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The Effects of Resistance Exercise on Cardiovascular Regulation in Collegiate Females

Eisuke Hiruma

Departmalest of Sport and Medical Science, Teikyo University, 359 Otsuka, Hachioji, Tokyo 192-0395, Japan

Abstract

The ideal intensity of the concentric resistance training (CON-T) is 70~80% of One-Repetition Maximum (1RM) to increase blood pressure during exercise and muscular strength and muscular mass after ideal training. CON-T with 50% of 1RM, however, increases muscular endurance and muscular strength without inducing Delayed Onset Muscle Soreness (DOMS). This study was to examine heart rate and blood pressure during lengthening and shortening resistance exercise with velocity in the collegiate females. Fourteen healthy females (21.0 ± 0.9 years) divided randomly into two groups (6sec group and 10sec group) and performed the following exercise regimens: 6sec group (3s for lengthening and shortening movement) and 10 sec group (5 s for lengthening and shortening movement) with 50% of One Repetition Maximum (1RM). Heart Rate (HR), Systolic (SBP) and Diastolic (DBP) blood pressures and SpO2 were recorded at rest and during resistance exercise continuously. The Mean Blood Pressure (MBP) and Heart-Rate Pressure Product (HRPP) were calculated. Exercise regimen in both groups consisted of one set was performed three times a week for 6 weeks. There were no significant differences between two groups at rest regarding 1RM, HR, SBP, DBP, MBP, HRPP and SpO2. 6sec group increased significantly HR, SBP, DBP, MBP and HRPP during exercise. The changes of cardiovascular measurements in 10sec group were less than in 6 sec group. 6sec and 10sec group significantly changed 1RM after 6 weeks of lengthening and shortening resistance exercise ($p<0.05$). The result of this investigation suggests that (1) 6sec group increased cardiovascular responses during lengthening and shortening resistance exercise with slow and low-intensity higher as compared with 10sec group. (2) there were no significantly differences in 1RM of muscle strength between 6sec and 10sec group after 6 weeks of this training.

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Introduction

Resistance exercise is one of the important physiological activity to gain muscular strength and muscles (hypertrophy) [1], and to prevent and to treat lifestyle-related diseases [2]. High intensity resistance exercise (70 to 80% of one repetition maximum) is recommended to increase muscular strength and to enhance muscular mass [1,3]. To increase muscular endurance, the intensity and the repetition of resistance exercise must be 50% 1RM, with more than 20 repetitions [1]. A few studies, however, have examined the effects of low-intensity resistance exercises and their effects upon muscular strength and size [4]. Goto et al. [5] claim that the slow movement type of resistance training with 40% 1RM lowered muscle oxygenation levels and enhanced hormonal response to increase muscular strength. Lengthening resistance-training interventions completed by the elderly have been implemented in various forms [6]. Resistance training protocol to management of blood pressure relies on the manipulation of exercise methods, volume, exercise orders, and velocity of muscle contraction, and resting interval between sets [4, 7, 8].

All variables increased significantly during both Isometric Muscle Contraction (ISO), concentric muscle contraction (CON) and Eccentric Muscle Contraction (ECC) exercise. Clinically, an isokinetic ECC exercise program enables older adults to work at the same torque output with less cardiovascular stress than ISO exercise [9]. The former studies of the relationship between resistance training and breathing, when healthy young subjects perform weight-lifting exercises the mechanical compression of blood vessels combines with a potent pressure response [10], and a Valsalva response to produce extreme elevations in blood pressure [11]. The high-intensity resistance training reduced arterial compliance and increases arterial stiffness [12-14]. CON exercise with high-intensity increased more cardiovascular responses than ECC [15].

The low-intensity ECC&CON resistance exercise with slow lifting prevented increase in cardiovascular responses in young health males [15]. In another low-intensity resistance training report in the elderly adults by Hiruma et al., [6] the lengthening-shortening resistance training with low-intensity in old adults significantly decreased blood pressure and significantly increased muscular strength and physical fitness ($p<0.01$) without Delayed Onset Muscle Soreness (DOMS). Thus, the aim of the present study was to examine the effect of lengthening and shortening resistance training on cardiovascular responses during resistance exercise with a velocity throughout days of continuous training. The hypothesis underlying any such program is that there will be a significant increase of muscular strength in collegiate females; it may also be expected that blood pressure and heart rate in 10sec group (lengthening for 5 seconds and shortening for 5 seconds) with low-intensity and slow-movement smaller changes as compared with 6sec group (lengthening for 3 seconds and shortening for 3 seconds) will be found.

Therefore, the purpose of this study was to investigate heart rate and blood pressure during lengthening and shortening resistance exercise with velocity in the collegiate females.

*Corresponding Author: Prof. Eisuke Hiruma, Departmalest of Sport and Medical Science, Teikyo University, 359 Otsuka, Hachioji, Tokyo 192-0395 , Japan; E-mail: hiruma@main.teikyo-u.ac.jp

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Methods

Subjects

The number of participants required for the present study was determined by sample size estimation utilizing G*Power (version 3.0.10) [16] based on data from a previous study [17] that analyzed the strength of elbow flexors and knee extensors in young and old individuals. The estimation was based on a difference in heart rate and blood pressure during leg-flexion and leg-extension exercise of about 6% between 6 seconds and 10 seconds of exercise velocity. This study used an α level of 0.05 and a power (1-β) of 0.95. Calculations demonstrated that a total of seven individuals were needed to test our hypothesis. Fourteen female college students (age 21.1±1.3 years, height 162.32±4.81 cm, weight 54.31±5.00 kg) volunteered to participate in the present study (Table) and signed informed consent documents in accordance with the ethical standards of American College of Sports Medicine and approved by Ethical Committee of Osaka International University.

They had regularly performed moderate exercise, but had not practiced weight training or received supplementation for at least 6 months before the present study. They were requested to and agreed not to attend any exercise and weight training, to refrain from ingesting alcohol, supplements, and nonsteroidal anti-inflammatory drugs, and to avoid therapeutic treatment and stretching during the present study period. Seven randomly selected subjects exercised 3 second of lengthening and 3 seconds of shortening resistance exercise with 50% of 1RM (6sec group). Seven other subjects performed 10 seconds of the same manner exercise for 10 seconds (10sec group).

	6sec Group (n=7)	10sec Group (n=7)
Age	20.7±1.0 years	21.3±0.9 years
Height	160.6±6.3 cm	163.0±2.9 cm
Body Mass	53.2±4.0 .kg	55.2±5.0.kg
Body Mass Index	20.6±1.0 kg·m^{-2}	20.1±1.kg · m^{-2}
Exercise Intensity	50.5±3.2%1RM	48.6±5.5%1RM
Repetitions	25-30 raps*	15-18 raps
*: P<0.05 6sec group vs 10sec group		

Table 1: Physical Characteristics of two groups (mean±SD).

Exercise intervention program and measurement of one repetition maximum

During training, subjects were supervised by an experienced fitness trainer and by a certified physician. The method of the resistance training for 10sec group followed the Hiruma et al. [18] protocol. Subjects exercised at 40-50% 1RM with 5 seconds for lengthening and 5 seconds for shortening three times a week for 6 weeks. 6sec group exercised three seconds for lengthening and shortening movement with 40-50% 1RM. Each exercise was repeated until the subjects could not maintain the velocity. Subjects exercised with set speed established by a metronome (YAMAHA Corp., Shizuoka, Japan). The goal of this progression was to induce volitional fatigue in the 25 to 30 repetition for 6sec group and the 15 to 20 repetition for 10sec group range of each subject throughout the training program. As training progressed, resistance was incremented: whenever 6sec group completed 30 repetitions or more and 10sec group completed 20 repetitions or more for at least 2 sessions at a given load while maintaining proper form, the intensity was increased by 5%. To identify the exercise intensity and the result of training, subjects took 1RM test of leg extension with both legs before and after 6 weeks of training period. The subjects seated on leg extension machine (Nautilus Japan) after 30 minutes of warming-up to measure 1RM and to exercise each regimen. The subjects were familiarized with the test procedure on several occasions before measurements. They sat on a chair with the back upright and with both legs firmly attached to the lever of the machines. A pivot point of the lever was accurately aligned with the rotation axis of both knee joints. The axis alignment of the joints and the machine, also, maintained during the movement. Two trials were examined for 1RM, and the highest value obtained was used for the 1RM.

Measurement of blood pressure

Blood pressure was assessed at rest after 15 minutes in a seated position. Systolic (SBP) and Diastolic (DBP) blood pressure during lengthening and shortening exercise was measured by one experienced specialist with a standard standing type sphygmomanometer (602OKOSE, Matsuyoshi Medical product, Japan) and stethoscope (Classic, Littman, 3M, United States). An experienced appraiser performed the measurements during rest and after exercise for all subjects. Mean arterial pressure (MAP) was calculated by using the following formula: MAP = DBP + [(SBP-DBP)/3].

Measurement of Heart rate (HR), SpO2 and Heart-rate pressure product (HRPP)

Pulse oximeter (Onyx Vantage, Star product Limited, Japan) used in this study attached to the finger tip of middle finger of right hand to measure SpO2 and heart rate at rest, and during lengthening and shortening exercise continuously. The index of cardiac oxygen consumption, Heart-Rate Pressure Product (HRPP), was calculated by using the following formula: RPP = (HR x SBP).

Statistical analysis

Data were analyzed using a two-way ANOVA. When ANOVA showed a significant effect, *Turkey's post hoc* test was used to identify the differences between each time point. All analyses were performed using Statistical analysis was using SYSTAT (version 11; SYSTAT software, Inc., Richmond, CA). Statistical significance was set at $p<0.05$.

Results

General

Subjects in 6sec group and 10sec group participated this lengthening and shortening resistance training for 6 weeks (total 18 exercises). There were no significant differences physical characteristics and exercise intensity (total exercise time in a training session) between both groups, but the repetitions in 6sec group were more than those in 10sec group ($P<0.05$) because of the faster velocity of exercise (Table). After 6 weeks of lengthening and shortening resistance exercise, the subjects in 6sec group and 10sec group significantly increased 1RM by 53.0% and 44.8%, respectively ($P<0.001$) (Figure 1).

Blood pressure

SBP, DBP and MBP responses during the different exercise regimes are presented in Figure 2. In comparison to rest value, SBP, DBP and MBP in both groups increased significantly during exercise ($p<0.001$). SBP, DBP and MBP significantly changed by 36.6%, 58.1% and 38.3% in 6sec group and 34.4%, 49.3% and 29.9% in 10sec group, respectively ($p<0.001$). There were no significant differences between 6sec group and 10sec group at rest and during each exercise.

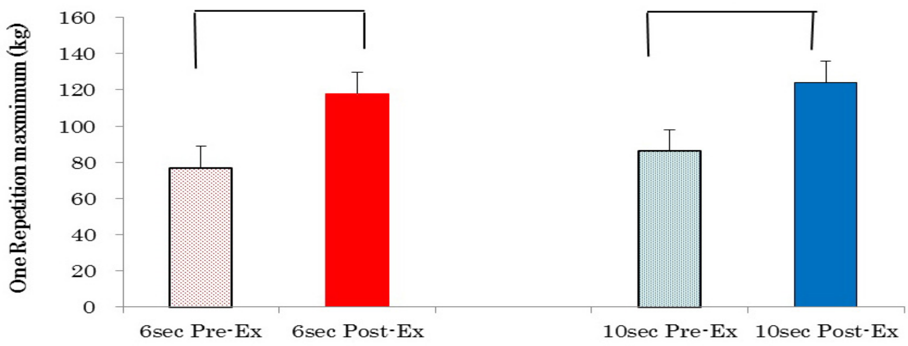

Figure 1: Changes in one repetition maximum before and after the six weeks of the resistance training. Dotted-open bars show pre-training and solid bars show post-training.
Values are means (±SD). ***: P< 0.001 Pre vs Post-Training.

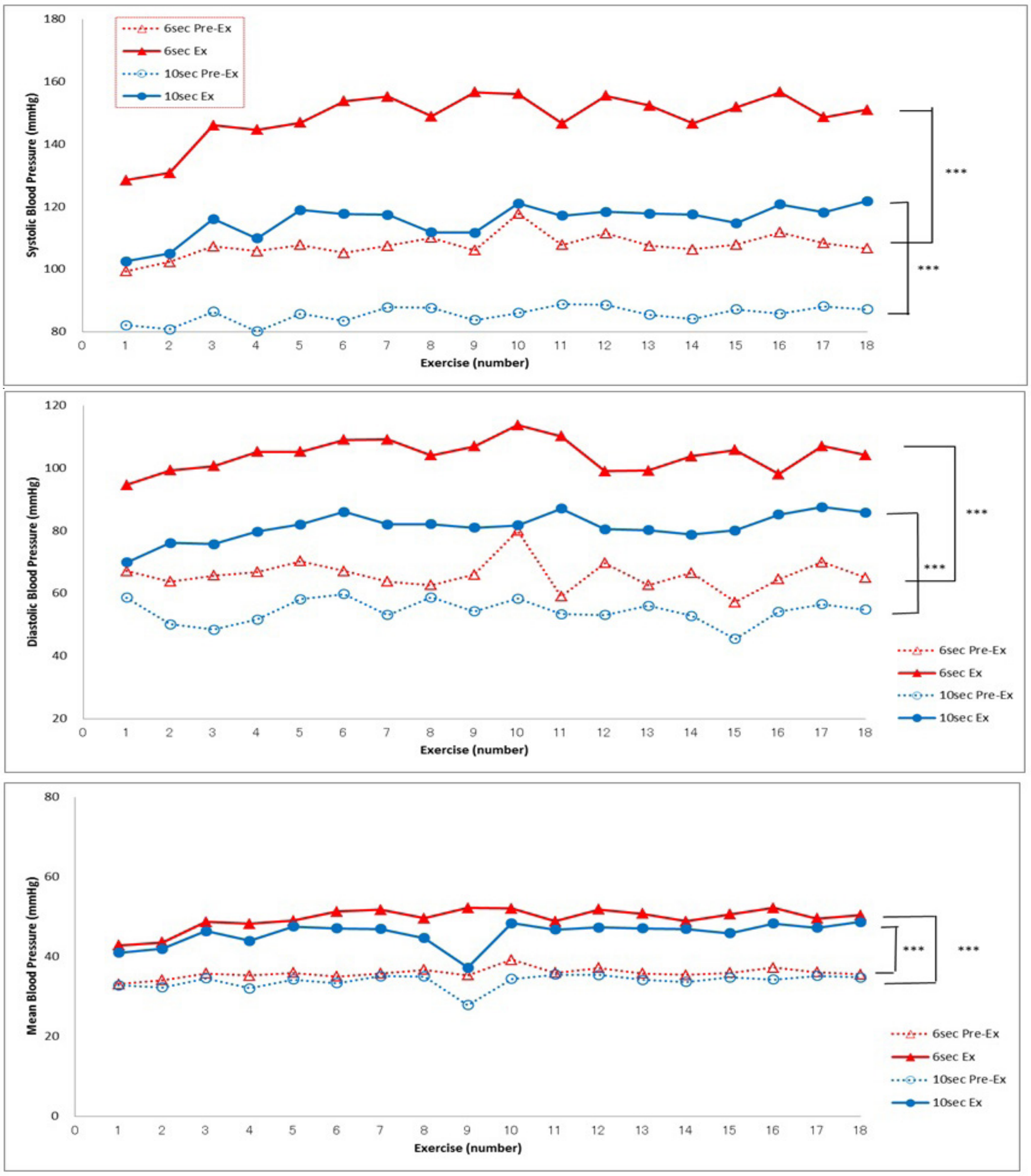

Figure 2: Changes in blood pressure before and during lengthening and shortening exercise 6 weeks of exercise period. Top: Systolic blood pressure, middle: diastolic blood pressure, bottom: mean blood pressure. Dotted lines show at rest and solid lines show during training. Values are means (±SD). ***: p<0.001 significantly different from rest

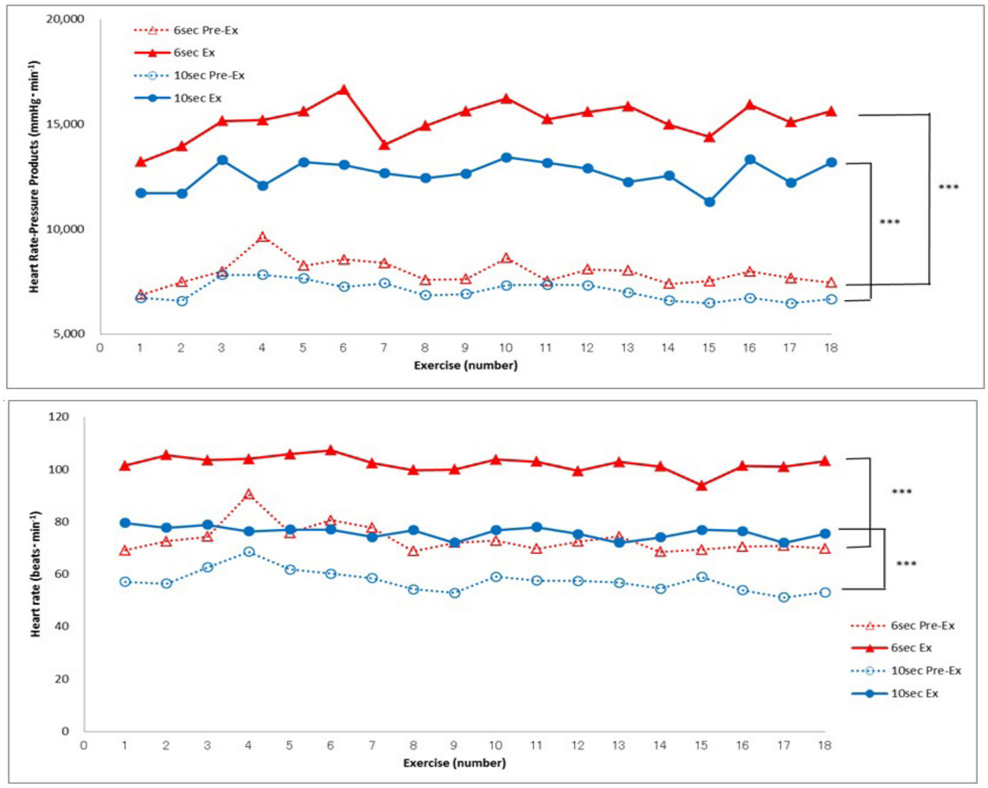

Figure 3: Changes in heart rate and heart-rate pressure product before and during lengthening and shortening exercise six weeks of exercise period. Top: heart-rate, bottom: heart-rate pressure product. Dotted lines show at rest and solid lines show during training. Values are means (±SD).
***: p<0.001 significantly different from rest

Heart-rate (HR), heart-rate pressure product (HRPP) and SpO2

HR at rest in 6sec group was higher as compared with that in 10sec group (Figure 3). The subjects changed significantly HP and HRPP during the resistance exercise by 38.3% and 38.7% in 6sec group and 29.9% and 37.4% in 10sec group, respectively (p<0.001). Even though 6sec group during exercise increased HP more than 10sec group, there were no significantly differences between two groups. HRPP in 6sec group were tended to be higher than that in 10sec group.

Dicussion

This study investigates the effect of lengthening and shortening resistance exercise on cardiovascular responses with different velocities in collegiate females. The main finding was that 6sec group, which exercised with lengthening for 3 seconds and shortening for 3 seconds, increased SBP, DBP, MBP, HR and HRPP more than 10sec group with lengthening for 5 seconds and shortening for 5 seconds, even though both groups exercised with 50% of 1RM for 6 weeks. Moreover, both groups increased cardiovascular responses significantly during the resistance exercise, even though there were no significantly differences between two groups. The larger increases in DBP, MBP and HR in 6sec group were associated with the faster velocity of the lengthening and shortening muscle contraction. Furthermore, 1RM in both 6sec group and 10sec group increased significantly by 53.0% and 44.8%, respectively (P<0.001).

In the study of the effect of exercise intervention on muscular strength, Campos et al. [3] found that resistance exercise at very high intensity (.90% 1RM]) with 3-5 repetitions, as well as high intensity (75% 1RM) with 9-11 repetitions produced a significant increase in muscular size and strength, and that a low intensity protocol (50% 1RM) with 20-28 repetitions improved muscular endurance. In other studies using 50% 1RM resistance training, slow-speed resistance exercise (three seconds for lifting, one second for resting, and three seconds for lowering) resulted in increases in muscular strength and muscular hypertrophy; plasma growth hormone concentrations with low intensity training were similar to those observed with high intensity training in healthy young males [4,5,19] . The resistance protocol in this study for 10sec group that trained with 50% 1RM and slow movement (five seconds for lifting and five seconds for lowing) was the same as described in a study by Hiruma et al. [6]. The 6sec group (three seconds for lengthening and three seconds for shortening) in this study provided results similar to these former studies [4,5] in that 1RM of 6 resistance exercises after 16 regimens with low intensity were significantly changed in both groups.

This study proposed the hypothesis that resistance training, with combined lengthening and shortening muscular contraction, was superior to produce neuromuscular adaptation and muscular strength. The lengthening and shortening training had a greater influence on functional capacity [20] and muscular strength and size [21,22] as compared with the shortening training alone. On the basis of these findings, it may be suggested that lengthening muscular contraction generated higher mechanical forces than shortening muscular contraction [23]. Although the intensity was 50% of 1RM which increased muscular endurance, the lengthening training with an intensity of 50% maximum isometric force induced muscular damage [24]. The eccentric ergometry training with low frequency (two times per week) and low intensity (female 30W, male 50W) was effective to decrease the type IIx/type II ratio and to increase relative thigh lean content [25]. Hiruma et al. [26] reported that the calf-raise exercises with a person's own body weight were similar to those observed during daily-life activity to induce a level of soft tissue damage and DOMS. The neuromuscular adaptation induced muscular function and muscular power [27,28]. It seems likely that much of the demonstrated improvements in strength were the result of remodeling in neuromuscular recruitment that resulted from this resistance training. Training regimens should incorporate a lengthening and shortening contraction component with slow movement to optimize the potential of increasing muscular strength.

The another finding in this study was that the slow velocity and the low intensity of lengthening and shortening resistance exercise significantly increased blood pressure and heart rate from at rest. In the former studies of high-intensity resistance exercise in young males, the subjects elevated blood pressure because of the mechanical compression of blood vessels to combines with a potent pressure response [10,11]. The possibility that high-intensity resistance training increases arterial stiffness was suggested because of its powerful sympathetic vasoconstrictive effect as well as its effect on arterial walls [29]. Thus, the exercise load (50% 1RM) in this study was less than the former studies of high intensity training (80% 1RM) prevented the increase in arterial walls. Another possibility of the increase in blood pressure was a Valsalva response. In the former study by Narloch et al. [30], MBP at 100% maximum with Valsalva was 311/284. The highest pressure recorded in an individual was 370/360. With slow exhalation, MBP was 198/175 when the same 100% maximum was lifted significantly ($p<0.05$). Arterial hypertension produced during heavy weight lifting with Valsalva is extreme and may be dramatically reduced when the exercise is performed with an open glottis (without Valsalva). In addition, the changes in SBP, DBP, MAP, and HRPP were significantly greater during ISO exercise than during ECC exercise ($p<0.001$) [9]. The general resistance exercise is consisted with CON and ECC contraction. Blood pressure during normal resistance exercise increases to maximal values due to the resistance encountered during the lifting (shortening) phase, and then it declines during the lowering (lengthening) phase [10, 15]. In this study, the subjects in both groups had the longer time of lengthening for 3 seconds or 5 seconds than the normal resistance exercise for one second. The subjects may be able to breathe continuously because of the low-intensity and slow-velocity of the resistance exercise, even though the breathing was not measured in this study.

The last finding in this study was that this resistance training in both 6sec and 10sec groups may not prevent arterial stiffness. The high-intensity (80% 1RM) resistance training reduce arterial compliance and increase arterial stiffness [12-14]. Resistance training protocol to management of blood pressure relies on the manipulation of exercise methods, volume, exercise orders, and velocity of muscle contraction, and resting interval between sets [4,7,8]. In the study for 6 weeks of the resistance training, the blood pressure in both groups did not change significantly at rest and during exercise. Acute intermittent elevations in arterial blood pressure during resistance exercise decrease elastin and increase collagen, which elicit the elasticity of the artery [10]. The increase in blood pressure and arterial stiffness with may relate to the increase in plasma endothelin-1 production and plasma noradrenalin concentration [19]. The adult subjects trained 8 weeks of lengthening and shortening with 10 seconds significantly decreased blood pressure [6]. Both groups in this study did not change blood pressure at rest after 6 weeks of training period, ever though.

In summary, subjects in 6sec group and 10sec group demonstrate significantly increase systolic and diastolic blood pressure and heart rate during the lengthening and shortening resistance intervention. Training both female groups improved muscular strength. One caveat is that the sample for this study consisted of a relatively small and homogeneous group of females, so these results should not be generalized broadly to the collegiate population.

Conclusion

The result of this investigation suggests that (1) 6sec group with 50%1RM increased cardiovascular responses during lengthening and shortening resistance exercise with slow and low-intensity higher as compared with 10sec group with 50%1RM and (2) both groups significantly increased 1RM after 6 weeks of this training session.

Special Recommendations

The Coronavirus Disease 2019 (COVID-19) occurred in December 2019 Wuhan-city, China. COVID-19 has rapidly spread all over the world. Especially, older people, disproportionally have been impacted, stayed home and isolated from community. Also, there is reduction in physical activity which maintains and increase physical fitness to be dwell old adults. The exercises in this study is effective to increase muscle strength with minimize the increase in blood pressure and heart rate as a home-exercise without resistance exercise machines.

Competing Interests

The authors declare that they have no competing interests.

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