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Acute and Chronic Effects of Exercise in Health

Impact of resistance exercise order on postexercise hemodynamic measures in middle-aged and older women

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Abstract - Aim: to compare the impact of different resistance exercise orders on postexercise hemodynamic measures in resistance-trained nonhypertensive middle-aged and older women. **Methods:** Twenty-three women (age 50-78 yrs) were randomized into two resistance training (RT) groups: one group started training sessions performing multi-joint exercises followed by single-joint exercises (MS, n = 12; 58.92 ± 5.53 yrs), while the other group performed their sessions in the opposite order (SM, n = 11; 57.93 ± 11.89 yrs). Both groups performed their RT sessions composed of 7 exercises performed in 3 sets of 10-15 repetitions maximum. Blood pressure was measured by automated equipment during pre-training and at 10, 20, 30, 40, 50, and 60 min after the training session. **Results:** Repeated-measures analysis of variance (ANOVA) identified an isolated effect of time only for systolic blood pressure (p = 0.003) with statistically significant reductions in pre-session measurement at 60 min post-session in both groups (MS: 117.67 ± 15.89 mmHg vs. 111.25 ± 11.84 mmHg and SM: 118.64 ± 15.13 mmHg vs. 111.50 ± 15.62 mmHg). Regarding diastolic blood pressure and subjective perception of effort, no difference was identified between groups (p > 0.05). **Conclusion:** We conclude that a RT session can promote post-exercise hypotension for systolic blood pressure after 60 min of recovery in middle-aged and nonhypertensive older women regardless of the exercise order.

Keywords: aging, resistance exercise, hypotensive effect.

Introduction

Hypertension is considered a public health problem worldwide. In Brazil, up to 40% of the population is expected to be affected[1], with approximately 50% of those being older adults[2]. This disorder is the major risk factor for cardiovascular disease and usually increases with age[1]. Cardiovascular disease is the leading cause of death, accounting for approximately 17.9 million deaths per year (31% of all-cause deaths)[3].

Engaging in regular physical exercise programs is strongly supported as a non-pharmacological strategy to treat and prevent hypertension[4]. Among the many types of physical exercise, resistance training (RT) has been widely employed in older adults due to its potential to increase lean body mass, enhance muscular strength[5,6], reduce body fat[7], and cause positive changes in the lipid profile[8]. In addition, RT can chronically reduce blood pressure (BP)[9] by inducing post-exercise hypotension (PEH), which is a reduction in BP below normal resting levels[9,10]. This reduction can be sustained for several hours after a training session and promotes cardiovascular protection by reducing the possibility of coronary arterial disease and stroke in normotensive and hypertensive individuals[11].

Several investigations involving RT and hemodynamic adaptations in older adults have analyzed PEH after a training session. However, results are conflicting, with some studies demonstrating significant reductions in PEH after a training session[12-16], while others do not present positive changes[17,18]. Some authors suggest that divergent results between protocols might be explained by differences in the variables of RT (e.g., volume, number of exercises, intensity, or health status)[17,19,20]. This has resulted in various studies focusing on manipulating RT variables to assess their impact on PEH, with exercise order being a major focus of some researchers. Jannig and colleagues[21] demonstrated that resistance exercise order influenced PEH in hypertensive older men and women. They found that performing resistance exercises either by alternating between upper and lower limbs or beginning sessions with upper limbs followed by lower limbs both promote PEH. On the contrary, other research has shown no effect of exercise order on PEH in normotensive older women[22]. These authors compared the effects of two orders of RT on post-exercise BP in trained non-hypertensive older women, with one group performing the RT from multi-joint to single-joint exercises, and the other group from single-joint to multi-joint exercises, and observed that there were no differences between the sessions in PEH[22].

Another study aimed to analyze the training effects of RT on muscular strength, hypertrophy, and anabolic muscles in 44 older women, who were randomly assigned to 1 of 3 groups: a no-order control group, and two RT groups performing a 12-week RT program in multi-joint to single-joint order, or in a multi-joint order. The RT protocol (3×/week) included 8 exercises, with 3 sets of 10-15 repetitions performed per exercise. The results were not different between the resistance exercise orders[23].

In this sense, considering the conflicting findings of the studies on the effect of resistance exercise order on PEH following RT, it seems necessary to further explore this phenomenon, especially in women. Therefore, this study aimed to compare the impact of different resistance exercise orders on PEH in resistance-trained nonhypertensive middle-aged and older women. We hypothesized that the RT program would elicit PEH and that different exercise orders would promote similar changes on PEH[22].

Methods

Participants

Recruitment was carried out through newspaper and radio advertisements and home delivery of flyers in the central city and residential neighborhoods. Initially, 41 women volunteered to participate in this study. All interested participants completed detailed health history and physical activity questionnaires and were subsequently admitted to the study if they met the following inclusion criteria: Non-hypertensive (systolic blood pressure < 140 mmHg and diastolic blood pressure < 90 mmHg), non-diabetic, free from any cardiac or renal dysfunction, non-smokers, not receiving hormonal replacement therapy, not performing any physical exercise more than once a week during the preceding 6 months. After individual interviews, 9 volunteers were excluded as potential candidates because they did not meet inclusion criteria.

Therefore, 32 participants were included in the study and were then submitted to a diagnostic, graded exercise stress test with a 12-lead electrocardiogram reviewed by a cardiologist. They were then released with no restrictions for participation in the study. Written informed consent was obtained from all participants after being provided with a detailed description of investigation procedures, benefits, and possible risks. This investigation was conducted according to the Declaration of Helsinki and approved by the local University Ethics Committee (Process 2.754.821).

The 32 participants were randomly assigned into two groups: one group performing RT from multi- to single-joint exercises (MS, n = 16), and the other group performing RT from single- to multi-joint exercises (SM, n = 16). Both groups performed their training protocols composed of 7 whole-body exercises twice a week for 16 weeks in 3 sets of 10-15 repetitions. During the intervention period, 9 participants dropped out of the study due to surgery, injury, personal reasons, or loss of interest. Afterwards, 23 women completed the study (MS = 12, SM = 11). During the last week of the intervention (week 17), all the participants were submitted to all the measures related to this investigation. Figure 1 presents the schematic design of participant recruitment and allocation.

Protocol

Body mass was measured to the nearest 0.1 kg using a calibrated electronic scale (Omron, Model HBF-214, Illinois, USA), with the participants wearing light workout clothing and no shoes. Height was measured to the nearest 0.1 cm with a stadiometer attached to the wall (E120A - Tonelli), with participants standing with no shoes. Body mass index (BMI) was calculated as body mass (kg) divided by height (m^2).

Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were performed with an automated electronic oscillometric arm BP monitoring device (G-Tech Home MSP20), while HR was measured with an HR monitor (Polar ElectroOu, Kempele, Finland). Measures were performed at pre-training session and after 10, 20, 30, 40, 50, and 60 min of recovery. Pre-training session measurements were conducted after a rest of 5 min. During measurements, participants were instructed to remain quiet, seated in a chair with back support, feet on the floor, right arm resting on a table, and raised to the height of the mid-point of the sternum. Laboratory temperature was controlled and maintained at approximately 25 °C, and all procedures followed the recommendations of the American Heart Association[24].

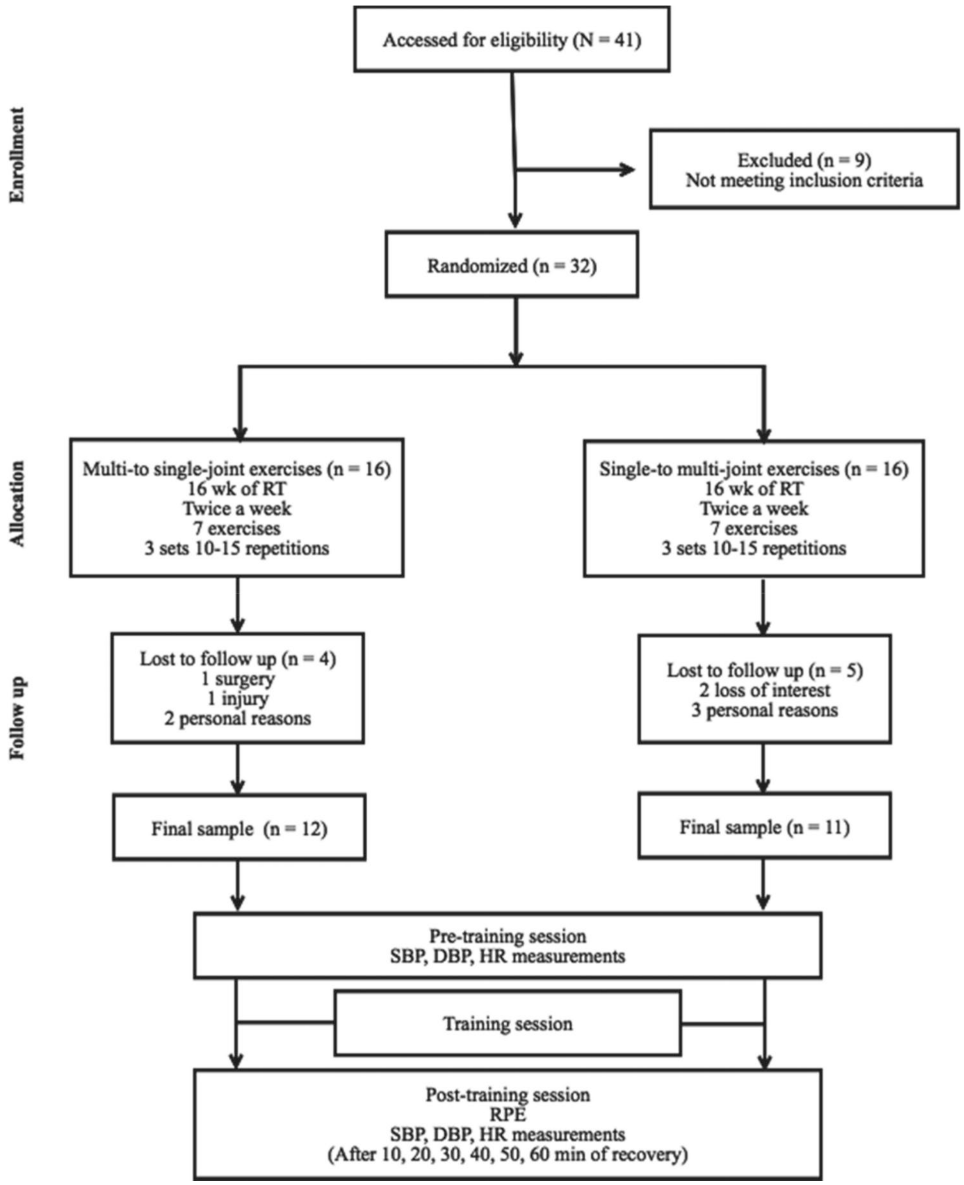

Figure 1 - Experimental design (flowchart).

Rating of perceived effort (RPE) was evaluated using the OMNI-RES scale[25] and applied to all participants at the end of the training session. Each participant was asked: "How much effort did you feel in your whole body during this training session?". Each RT session was composed of 7 exercises for each training group. For the MS group, the order was chest press (CP), seated row (SR), triceps pushdown (TP), preacher curl w/barbell (PC), horizontal leg press (LP), knee extension (KE), and seated calf raises (CR). For the SM group, the order was PC, TP, CP, SR, CR, KE, and LP. All participants performed 3 sets of 10-15 repetitions maximum for each exercise. Participants were instructed to inhale during eccentric muscle actions and exhale during concentric muscle actions while maintaining a constant movement velocity at a ratio of 1:2 (concentric and eccentric phases, respectively).

For both groups rest intervals between sets and exercises were 2-min and 3-min, respectively. Instructors adjusted the loads of each exercise according to the participant's ability and improvements in exercise capacity throughout the study to ensure that exercises were performed with as much resistance as possible while maintaining proper execution technique. Training load and the number of repetitions were recorded to ensure equitable training intensity for both groups during the training session.

Statistical analysis

Normality was checked by the Shapiro-Wilk test. Data were expressed as means and standard deviations.

Baseline differences between groups were explored with an independent t-test with Levene's test was used to analyze the homogeneity of variances. Two-way analysis of variance (ANOVA) for repeated measures was used for within-group comparisons. In variables where sphericity was violated as indicated by Mauchly´s test, analyses were adjusted using a Greenhouse-Geisser correction. When the F-ratio was significant, Bonferroni's post hoc test was employed to identify mean differences. For all statistical analyses, significance was accepted at $p < 0.05$. Data were stored and analyzed using STATISTICA software version 10.0 (StatSoft Inc., Tulsa, OK, USA).

Result

There were no differences in age and anthropometric variables between groups (Table 1). Table 2 shows the hemodynamic variables and RPE at pre- and post-training sessions for the groups. SBP significantly decreased after 60 min of recovery ($F = 3.48$, $p = 0.003$), with no difference between groups at any other time points of measurements (MS: reductions of 5 mmHg; SM: reductions of 3.8 mmHg). DBP and HR did not change throughout the experiment. Both groups reported their RPE as somewhat hard (6 to 7 on the Omni scale), with no difference between groups.

Figure 2 shows the total load (kg) and total repetitions performed by the groups during training sessions. Both groups performed the exercises at the same intensity (Total load: MS = 192.08 40.12 kg vs. SM = 182.27 23.84 kg, $p = 0.49$) and volume (Total repetitions: MS = 288.92 ± 23.91 reps vs. SM = 285.00 ± 35.46 reps, $p = 0.76$).

Table 1 - General characteristics of the groups.

Variables	MS (n = 12)	SM (n = 11)	p
Age (years)	56.67 ± 7.34	57.93 ± 11.89	0.73
Body mass (kg)	75.6 ± 12.04	71.96 ± 12.87	0.44
Height (m)	1.55 ± 0.07	1.58 ± 0.04	0.13
Body mass index (kg/m^2)	32.58 ± 4.73	28.75 ± 5.18	0.06

Note. MS = group that performed resistance training from multi- to single-joint exercises; SM = group that performed resistance training from single- to multi-joint exercises. Data are presented as mean and standard deviation.

Discussion

This study sought to compare the impact of two different resistance exercise orders on PEH in resistance-trained middle-aged and older women. Our results showed significant reductions in SBP over a 60-min recovery, with no difference between the exercise orders, confirming our original hypothesis. These findings reinforce the positive impact of RT on hemodynamic parameters in older women and add that the exercise order of RT does not play a significant role in PEH.

Previous systematic reviews and meta-analyses showed significant PEH after the performance of resistance exercises[9,10]. Casonato and colleagues[9], for example, found an overall reduction in SBP of −3.3 (−4.0 to −2.6), −5.3 (−8.5 to −2.1), and −1.7 (−2.8 to −0.67) mm Hg after 60 min, 90 min and 24 h of resistance exercise, respectively. Corroborating this evidence, our study found a significant reduction of 6.4 and 7.1 mmHg, for MS and SM, respectively, after a resistance exercise session. This fact can be explained by the physiological adaptive

Table 2 - Behavior of systolic and diastolic blood pressure, heart rate, and rating of perceived exertion according to different resistance exercise orders in middle-aged and older women.

Variableas	Pre-training	Post-training					
		10 min	20 min	30 min	40 min	50 min	60 min
SBP (mmHg)							
MS (n = 12)	117.67 ± 15.89	115.83 ± 10.35	108.25 ± 9.01	110.83 ± 15.32	110.42 ± 13.73	115.75 ± 12.79	111.25 ± 11.84*
SM (n = 11)	118.64 ± 15.13	119.29 ± 18.57	114.93 ± 16.59	112.64 ± 15.71	116.36 ± 15.53	115.14 ± 16.68	111.50 ± 15.62*
DBP (mmHg)							
MS (n = 12)	72.17 ± 7.02	75.75 ± 9.35	66.58 ± 7.76	70.67 ± 7.04	72.75 ± 8.58	70.58 ± 10.94	71.75 ± 6.36
SM (n = 11)	76.36 ± 12.88	71.21 ± 12.15	71.71 ± 10.43	72.57 ± 11.00	71.21 ± 12.83	64.71 ± 19.96	66.93 ± 10.96
HR (bpm)							
MS (n = 12)	79.08 ± 12.25	94.08 ± 13.55	96.92 ± 17.20	94.92 ± 17.34	94.17 ± 20.99	86.75 ± 21.91	85.75 ± 21.11
SM (n = 11)	86.64 ± 16.38	95.36 ± 21.22	98.71 ± 21.15	99.43 ± 19.98	95.14 ± 20.69	91.43 ± 19.20	89.93 ± 18.84
				RPE			
MS (n = 12)				7.08 ± 0.99			
SM (n = 11)				6.71 ± 0.73			

Note. SBP = systolic blood pressure; DBP = diastolic blood pressure; HR = heart rate; MS = group that performed resistance training from multi- to single-joint exercises; SM = group that performed resistance training from single- to multi-joint exercises; RPE = rating of perceived effort evaluated using the OMNI-RES scale[25]. Data are presented as mean and standard deviation.

*significant difference ($p < 0.05$).

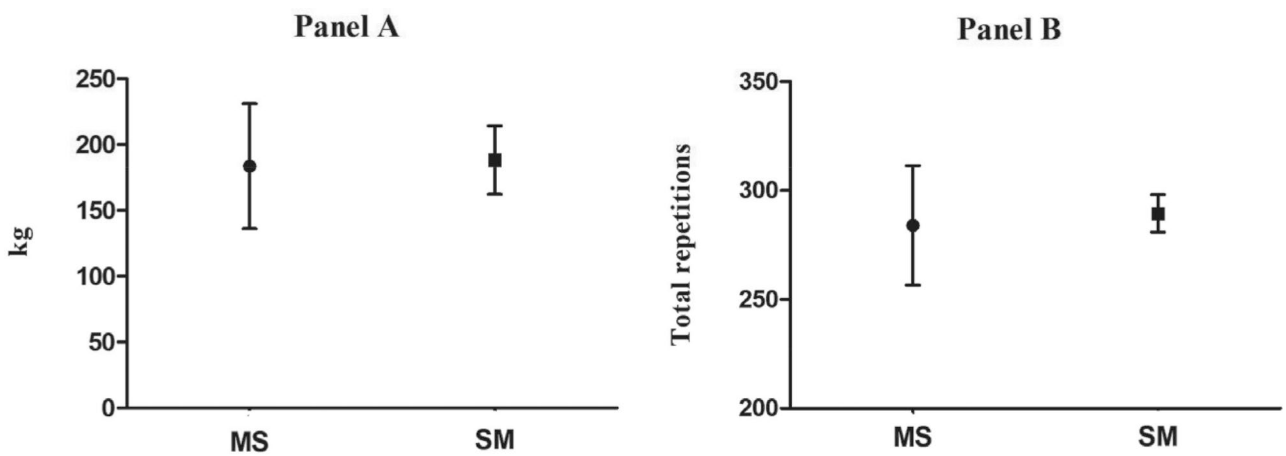

Figure 2 - Total load in kg (panel A), and total repetitions (panel B) of the groups. MS = group that performed RT from multi- to single-joint exercises; SM = group that performed RT from single- to multi-joint exercises.

decrease in blood pressure after a physical exercise session[4], with the magnitude of reduction seeming to be greater during the first few hours after exercise[4,26,27]. These findings are clinically relevant since a reduction of 5 mmHg in systolic BP reduces mortality due to stroke by 14%, mortality due to coronary heart disease by 9%, and all-cause mortality by 7%[28].

Although there is a consensus in the literature that possible mechanisms that alter BP and lead to PEH are related to reductions in cardiac output, peripheral vascular resistance, or both[29], it is still unclear which exact mechanism would lead to this phenomenon. The resetting in the baroreflex that blunts sympathetic outflow to the vascular beds occurs after exercise, which reduces the vasoconstriction responsiveness, contributing to sustained vasodilation post-exercise. Also, a decreased sympathetic tone and vagal activity increase after exercise would lead to reduced cardiac output[30].

Studies indicate that characteristics of the subjects evaluated and the training variables utilized, such as frequency, intensity, and time, could influence the HPE modulation[31]. In older adults, PEH would seem to be more linked to a reduction in cardiac output. There is a process of loss of vascular compliance with age, either by structural mechanisms (exchange of elastic tissue for collagen) or by autonomic or hormonal factors (vasodilating substances). Thus, peripheral vascular resistance would be increased and, consequently, another cardiovascular pathway would be needed to induce PEH such as reduced cardiac output. In this line, Rezk et al.[32] found a reduction in cardiac output due to a decrease in stroke volume, which was probably due to a reduction in preload, which was a major factor. Delayed blood pressure decline during recovery is associated with adverse clinical outcomes. Thus, in addition to being used as a routine safety measure during stress testing, exercise and recovery blood pressures can be useful to identify high-risk individuals and as aids to optimizing care through proper follow-up[33].

Although PEH is more evident in hypertensive individuals, this phenomenon also occurs in normotensive individuals[9,26,30]. In fact, in our study, most of the participants were considered normotensive, with some classified as pre-hypertensive. Although the protective role of PEH in normotensive individuals is not clear, it is known that even values considered to be normal SBP (>110-115 mmHg) are associated with a higher risk of mortality and cardiovascular diseases[34]. In this sense, our findings become even more relevant as they show the positive effects of resistance exercise in normotensive elderly people, which reinforces the preventive role of this type of exercise in attenuating the increase in blood pressure associated with age and the consequences of sustained values of exercise. blood pressure even at levels considered normal.

Some investigations have analyzed the impact of a RT program on hemodynamic measures without regard to exercise order. For example, Rodrigues and colleagues[13] submitted eleven hypertensive older women (68.2 ± 5.1 yrs) to one session of RT (10 exercises, 3 sets of 10 repetitions at 70% of their 10 repetition maxima). They found significant reductions of 10 mmHg in SBP and 4 bpm in HR after 30 min of recovery; however, the significant reductions for SBP were only observed after 45 min of recovery. A previous study from our laboratory showed a significant reduction (~5 mmHg) in SBP after one hour of recovery in normotensive older women after a RT session (8 exercises, 2 sets of 10-15 repetitions)[12]. On the other hand, Coelho-Júnior and colleagues[17] did not find significant changes in SBP and DBP after a RT protocol (9 exercises, 2 sets of 12-15 repetitions) in older women but did find a decrease in HR although only after 60 min of recovery. Another investigation[18], employing a very similar RT protocol to that of Rodrigues et al.[13], did not find significant changes in SBP, DBP, or HR after a single bout of exercise in 15 hypertensive older women. Orsano et al.[18] suggested that the volume of the training session (10 exercises x 3 sets) probably induced metabolic stress that would require more time for post-exercise recovery, which is a plausible hypothesis since the RT applied in the current study was composed of a lower volume (7 exercises x 3 sets).

Regarding exercise order, only a few studies have been conducted. Jannig and colleagues[21] submitted hypertensive older men and women to three different protocols and observed PEH for SBP after 20 and 40 min of recovery (−4.5 mmHg) when the subjects performed the resistance exercises alternating from upper to lower limbs or beginning the session with upper limbs, followed by lower limbs. Their other protocol (from lower to upper limbs) did not promote PEH. A recent study by Cardozo et al.[35] analyzed hypertensive older women who were divided into upper-limb and lower-limb exercise groups, with both performing resistance exercises from MS to SM. They observed PEH with significant reductions for SBP for both groups between 20 min (−6 mmHg) and 40 min (−9 mmHg) of recovery, with no difference between exercise orders. A recent study from our laboratory with previously resistance-trained, nonhypertensive older women showed that PEH for SBP occurred after 15 min (−5.1 mmHg) and 30 min (−5.6 mmHg) of recovery, also with no difference between the exercise orders[22].

We need to highlight the strengths of the study. We controlled the temperature during hemodynamic measures, only one single examiner performed all measures, RT programs performed by the participants were personally supervised, which guarantees homogeneity in their training status, and loads employed during training sessions between groups were similar, which guaranteed the same intensity for the groups.

In future research on this topic, we suggest that the SBP measurement be performed immediately after exercise, as well as one or more additional assessments during the 12 weeks to follow the evolution.

Conclusions

In conclusion, results of the current study indicate that a RT session promoted PEH for SBP after 60 min of recovery in middle-aged and older women, regardless of the exercise order. These findings are clinically relevant for strength and conditioning professionals, as well as for gerontologists and personal trainers, who work with physical exercise and aging women, indicating that this population can benefit from RT programs and that exercise order does not play a significant role in PEH. Therefore, when prescribing a RT routine for this population, in order to promote significant PEH, the focus might be addressed to the other RT variables involved in a RT program, rather than the exercise order.

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