apart, placed parallel to and just lateral to the medial  |
|               |                         |                        | shaft of the tibia (shin), at approximately one-quarter to one-third the distance      |
|               |                         |                        | between the knee and the ankle.                                                       |

Table 1. Exercise equipment and electrode attachment area depending on muscle type
for isotonic resistance training.

Muscle activity was measured using a TeleMyo 2400T apparatus (Noraxon U.S.A. Inc., Scottsdale, AZ, USA) following the Jeffrey guide for surface electromyography (EMG). The electrodes were attached after the removal of hair and cleansing of the skin with alcohol. Bipolar Ag-AgCL surface electrodes (10 mm in diameter) with their included conductivity gel (Noraxon) were attached following the muscle fiber direction and connected to an EMG bipolar amplifier. EMG signals were sampled at 1,500 Hz. The resulting raw data were processed by full-wave rectification, smoothed using a root mean square (RMS) algorithm and a window of 100 ms, and then passed through a band-pass filter of 10-350 Hz. EMG analysis was performed with the MyoResearch XP software (Noraxon).

Subjects rated their perceived level of muscle activity using the Borg Scale (14), with fairly light, hard, and very hard scored as 11, 15, and 19, respectively, and a supervisor recoded the number of repetitions at each level.

The data were expressed as the mean ± standard deviation. Data were analyzed using the IBM SPSS statistics version 20.0 statistical software (IBM Corp., Armonk, NY, USA). Multiple regression was used to examine the effects of muscle activity and number of repetitions on RPE. The significance level was p<0.05.

### RESULTS

The average ages, heights, weights, and VO_{2}max values of the two groups were comparable. The results were expressed as whole muscle, tonic muscle, and phasic muscle.

For males and females, as the number of tonic and phasic muscle repetitions increased, RPE increased, but muscle activity did not show a significant effect except for phasic muscle in women. The number of repetitions had a greater effect on RPE than muscle activity (β=0.616 and β=0.171, respectively) in phasic muscle in females (Table 2).

Concerning the iliopsoas muscle of the tonic muscle group, RPE increased in males and females as the number of repetitions increased, but it did not increase as the muscle activity increased. Concerning the hamstring of the tonic muscle group, as muscle activity and the number of repetitions increased in men, RPE increased. The number of repetitions displayed a greater effect than muscle activity (β=0.889 and β=0.234, respectively; p<0.05). In females, RPE increased as the number of repetitions increased (p<0.05), but muscle activity did not show a significant effect. Concerning the gastrocnemius muscle, increased muscle activity and number of repetitions increased RPE in males and females. However, the number of repetitions (β=0.788 and β=0.861, respectively) showed a greater influence than muscle activity (β=0.252 and β=0.175, respectively) (p<0.05). Concerning the pectoralis major muscle, an increase in RPE with an increased number of repetitions was evident in men and women (p<0.05), but muscle activity did not show a significant difference. For the whole tonic muscle group, muscle activity and the number of repetitions had significant effects on RPE but only in the hamstring muscle in men and gastrocnemius muscle in males and females (Table 3).

In the phasic muscle group, the gluteus maximus muscle showed an increased RPE as the number of repetitions increased in males and females (p<0.05), but muscle activity did not show any significance. The same pattern was evident for the quadriceps and tibialis anterior muscles. The rhomboid muscle in men displayed an increased RPE with increased muscle activity and number of repetitions, with repetition showing a greater influence (β=0.550) than muscle activity (β=0.418). In women, rhomboid muscle activity did not show any significance (Table 4).

### DISCUSSION

This study investigated the effects of the muscle activity and number of exercise repetitions of the tonic and phasic muscles on the RPE.

In the overall comparison between the tonic and phasic muscles, only phasic muscles in females displayed an increased RPE when muscle activity increased. Increased number of repetitions in all muscles of males and females was associated with an increased RPE. In the phasic muscles of females in particular, the number of repetitions and muscle activity significantly influenced RPE. In resistance training, RPE increases as heart rate increases (15). Also, as intensity increases, RPE and muscle activity increase (7). Therefore, it is safe to conclude that as the intensity and heart rate increase, RPE increases. EMG activity can mediate RPE (16), indicating that RPE could be used to regulate the intensity of exercise (17).

Among the tonic muscle group, the hamstring muscle in men and gastrocnemius muscle in males and females was associated with an increased RPE and increased muscle activity. RPE was affected by the number of repetitions more than by muscle activity.

In the phasic muscle group, the rhomboid muscle in males displayed an increased RPE and increased muscle activity. Again, the number of repetitions had a more significant effect on RPE. These results show that when the number of repetitions increases, RPE increases proportionally, which is similar to the results of a previous study (18). The results were also similar to those of study in which RPE significantly increased as repetitive muscular contractions were performed (19). Males had higher muscular activity than females.

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**Table 2.** Multiple regression analysis of factors related to rating of perceived exertion (RPE) in total tonic muscle and total phasic muscle

| Independent variables | B    | SE   |
|-----------------------|------|------|
| Total tonic muscle   |      |      |
| M                     | 0.034| 0.003|
| Number of repetitions*|      |      |
| F                     | 0.000| 0.006|
| Electromyography      |      |      |
| Number of repetitions*| 0.048| 0.004|
| Electromyography      | 0.000| 0.009|
| Total phasic muscle  |      |      |
| M                     | 0.025| 0.002|
| Number of repetitions*|      |      |
| Electromyography      | 0.010| 0.005|
| F                     | 0.026| 0.003|
| Electromyography*     | 0.015| 0.007|

*p<0.05
M: male; F: female

*β*: significance level
females in every aspect and this is consistent with a prior study. However, another study reported a significantly higher RPE in females than in men as the number of repetitions increased. The collective data indicate that RPE can be used effectively to monitor and prescribe resistance exercise and is an effective technique to control the intensity of resistance exercise.

To conclude, tonic muscles and phasic muscles have a different effect on RPE through muscle activity and number of repetitions. Differences within the groups were evident. The present study could not compare the characteristics of all the muscles in the phasic and tonic muscle groups.

Finally, because the experimental group only consisted of males and females in their 20s, the results cannot be generalized to all ages. The present results along with those of studies assessing resistance exercise for the elderly, aerobic exercise, aquatic exercise, treadmill walking, and muscular exhaustion recovery are expanding the knowledge of the relationships of muscle groups with RPE.

| Table 3. Multiple regression analysis of factors related to rating of perceived exertion (RPE) in tonic muscle |
|-------------------------------------------------|--------|--------|
| Independent variables                           | B      | SE     |
| Iliopsoas                                       |        |        |
| M                                               |        |        |
| Number of repetitions*                          | 0.030  | 0.004  |
| Electromyography                                | 0.005  | 0.025  |
| F                                               |        |        |
| Number of repetitions*                          | 0.041  | 0.006  |
| Electromyography                                | 0.061  | 0.042  |
| Hamstring                                       |        |        |
| M                                               |        |        |
| Number of repetitions*                          | 0.054  | 0.006  |
| Electromyography*                               | 0.036  | 0.014  |
| F                                               |        |        |
| Number of repetitions*                          | 0.079  | 0.010  |
| Electromyography                               | −0.037 | 0.021  |
| Gastrocnemius                                   |        |        |
| M                                               |        |        |
| Number of repetitions*                          | 0.049  | 0.005  |
| Electromyography                                | 0.045  | 0.015  |
| F                                               |        |        |
| Number of repetitions*                          | 0.085  | 0.008  |
| Electromyography                                | 0.060  | 0.029  |
| Pectoralis major                                |        |        |
| M                                               |        |        |
| Number of repetitions*                          | 0.049  | 0.005  |
| Electromyography                                | 0.045  | 0.015  |
| F                                               |        |        |
| Number of repetitions*                          | 0.079  | 0.010  |
| Electromyography                               | −0.037 | 0.021  |

*p < 0.05
M: male; F: female

| Table 4. Multiple regression analysis of factors related to rating of perceived exertion (RPE) in phasic muscle |
|-------------------------------------------------|--------|--------|
| Independent variables                           | B      | SE     |
| Gluteus maximus                                  |        |        |
| M                                               |        |        |
| Number of repetitions*                          | 0.044  | 0.004  |
| Electromyography                                | −0.007 | 0.007  |
| F                                               |        |        |
| Number of repetitions*                          | 0.038  | 0.004  |
| Electromyography                                | 0.011  | 0.017  |
| Quadriceps                                      |        |        |
| M                                               |        |        |
| Number of repetitions*                          | 0.056  | 0.008  |
| Electromyography                               | 0.007  | 0.017  |
| F                                               |        |        |
| Number of repetitions*                          | 0.105  | 0.010  |
| Electromyography                               | −0.034 | 0.024  |
| Tibialis anterior                               |        |        |
| M                                               |        |        |
| Number of repetitions*                          | 0.021  | 0.004  |
| Electromyography                                | 0.016  | 0.020  |
| F                                               |        |        |
| Number of repetitions*                          | 0.033  | 0.004  |
| Electromyography                                | 0.014  | 0.027  |
| Rhomboid                                        |        |        |
| M                                               |        |        |
| Number of repetitions*                          | 0.024  | 0.005  |
| Electromyography*                               | 0.041  | 0.012  |
| F                                               |        |        |
| Number of repetitions*                          | 0.080  | 0.014  |
| Electromyography                                | 0.003  | 0.015  |

*p < 0.05
M: male; F: female
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