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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

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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 system[1)]. RPE is significantly related to oxygen uptake measurement and the amount of exertion[2)], and so it is used to assess and regulate the intensity of physical activity[3)]. The Borg Scale is a subjective assessment of exercise intensity. Nonetheless, it provides valuable information concerning RPE[4)].

RPE is an area of active interest for psychologists and physiologists concerning physical activity and sports[5)]. 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 studied[6)]. RPE is related to the muscle soreness and stiffness after a marathon[7)] and is increased during shorter, rather than longer, rest intervals[8)]. 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 VO_2 but does affect RPE[9)]. 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 conditions[10)].

Tonic and phasic muscles are usually classified according to the phylogenetic development criteria of Janda[11)]. 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 activity[12)].

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Table 1. 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. Two active electrodes, 2 cm apart, are placed parallel to the muscle fibers.
	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.
Phasic muscle	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 the scapula at a 55-degree oblique angle.
	Quadriceps (rectus femoris)	Seated leg press 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 placed 2 cm apart, parallel to the muscle fibers.
	Upper gluteus maximus	Smith machine	Two active electrodes (3 cm apart) are placed half the distance between the trochanter (hip) and the sacral vertebrae in the middle of the muscle on an oblique angle at the level of the trochanter or slightly above.
	Tibialis anterior	Power leg press	Two active electrodes, 2 cm apart, are 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.

The phasic system emerges shortly after birth and consists of the extensors. These muscles emerge in extensor synergies[12] 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_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. The 1RM was measured using the Commander PowerTrack II™ (JTECH Medical, Midvale, UT, USA), with the weight increased until the participant could not lift the equipment[13]. Each participant was observed by an examiner while exercising, and the intensity of the exercise was set to 70% of their 1RM. Table 1 summarizes the equipment used

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 muslce	M	Number of repetitions*	0.034	0.003
		Electromyography	0.000	0.006
	F	Number of repetitions*	0.048	0.004
		Electromyography	0.000	0.009
Total phasic muscle	M	Number of repetitions*	0.025	0.002
		Electromyography	0.010	0.005
	F	Number of repetitions*	0.026	0.003
		Electromyography*	0.015	0.007

*$p < 0.05$
M: male; F: female

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[14] 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 10–350HZ. EMG analysis was performed with the MyoResearch XP software (Noraxon).

Subjects rated their perceived level of muscle activity using the Borg Scale[15], 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_2max 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 woman. 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[16]. Also, as intensity increases, RPE and muscle activity increase[17]. Therefore, it is safe to conclude that as the intensity and heart rate increase, RPE increases. EMG activity can mediate RPE[18], indicating that RPE could be used to regulate the intensity of exercise[19].

Among the tonic muscle group, the hamstring muscle in men and gastrocnemius muscle in males and females were 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[20]. The results were also similar to those of study in which RPE significantly increased as repetitive muscular contractions were performed[21]. Males had higher muscular activity than

Table 3. Multiple regression analysis of factors related to rating of perceived exertion (RPE) in tonic muscle

			Independent variables	B	SE
Tonic Muscle	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*	0.035	0.004
			Electromyography	−0.001	0.015
		F	Number of repetitions*	0.046	0.008
			Electromyography	0.017	0.019

*$p < 0.05$
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
Phasic Muscle	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

females in every aspect and this is consistent with a prior study[21]. However, another study reported a significantly higher RPE in females than in men as the number of repetitions increased[22]. The collective data indicate that RPE can be used effectively to monitor and prescribe resistance exercise[23, 24] and is an effective technique to control the intensity of resistance exercise[18, 25].

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[26], aerobic exercise[27], aquatic exercise[28], treadmill walking[29], and muscular exhaustion recovery[30] are expanding the knowledge of the relationships of muscle groups with RPE.

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