

Research article

High-velocity resistance exercise protocols in older women: Effects on cardiovascular response

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Abstract

Acute cardiovascular responses to different high-velocity resistance exercise protocols were compared in untrained older women. Twelve apparently healthy volunteers (62.6 ± 2.9 y) performed three different protocols in the bench press (BP). All protocols involved three sets of 10 repetitions performed with a 10RM load and 2 minutes of rest between sets. The continuous protocol (CP) involved ten repetitions with no pause between repetitions. The discontinuous protocols were performed with a pause of five (DP5) or 15 (DP15) seconds between the fifth and sixth repetitions. Heart rate (HR), systolic blood pressure (SBP), rate pressure product (RPP), Rating of Perceived Exertion (RPE), and blood lactate (BLa) were assessed at baseline and at the end of all exercise sets. Factorial ANOVA was used to compare the cardiovascular response among different protocols. Compared to baseline, HR and RPP were significantly ($p < 0.05$) higher after the third set in all protocols. HR and RPP were significantly ($p < 0.05$) lower in DP5 and DP15 compared with CP for the BP exercise. Compared to baseline, RPE increased significantly ($p < 0.05$) with each subsequent set in all protocols. Blood lactate concentration during DP5 and DP15 was significantly lower than CP. It appears that discontinuous high-velocity resistance exercise has a lower cardiovascular demand than continuous resistance exercise in older women.

Key words: Aging, weight training, blood pressure, heart rate, perceived exertion.

Introduction

Aging is associated with a progressive loss of muscle mass and strength, leading to a decline in physical function and increased disability (Baumgartner et al., 1998; Roubenoff et al., 1997). Muscular strength tends to peak between the second and third decade of life and remains essentially unchanged until about 50 years, when loss begins to occur at an accelerated rate (Nair, 1995). This process is believed to be caused by both muscle tissue atrophy and a loss of muscle fibers (Kamel, 2003; Lexell, 1995). Type II fibers, also known as fast-twitch fibers, are more affected by aging than type I fibers, which leads to a diminished ability to develop muscle power (Hakkinen et al., 2001a; 2001b; Izquierdo et al., 1999).

Despite the structural and functional changes that occur with aging, skeletal muscle trainability appears to

be preserved, and many positive physiological adaptations occur in older persons as a result of exercise. In this regard, resistance exercise is recognized as a safe and effective strategy to improve lean body mass, muscle strength, and power as well as the ability to perform functional tasks (Bottaro et al., 2007; Galvao and Taaffe, 2005; Skelton et al., 1995). However, when prescribing resistance exercise to this population, assessment of acute physiological responses to exercise is of particular importance, especially when safety is considered. During resistance exercise, a number of acute changes occur in the cardiovascular system, such as increases in heart rate (HR), blood pressure (BP), and rate pressure product (RPP). These acute cardiovascular responses are influenced by numerous factors, including active muscle mass, exercise intensity, number of repetitions, type of exercise, and type of muscle contraction (Mayo and Kravitz, 1999; Rozenek et al., 1993).

Numerous studies have investigated the chronic effects of low-velocity and/or high-velocity resistance training on improving muscular fitness and functional performance in the elderly (Bottaro et al., 2007; Earles et al., 2001; Fielding et al., 2002; Hakkinen et al., 2001a; 2001b; 2002; Henwood and Taaffe, 2005; Hruda et al., 2003; Izquierdo et al., 2001; Miszko et al., 2003; Newton et al., 2002). Other studies have investigated the acute effects of resistance training and isometric muscle contractions on acute cardiovascular response in older adults (Petrofsky and Lind, 1975; Rozenek et al., 1993; Sagiv et al., 1988; Van Loan et al., 1989; Wescott and Howes, 1983). However, limited research has been published that compares the acute cardiovascular responses to different protocols of high-velocity resistance exercise in older adults.

One strategy that could be used to reduce cardiovascular stress imposed by high-velocity resistance training is the use of pauses between repetitions. Coelho et al. (2003) compared two formats of high-velocity resistance training protocols (continuous vs discontinuous) on HR and rate of perceived exertion (RPE) in young subjects and concluded that the discontinuous protocol was significantly less demanding. However, the authors did not evaluate SBP, and studies in younger persons may not be fully applicable to the elderly since previous studies have reported different cardiovascular responses between younger and older persons (Smolander et al.,

1998; Van Loan et al., 1989). We are unaware of any published studies analyzing high-velocity continuous and discontinuous resistance training protocols on acute cardiovascular responses (HR, BP, RPP) and RPE in older subjects. Therefore, the purpose of the present study was to evaluate and compare the effects of one continuous and two discontinuous high-velocity resistance exercise protocols on the cardiovascular responses in older women.

Methods

Subjects

Twelve apparently healthy older women between 60 and 70 years old (62.6 ± 2.9 y) participated in the study protocol. All volunteers were untrained and had not performed resistance training regularly in the year before the study. Exclusion criteria included orthopedic or neurological conditions that could limit exercise, history of cardiovascular or other systemic diseases that could interfere with the tests, and intake of medications that could influence acute cardiovascular responses to exercise. The University's ethical review board approved the study design, and all subjects read and signed a consent form prior to participation in the study.

Anthropometry

Body weight was assessed with a digital scale to the nearest 0.1 kg, and height was assessed with a stadiometer to the nearest 0.1 cm (Toledo do Brazil, São Bernardo do Campo, SP – Brazil). Measurements were made with the subjects in light clothes and shoes removed. Body mass index (BMI) was calculated as body weight (in kilograms) divided by the square of height (in meters).

Ten maximum repetition (10RM) tests

To reduce the effects of neurological adaptation from familiarization to baseline measures and to maximize reliability, subjects trained for three weeks (2 d/wk) before the first 10RM test.

In the week before the experiment, the load for 10RM was determined for each subject in the horizontal bench press (BP) exercise by using the maximum weight that could be lifted for 10 consecutive repetitions. If the subject did not accomplish 10RM in the first attempt, the weight was adjusted by 4-10 kg and a minimum of five minutes of rest was given before the next attempt. Only three trials were allowed per testing session. The tests were repeated in all subjects and data were analyzed by Pearson product moment correlations to estimate day-to-day 10RM reliability ($r = 0.97$, $p < 0.01$). BP 10RM loads were 19.7 ± 2.9 kg.

Experimental procedures

To avoid any threats of internal validity, all 12 subjects performed each of the three protocols in a counterbalance order; for some the first testing session was the continuous protocol (CP) while others started with the discontinuous protocols of either 5 (DP5) or 15 (DP15) seconds rest between the fifth and sixth repetitions. At

least 48 but not more than 72 hrs of recovery time was allowed between each training session. All tests were conducted in the same facility between 1:30 PM and 4:00 PM. Subjects refrained from ingesting caffeine and alcohol for 24 hours before all tests, and no other strenuous exercise was performed before the experimental sessions. After baseline measurements of SBP and HR, volunteers warmed up on a stationary bicycle for 10 minutes, followed by one set of 10 repetitions at 50% of the 10RM load.

During the continuous protocol (CP) subjects performed 10 repetitions with no pause between them. The two discontinuous protocols were performed with a pause of five (DP5) or 15 (DP15) seconds between the fifth and sixth repetitions. During the pauses of the discontinuous protocols the weight was re-racked. All protocols were performed at the load obtained during the 10RM test with two minutes rest intervals between sets. However, to maintain the same training volume, subjects who did not complete 10 repetitions of the second or third sets during the first random protocol (CP, DP5, or DP15) were instructed to repeat the same number of reps during the second and the third protocols. Subjects were instructed to perform repetitions with maximum velocity in the concentric phase and to take 2-3 seconds to complete the eccentric phase. The same technician controlled the rest intervals during all tests using a digital chronometer. Subjects were instructed on proper breathing technique to discourage the Valsalva maneuver.

Heart rate, blood pressure and rate pressure product

Heart-rate (HR) was assessed using a portable telemetric device (Polar S810, Polar Electro Inc, Kempele – Finland). Using standardized techniques, a trained technician measured systolic blood pressure (SBP) by auscultation using a mercury column sphygmomanometer (Glicomed, Rio de Janeiro, RJ - Brazil). Rate pressure product (RPP) was also calculated ($RPP = HR \times SBP \times 10^{-2}$, arbitrary units), as it is considered a reliable predictor of myocardial oxygen demand (Gobel et al., 1978; Kitamura et al., 1972; Nelson et al., 1974; White, 1999).

We are aware that intra-arterial pressure measurement is considered the golden standard method for assessing blood pressures and that the auscultation method tends to underestimate this parameter. However, the intra-arterial measurement is an invasive procedure that might put participants at risk, which leads to a recommendation to avoid its use in healthy subjects (Perloff et al., 1993; Raftery, 1991), and we found it particularly limiting in older subjects. Even though the error margin of the auscultation method is higher, the assumption that the tendency to underestimate SBP is constant throughout the exercises makes it suitable for comparing cardiovascular demand from different protocols of exercise in the same person.

During the adaptation phase, baseline SBP was measured and mean and standard deviation (SD) were calculated in order to set reference values. Before the beginning of the tests, subjects sat for 20 minutes in a quiet place for HR and SBP measurements. SBP was recorded as the moment of hearing the first Korotkoff

Table 2. Heart rate (beats/min) in the bench press exercise during different protocols. Data are means (\pm SD).

	Baseline	Set 1	Set 2	Set 3
CP	79 (11)	98 (14) *	100 (13) * ‡	101 (14) * ‡
DP5	80 (9)	94 (13) * †	95 (13) * †	95 (13) * †
DP15	79 (8)	95 (8) *	95 (9) * †	95 (10) * †

CP = continuous protocols, DP5 = discontinuous protocol with a 5-second pause between the fifth and sixth repetition, DP15 = discontinuous protocol with a 15-second pause between the fifth and sixth repetition. * $p < 0.05$ vs baseline; ‡ $p < 0.05$ vs 1st set; † $p < 0.05$ vs CP.

sound and diastolic BP (DBP) as the moment of disappearance of the Korotkoff sound. If the values obtained at the baseline testing were out of the range defined as mean \pm SD of the reference values, the tests were not performed. HR was constantly measured and the highest value of HR obtained at the end of the exercise was used in the analysis. SBP was measured immediately after the end of each set of the BP exercise. Each resting blood pressure was measured by the same technician in all subjects, and reliability data were analyzed ($r = 0.96$, $p < 0.01$).

Rating of perceived exertion (RPE)

RPE was assessed immediately after each set using the OMNI-RES scale (Robertson *et al.*, 2003). The reproducibility of the RPE test was 0.84 ($p < 0.01$) for the BP exercise.

Blood lactate (BLa)

A small sample of blood (25 μ l) was taken from the right ear lobe after the completion of each protocol. Blood from these incisions was allowed to flow into a Brand NH4 heparinized capillary tube. From the capillary tube, the blood was added to a labeled Eppendorf tube filled with buffer (1% sodium fluoride) at a ratio of 1:3 (blood to buffer). These samples were then placed in a refrigerator at approximately 4°C to be further analyzed using the YSI 1500 Lactate Analyzer (Yellow Springs Instrument Co., Yellow Springs, OH – USA).

Statistical analysis

Standard statistical methods were used to calculate means and standard deviations (SD). Differences in HR, SBP, RPP and RPE were assessed using factorial ANOVA; a 3 x 4 design [protocol (CP, DP5, DP15) x time (baseline, first, second, and third sets)] was used for HR, SBP, RPP, and a 3 x 3 design [protocol (CP, DP5, DP15) x time (first, second, and third sets)] was used for RPE. Differences in BLa responses were assessed with a one way repeated measure ANOVA. Multiple comparisons with confidence interval adjustment by the LSD procedure were used for post-hoc comparisons when necessary. The $p \leq 0.05$ criterion was used for establishing statistical significance. All statistical analyses were done with the SPSS 10.0 software (SPSS, Chicago, IL – USA).

Results

Descriptive characteristics of the sample (N = 12) are presented in Table 1.

Table 1. Subjects characteristics. Data are means (\pm SD).

Variable	Values
Age (years)	62.6 (2.9)
Body weight (kg)	57.3 (7.9)
Height (m)	1.53 (0.07)
BMI (kg/m ²)	24.4 (2.9)
Leg Press – 10 RM (kg)	66.5 (9.7)
Heart rate (bpm)	78.3 (8.1)
Systolic blood pressure (mmHg)	117.8 (3.2)
Rate pressure product (mmHg x beats/min)	9217.9 (1019.6)

Heart rate (HR)

Table 2 represents the HR values for different protocols during the BP exercises. Within protocol analysis revealed that HR was significantly lower at baseline when compared to the first, second, and third sets ($p < 0.05$). During the CP, HR was higher in the second and third sets in comparison to the first set ($p < 0.05$). Moreover, after the second and third sets, HR was higher during CP than both DP5 and DP15 ($p < 0.05$).

Systolic blood pressure (SBP)

The SBP values are presented in Table 3. Within group analysis for all protocols revealed that SBP was lower at baseline than after the first, second, and third sets, and lower after the first set in comparison with the second and third sets ($p < 0.05$). No significant differences in SBP were found between-groups.

Rate pressure product (RPP)

The values for RPP are presented in Figure 1. In all protocols, RPP was lower at baseline than after the first, second, and third sets ($p < 0.05$), and RPP was lower in the first set in comparison to the second and third sets ($p < 0.05$). In the second and third sets, RPP was higher for the CP in comparison to both DP5 and DP15.

Rate of perceived exertion (RPE)

RPE values are presented in Figure 2. According to the results, RPE progressively increased throughout the sets. RPE in the third set was higher than both second and first,

Table 3. Systolic blood pressure (mmHg) in bench press exercise during different protocols. Data are means (\pm SD).

	Baseline	Set 1	Set 2	Set 3
CP	117.5 (6.5)	132.5 (11.3) *	148.3 (14.0) * ‡	147.5 (14.8) * ‡
DP5	120.4 (2.5)	134.5 (8.3) *	143.3 (6.1) * ‡	145.0 (9.0) * ‡
DP15	116.6 (4.9)	133.7 (9.3) *	141.6 (8.3) * ‡	144.5 (13.3) * ‡

CP – continuous protocols, DP5 – discontinuous protocol with a 5-second pause between the fifth and sixth repetition, DP15 – discontinuous protocol with a 15-second pause between the fifth and sixth repetition. * $p < 0.05$ vs baseline; ‡ $p < 0.05$ vs 1st set.

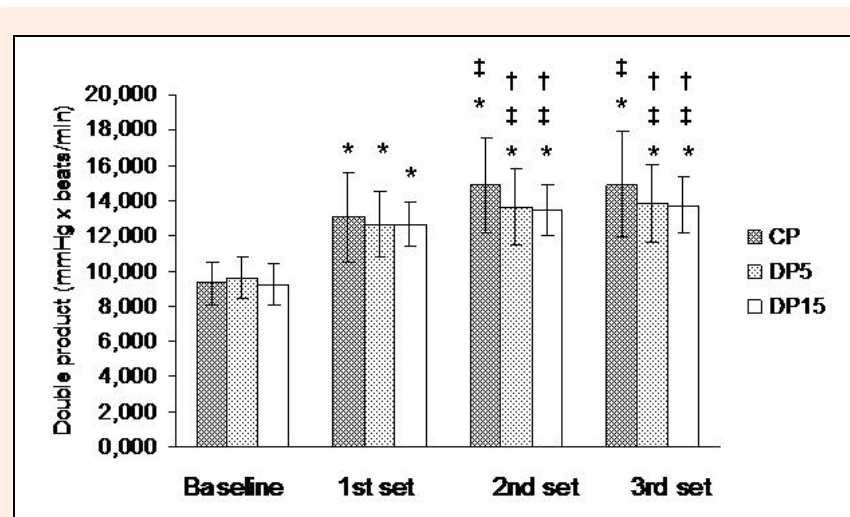


Figure 1. Rate pressure product (mmHg x beats/min) in the bench press exercise during different protocols. Data are means (\pm SD). CP – continuous protocols, DP5 – discontinuous protocol with a 5-second pause between the fifty and sixtieth repetition, DP15 – discontinuous protocol with a 15-second pause between the fifty and sixtieth repetition. * $p < 0.05$ vs baseline; ‡ $p < 0.05$ vs 1stset; † $p < 0.05$ vs CP.

and RPE in the second was higher than first ($p < 0.05$). However, there were no differences for RPE among the three protocols.

Blood lactate (BLa)

Values of BLa after different protocols are illustrated in Figure 3. For the BP exercise, BLa concentration after CP was higher in comparison to DP15 ($p < 0.05$). However, after DP5, BLa was not significantly higher than DP15.

Discussion

Previous reviews have stated that high-velocity resistance training may provide specific benefits to elderly subjects (Kraemer et al., 2002; Porter, 2006), and this has been supported in recent experiments (Bottaro et al., 2007; Henwood and Taaffe, 2005; 2006). However, myocardial oxygen consumption (HR x SBP) increases substantially

during the performance of dynamic resistance exercise (Fleck and Kraemer, 2004). Inability to supply oxygen to the myocardium when demand is high appears to be related to several cardiovascular events, including transient myocardial ischemia, acute myocardial infarction, and sudden death (Witke, 1999). Both research findings and clinical experience indicate that resistance exercise is relatively safe (Williams et al., 2007). However, most studies of resistance exercise have enrolled selected, low-risk individuals, and many are too small to provide reliable estimates of event rates on a population-wide basis (McCartney, 1999). Thus, monitoring cardiovascular responses to resistance exercise with measures of HR, BP, and perceived exertion are commonly recommended (Williams et al., 2007).

Analogous to the risks associated with aerobic exercise, cardiovascular risks associated with resistance training are likely determined by the age of the

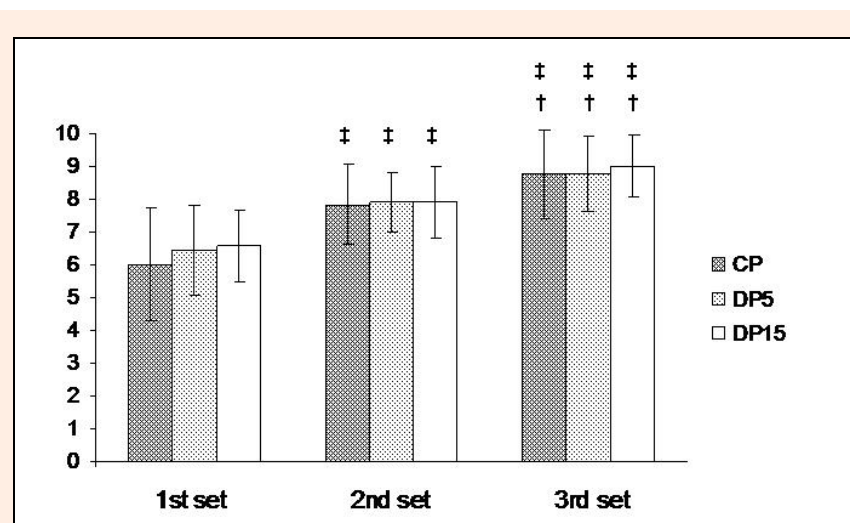


Figure 2. Rate of perceived exertion (OMNI-RES) in the bench press exercises during different protocols. Data are means (\pm SD). CP – continuous protocols, DP5 – discontinuous protocol with a 5-second pause between the fifty and sixtieth repetition, DP15 – discontinuous protocol with a 15-second pause between the fifty and sixtieth repetition. ‡ $p < 0.05$ vs 1st set; † $p < 0.05$ vs 2nd set.

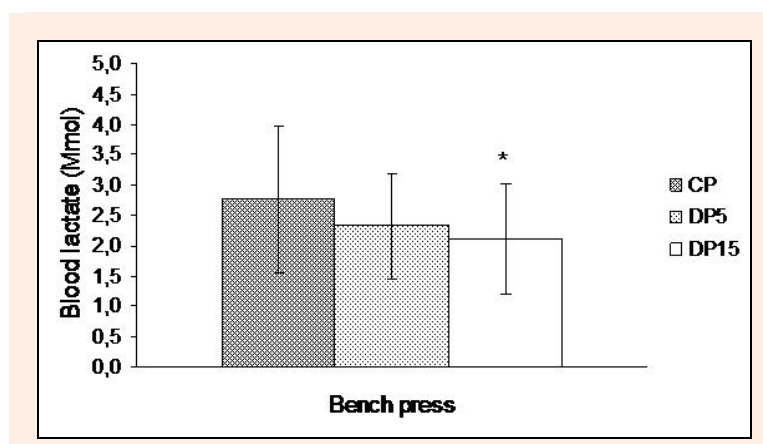


Figure 3. Blood lactate concentration (mmol/l) in the bench press exercises after different protocols. Data are means (\pm SD). CP – continuous protocols, DP5 – discontinuous protocol with a 5-second pause between the fifty and sixtieth repetition, DP15 – discontinuous protocol with a 15-second pause between the fifty and sixtieth repetition * $p < 0.05$ vs CP.

participant, his or her habitual physical activity and fitness level, underlying CVD, and the intensity of resistance training. Although excessive BP elevations have been documented with high-intensity resistance exercise, for example, 80% to 100% of 1-RM performed to exhaustion, such elevations are generally not a concern with low- to moderate-intensity resistance training performed with correct breathing technique and avoidance of the Valsalva maneuver (McCartney, 1999). The present study used moderate-intensity training in older women, and the Valsalva maneuver was avoided. All subjects completed the test protocols without incidents.

According to our results, all protocols lead to increases in HR, SBP, and RPP in comparison to baseline. Other studies that have characterized the continuous blood pressure response to weight lifting through the use of intra-arterial cannulation and blood pressure recordings have shown similar specific blood pressure responses as demonstrated in the present study (Fleck and Dean, 1987; Gotshall et al., 1999; MacDougall et al., 1992). Gotshall et al. (1999), using three sets of 10RM, reported that SBP and mean pressures increased progressively within each set with the number of the repetition and also increased with each subsequent set of double-leg presses.

The peak pressures reported by Gotshall et al. (1999) were higher than those reported in the present study; however, the subjects in the Gotshall et al. (1999) study were college age males while participants in the current study were older women. Additionally, subjects in the Gotshall et al. (1999) study performed lower body exercise (double-leg press) and subjects in the present study performed upper body exercise (BP).

The HR response to exercise involves an integration of the cardiovascular, muscular, and central nervous systems (Mayo and Kravitz, 1999; Mitchell et al., 1980; 1981). Contraction of skeletal muscle, activation of afferent fibers by stretch, and increased metabolite production can contribute to changes in HR during resistance training (Stone et al., 1985). In addition, exercise also promotes a rise in plasma catecholamines, an increase in sympathetic stimulation, and a decrease in parasympathetic drive (Mayo and Kravitz, 1999). The acute blood pressure response to resistance training is comprised of central and

peripheral components (Mayo and Kravitz, 1999). The central mechanisms arise from supraspinal brain regions and are directly related to voluntary effort, while the peripheral components originate in the active muscle (Mitchell, 1990; Sale et al., 1994). Additionally, the high intra-muscular pressure associated with resistance exercise promote mechanical compression of arterial vessels, occluding blood flow to the active tissues (Lind et al., 1964). These lead to increases in metabolic by-products such as H^+ , lactate, and ADP, which, in turn, activate nerve endings and stimulate the pressure reflex (Mayo and Kravitz, 1999).

Between groups comparison revealed that RPP and HR was lower in DP5 and DP15 than CP in the second and third sets of the BP exercise. No between-groups difference in SBP occurred between CP and both discontinuous protocols during the BP exercise. Therefore, data analysis revealed that differences in RPP during the BP exercise seem to be mainly determined by differences in the HR response.

In a previous study, older subjects performed hip flexion and shoulder abduction under two different protocols (Veloso et al., 2003). In one protocol, four sets of six repetitions were performed; in the other, subjects performed two sets of 12 continuous repetitions, both at the load obtained in the 12RM test. In both protocols, hip flexion and shoulder abduction were performed in an alternate manner with no rest between exercises. According to the results, there were no differences between protocols for HR, however, significant differences were observed in SBP and RPP when the second continuous set was compared to the second intermittent set. Nevertheless, the exercises were performed in an alternate manner with no rest between them despite the continuous or intermittent nature of the protocol, which limits comparison with the present study.

In agreement with the present study, Coelho et al. (2003) found that BLA and HR responses to a continuous resistance training protocol (12 repetitions performed at high velocity) was significantly higher than after a discontinuous protocol (15-second pause between the sixth and seventh repetitions) in young subjects. However, the authors reported significant differences in RPE, which is in

contrast to the present study. After considering the Coelho et al. (2003) study, we also hypothesized that CP would elicit a higher RPE than DP15 of the same external work. This difference might be related to the resistance training protocol. The protocol of Coelho et al. (2003) involved the performance of 12 repetitions in six exercises, which should have been more metabolically demanding, as seen by BLa values more than twice as high as the values found in the present analysis. Another difference may be the methods used in the analysis; the present study used the OMNI-RES scale, while Coelho et al. (2003) used the CR-10 scale.

It is possible that during DP15 and DP5, at least partial recovery of CP stores may have occurred, leading to an increased utilization of the ATP-CP anaerobic metabolic pathway. Additionally, the utilization of pauses during the sets may have lead to a reduced vascular occlusion. These may have decreased metabolite accumulation and thus, to a lower stimulus to chemical receptors. BLa analysis showed that BLa values for CP and DP5 were higher than values for DP15; therefore, the stimulation of chemical receptors may have been weaker for CP and DP5.

Conclusion

In conclusion, based on the present findings, it appears that discontinuous high-velocity resistance exercise may have a lower cardiovascular demand than continuous resistance exercise in older women. There was a 7.2% reduction in RPP for DP5 compared to CP at the end of the third set, and a SBP reduction of ~ 5 mmHg and ~3 mmHg for the second and third set, respectively. Although the difference between protocols is not great, it may still be physiologically relevant. According to Whelton et al. (2002), even a modest 3 mmHg drop in SBP has been associated with reduced cardiac morbidity by 5% to 9%, stroke by 8% to 14%, and all-cause mortality by 4%.

Also, it appears that there is no difference between DP5 and DP15 on RPP. Thus, applying a 5-second pause might be a good strategy to decrease cardiovascular strain during high-velocity muscle contraction resistance training in older women. It is worth noting that, although no difference was reported between DP5 and DP15, a 15-second pause could be distinguished as a rest interval between sets and create a false set leading to different chronic adaptations.

These findings may help exercise scientists prescribe high-velocity resistance exercise in a safe manner. It is not known, however, whether the chronic physiological adaptations associated with resistance exercise are similar for continuous and discontinuous protocols; therefore, future studies regarding this topic are warranted.

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Key points

- The assessment of cardiovascular responses to high-velocity resistance exercise in older individuals is very important for exercise prescription and rehabilitation in elderly population.
- Discontinuous protocol decrease myocardial oxygen consumption (HR x SBP) during the performance of dynamic high-velocity resistance exercise in older women.
- The decrease in RPP (~ 8.5%) during the discontinuous protocol has clinical implications when developing high-velocity resistance exercise strategies for elderly individuals.

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