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Changes in stress hormone levels with the application of vibrations before resistance exercises at different intensities

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Abstract. [Purpose] The purpose of the present study was to determine whether vibrations should be applied before resistance exercises by examining changes in stress hormone levels with vibrations applied before different exercise intensities. [Subjects] Eighteen male subjects in their 20s were included, and were randomly divided into one-repetition maximum (1RM) 50% group (50% RMG, n = 6), 1RM 70% group (70%RMG, n = 6), and 1RM 90% group (90% RMG, n = 6). [Methods] Three sets of Smith squats were performed at 1RM 50%, 70%, and 90% according to resistance intensities, and vibrations were applied for 1 min at a fixed frequency of 30 Hz before each set. Epinephrine, norepinephrine, and dopamine stress hormone levels were analyzed. [Results] Epinephrine levels were significantly higher immediately after exercise than at rest in the 50%RMG; however, no significant changes were noted in the 70%RMG and 90%RMG. Norepinephrine levels were significantly higher immediately after exercise than at rest in all three groups. However, no significant changes in dopamine levels were noted in the three groups. [Conclusion] The application of vibrations at a frequency of 30 Hz before 70%RM and 90%RM resistance exercises suppressed increases in the stress hormone epinephrine levels immediately after exercise.
Key words: Muscle resistance exercise, Vibration, Stress hormone

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INTRODUCTION

Resistance exercise helps improve the strength of all the muscles of the body and can be performed continuously at any location. Well-designed resistance exercise programs have been reported to effectively improve muscle strength and the ability to perform exercise, increase fat-free mass, and decrease body fat[1)]. The most important aspect of resistance exercise is identifying the appropriate intensity for the exercise, and repetition maximum (RM) is most frequently determined for identifying the appropriate intensity. During resistance exercises, 1RM should be changed depending on exercise intensities in order for the exercise to be effective[2)]. Resistance exercise at 80% RM or higher are classified as muscle strengthening exercise, that at 75% RM as muscle strength exercise, and that at 60% RM as muscle endurance exercise. Although resistance exercises at 70–80% RM are effective for muscle strength enhancement in beginners, those at 85% RM or higher are effective for muscle strength enhancement in experts[3)]. However, resistance exercises performed without considering a participant's ability can result in injury. The degrees of muscle damage are similar during high-, medium-, and low-intensity resistance exercises[4)]. However, different degrees of muscle damage have been reported to occur according to the type of muscle resistance exercise, the degree of muscle contraction, and exercise load[5)]. Based on the findings of studies on muscle damage, muscle fatigue, and changes in hormone levels after muscle resistance exercise, studies that aim to minimize side effects after exercise should be performed. Vibrations of muscles before exercise have positive effects on motor skill improvement, and are used to increase the metabolic and blood flow rates of individuals in the fields of sports and rehabilitation[6)]. The effects of vibrations vary with frequency, and frequencies of 15–50 Hz have been reported to promote oxidation, increase oxygen uptake, help blood circulation, and raise skin temperature[7)].

One study reported that muscle pain reduced after stretching on a machine vibrating at a frequency of 35 Hz before resistance exercises[8)]. Another study with 20 adults showed that blood flow through the quadriceps femoris and gastrocnemius increased with the application of vibrations, which caused the inflow of blood into the muscles[9)]. Additionally, a study reported that muscle pain and creatine phosphokinase (CPK) level decreased significantly with the application of vibrations at a frequency of 50 Hz before treadmill exer-

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Table 1. Changes in stress hormones (in pg/ml) after the application of vibrations during resistance exercises at different intensities

	Group	At rest	Immediately after exercise	At 24 hours after exercise
Epinephrine	50%RM	44.7 ± 16.5	99.9 ± 30.0*	52.2 ± 28.4
	70%RM	70.2 ± 27.3	112.3 ± 48.0	62.7 ± 20.3
	90%RM	56.5 ± 13.8	68.5 ± 26.6	59.6 ± 30.4
Norepinephrine	50%RM	403.8 ± 192.3	1196.1 ± 659.6*	362.0 ± 156.6
	70%RM	466.9 ± 174.0	1219.7 ± 542.4*	336.9 ± 93.3
	90%RM	489.7 ± 255.4	815.6 ± 434.4*	295.6 ± 89.5
Dopamine	50%RM	32.7 ± 6.0	45.4 ± 12.4	31.7 ± 3.2
	70%RM	33.6 ± 5.9	32.0 ± 3.2	32.2 ± 3.5
	90%RM	34.8 ± 5.8	39.1 ± 15.5	31.5 ± 2.6

* Statistically significant difference between rest (p<0.05)

cise[10].

Although studies on the positive effects of vibrations on muscles have been performed, no study has evaluated the effects of vibrations before resistance exercise at different intensities on the levels of stress hormones. Therefore, the purpose of the present study was to determine whether vibrations should be applied before resistance exercise by examining changes in stress hormones levels with the application of vibrations resistance exercises at different intensities.

SUBJECTS AND METHODS

The present study included 18 healthy male subjects in their 20s, having less than 6 months of experience in weight training and residing in K City, South Korea. The subjects were randomly divided into 1RM 50% group (50%RMG, n = 6), 1RM 70% group (70%RMG, n = 6), and 1RM 90% group (90%RMG, n = 6). Subjects in the 50%RMG had a mean age, height, and weight of 21.5 ± 2.42 years, 170.2 ± 6.68 cm, and 71.1 ± 14.11 kg, respectively. Those in the 70%RMG had a mean age, height, and weight of 22.3 ± 2.40 years, 172.9 ± 6.14 cm, and 70.5 ± 7.23 kg, respectively. Additionally, those in the 90%RMG had a mean age, height, and weight of 21.12 ± 2.13 years, 172.1 ± 5.35 cm, and 70.38 ± 6.35 kg, respectively. The subjects voluntarily participated in the study after receiving explanations about the intent and purpose of the study. The three groups had no statistically significant differences of physical characteristic of subjects such as age, height, body weight and body fat ($p < 0.05$); therefore, the groups were homogeneous. The Smith squat exercise for resistance training was used to examine changes in the levels of stress hormones with the application of vibrations before resistance exercises at the following intensities: 1RM 50% (maximum number of repetitions ≥30), 1RM 70% (maximum number of repetitions 12–15), and 1RM 90% (maximum number of repetitions 3–4). The subjects performed three sets of Smith squats, and vibrations were applied for 1 min before each set. A vibratory apparatus Sky Life-SM290 (Maxton, Korea) capable of frequencies of 2–60 Hz was used. The frequency was fixed at 30 Hz, and vibrations were applied at knee flexion to sufficiently stimulate the quadriceps femoris and gastrocnemius. Blood was collected at rest, immediately after exercise, and 24 h after recovery from exercise to analyze levels of the stress hormones epinephrine, norepinephrine, and dopamine. To examine changes in the levels of the stress hormones in each group, one-way repeated ANOVA was performed using SPSS 20.0 for Windows on the basis of the levels at rest in each group. The significance level α was set at 0.05. All of the subjects understood the purpose of this study and provided written informed consent prior to their participation in the study in accordance with the ethical standards of the Declaration of Helsinki.

RESULTS

Epinephrine levels were significantly higher immediately after exercise than at rest in the 50%RMG ($p < 0.05$); however, no significant changes were noted in these levels in the 70%RMG and 90%RMG. The levels of norepinephrine were significantly higher immediately after exercise than at rest in all the three groups ($p < 0.05$). However, no significant changes in the levels of dopamine were noted in any of the three groups (Table 1).

DISCUSSION

Physiological stress in the body is determined by assessing changes in catecholamines and cortisol levels, and epinephrine and norepinephrine are considered representative catecholamines[11].

Epinephrine and norepinephrine levels increase when the sympathetic system is activated by physical activities. During exercise, epinephrine is secreted from the adrenal medulla and norepinephrine from the sympathetic terminal[12]. The major function of epinephrine includes promoting glycogenolysis and lipolysis during energy metabolism, and norepinephrine is a precursor of epinephrine, which is secreted from the sympathetic terminal to function as a neurotransmitter. The arterial plasma levels of these two hormones are known to continuously increase with exercise time and intensity. Epinephrine levels do not increase during low-intensity exercise not involving mental stress, and its levels increase when oxygen uptake rises to at least 60%

of the maximum oxygen uptake. Norepinephrine levels increase at exercise intensities that increase oxygen uptake to >50% of the maximum oxygen uptake, and its levels have been reported to increase by up to six times those at rest during maximum intensity exercise[13]. Therefore, measurement of the levels of stress hormones help evaluate the degree of physiological stress in the body according to the intensity of resistance exercise, and enable the identification of changes in the levels after vibrations are applied. In the present study, epinephrine levels were significantly higher immediately after exercises than at rest in the 50%RMG ($p < 0.05$), and no significant changes in these levels were noted in the 70%RMG and 90%RMG. Therefore, the application of vibrations at a frequency of 30 Hz before the 70%RM and 90%RM resistance exercises did not result in significant changes in epinephrine levels immediately after exercise.

The use of vibrations at frequencies of 20–50 Hz is recommended because vibrations at frequencies below 20 Hz induce excessive relaxation of muscles and those at frequencies over 50 Hz cause muscle pain[14]. In general, vibration of muscles at 25–45 Hz is used to increase muscle strength and mass[15], and the application of vibrations has been reported to have positive effects on the muscle function recovery of delayed-onset muscle soreness[16].

The positive effects of vibrations on muscles can be explained by neurophysiological factors[17]. Vibrations suppress interneuronal activities of the skin and spinal cord receptors that reduce pain signals crossing α-exercise nerves and C fibers and instead cause the migration of these signals to the spinal cord and brain[8]. In addition, vibrations have been shown to affect capillary vessels and reduce lactic acid levels[9], and a study has presented the mechanism underlying the activation of the neuromuscular system that may improve the ability of the neuromuscular system to function appropriately[18]. The activation of muscle spindle receptors with vibrations has been reported to have positive effects not only on the directly stimulated muscles but also on the surrounding muscles.[19] A study of 29 male subjects who ran downhill for 40 min reported that the levels of the inflammatory markers IL-6 and histamine, as well as muscle pain in the femoral region decreased significantly in the group in which vibrations were applied before the run[20]. On the basis of the results, vibrations of muscles before activities may help reduce epinephrine levels. In the present study, vibrations applied at a frequency of 30 Hz before 70%RM and 90%RM resistance exercises suppressed increases in epinephrine levels immediately after exercise. In the future, studies on the effects of vibrations on muscles and the areas of application should be performed by using different intensities of resistance, frequencies of vibration, and physiological variables.

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