Effect of 24 sessions of stretching exercises performed before resistance exercises on hemodynamic responses
Efecto de 24 sesiones de ejercicios de estiramiento realizados antes de ejercicios de resistencia sobre las respuestas hemodinámicas

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Abstract. The present study aimed to compare the effect of 24 sessions of stretching exercises performed before resistance exercises versus resistance exercise sessions on the hemodynamic responses of sedentary individuals. Thirty volunteers (26.76±6.29 years old, 81.56±10.66 kg body weight, 1.74±0.07 m height, and 26.74 ±.82 kg/m2 body mass index) participated in this study. After performing the test and retest of 10 maximum repetitions (10RM), the volunteers were divided into 3 groups: a) stretching exercise + resistance exercise (SE+RE); b) resistance exercise (RE) and c) control group (CG). The RE was composed of 3 sets of 10 repetitions at 80% of 10RM with a 2-minute interval between sets of RE preceded or not by 3 sets of 30 seconds of SE. Blood pressure (BP) was assessed using an automatic oscillometric device at session 0, session 12 and session 24 of training. Systolic BP (SBP), diastolic BP (DBP), mean BP (MAP), heart rate (HR), double product (DP) and oxygen saturation (SpO2) were measured after 10 minutes of rest. Comparison between groups was performed by Kruskal Wallis test with Bonferroni correction and 5% significance ($p < 0.05$). DBP showed significant difference when comparing session 0 vs. session 24 ($p = 0.006$) for the RE protocol. MAP decreased significantly after session 24 for the RE protocol compared to the other protocols ($p = 0.016$) and difference between session 0 vs. session 24 ($p = 0.022$). Significant difference was found in SE + RE protocol ($p = 0.029$) compared to session 0 vs. session 24 GC. This study showed that RE improved the DBP and MAP response and that the combination of SE+RE improved the SpO2 response after 24 training sessions.
Keywords: stretching, strength training, cardiovascular system, blood pressure, heart rate

Resumen. El presente estudio tuvo como objetivo comparar el efecto de 24 sesiones de ejercicios de estiramiento realizados antes de ejercicios de resistencia versus sesiones de ejercicios de resistencia sobre las respuestas hemodinámicas de individuos sedentarios. Treinta voluntarios (26.76±6.29 años de edad, 81.56±10.66 kg de peso corporal, 1.74±0.07 m de altura y 26.74±.82 kg/m2 de índice de masa corporal) participaron en este estudio. Después de realizar la prueba y la retest de 10 repeticiones máximas (10RM), los voluntarios se dividieron en 3 grupos: a) ejercicios de estiramiento + ejercicios de resistencia (EE+ER); b) ejercicios de resistencia (ER) y c) grupo de control (GC). El ER se compuso de 3 series de 10 repeticiones al 80% de 10RM con un intervalo de 2 minutos entre series de ER precedidas o no por 3 series de 30 segundos de EE. La presión arterial (PA) se evaluó utilizando un dispositivo oscilométrico automático en la sesión 0, sesión 12 y sesión 24 de entrenamiento. La presión arterial sistólica (PAS), la presión arterial diastólica (PAD), la presión arterial media (PAM), la frecuencia cardíaca (FC), el doble producto (DP) y la saturación de oxígeno (SpO2) se midieron después de 10 minutos de reposo. La comparación entre grupos se realizó mediante la prueba de Kruskal Wallis con corrección de Bonferroni y un 5% de significancia ($p < 0.05$). La PAD mostró una diferencia significativa al comparar la sesión 0 vs. la sesión 24 ($p = 0.006$) para el protocolo ER. La PAM disminuyó significativamente después de la sesión 24 para el protocolo ER en comparación con los otros protocolos ($p = 0.016$) y la diferencia entre la sesión 0 vs. la sesión 24 ($p = 0.022$). Se encontró una diferencia significativa en el protocolo EE+ER ($p = 0.029$) en comparación con la sesión 0 vs. la sesión 24 del GC. Este estudio mostró que el ER mejoró la respuesta de la PAD y la PAM, y que la combinación de EE+ER mejoró la respuesta de SpO2 después de 24 sesiones de entrenamiento.
Palabras clave: estiramiento, entrenamiento de fuerza, sistema cardiovascular, presión arterial, frecuencia cardíaca.

Introduction

Stretching exercises (SE) are commonly performed by individuals at different levels of physical fitness to enhance joint range of motion and flexibility (Behm et al., 2016; Garber et al., 2011; da Silva Araújo et al. 2024; Moreno & Jurado, 2022; Junior & da Silva Neto, 2021) . While flexibility training has been shown to positively impact balance and stability responses (Costa et al., 2009).

SE can induce changes in blood vessel caliber that influence the acute heart rate (HR) response through mechanisms distinct from blood pressure response (Gladwell & Coote, 2002). This effect leads to a significant elevation in HR for up to 5 minutes (Farinatti, Brandão, et al., 2011; Farinatti, Soares, et al., 2011). The mechanoreceptor system is particularly sensitive to vessel caliber changes, resulting in HR elevation even without concurrent blood pressure modification (Gladwell et al., 2005). Additionally, stretching muscle fibers during SE can cause a signifi-

cant reduction in oxygen saturation (SpO2), as noted by McCully (2010).

In terms of cardiovascular responses, RE has been associated with improvements in endothelial function and reductions in peripheral vascular resistance (MacDonald et al., 2016). Single RE sessions have demonstrated hypotensive effects (HPE) of varying magnitudes (Bentes et al., 2017; Rossi et al., 2013; Quesada & Solera Herrera, 2017), with a notable chronic effect (Casonatto et al., 2011). Moreover, even modest reductions of 3-4 mmHg in blood pressure have been linked to cardiovascular benefits and decreased risk of vascular events, often necessitating metabolic overload (Figueiredo et al., 2014) as recommended by The American College of Sports Medicine (2004).

The interaction between different combinations and sequences of RE and SE on acute cardiovascular responses has been explored in a series of elegant studies studies (G. da S. Araujo et al., 2019; G. S. Araujo et al., 2018; Costa e Silva et al., 2019; da Silva et al., 2019; Santos et al., 2014; SOUSA et al., 2019). Silva et al. (2019) reported increased acute cardiovascular responses when SE was combined with RE, assessed using the double product. Silva et al. (2019) and Souza et al. (2019) found that the combination of SE and RE aided in the recovery of cardiovascular responses and induced post-exercise hypotension (PEH) when SE followed the RE session (SOUSA et al., 2019), without significant increases in systolic blood pressure (SBP) in combinations of SE+RE and RE+SE (da Silva et al., 2019). Araújo et al. (2019) demonstrated near-resting level parasympathetic recovery activity after the RE+SE session. Santos et al. (2014) showed that a single series of quadriceps SE followed by unilateral RE knee extension (SE+RE) led to significant reductions in SBP and diastolic pressure (DIP) responses.

The combination of stretching exercises (SE) with resistance exercises (RE) is a common practice in fitness and training regimens (Fernández-Ozcorta et al., 2024; Khortabi et al., 2023; Kubo et al.; 2002). Additionally, hemodynamic responses, which include factors such as blood pressure, heart rate, and oxygen saturation, provide crucial indicators of cardiovascular health and physiological adaptations. Investigating how these responses vary between SE+RE and RE sessions is relevant, especially considering the growing interest in the impact of exercise on cardiovascular function. Therefore, the study aims to compare the hemodynamic responses of untrained adults after 24 sessions of stretching exercises performed before resistance exercises (SE+RE) with those of resistance exercise sessions (RE) alone.

Methodology

The study comprised a total of 26 sessions conducted three times a week on non-consecutive days, consistently at the same time of day. During the initial visit, anthropometric measurements, a 10-repetition maximum test (10RM), and orientation regarding SE and RE were conducted. In the subsequent visit, all participants underwent a 10RM retest to assess load reproducibility. Starting from the third to the 26th visit, volunteers were randomly assigned to one of three experimental groups: a) stretching exercises + resistance exercises with 120-second intervals between sets (SE+RE120"), b) resistance exercises with 120-second intervals between sets (RE120"), and c) a no-exercise control group (CG). Hemodynamic parameters, including SBP, DBP, MAP, DP, HR, and SpO2, were assessed in a laboratory setting after a 10-minute rest in the dorsal decubitus position. Before each session, participants were instructed to abstain from consuming caffeinated or alcoholic beverages and to maintain their regular eating habits throughout the research period (three days a week on non-consecutive days for eight weeks). (see Figure 1).

Subjects

Thirty men, with an average age of 26.76 ± 6.29 years, body weight of 81.56 ± 10.66 kg, height of 1.74 ± 0.07 cm, and body mass index of 26.74 ± 2.82 kg/m2, were divided into three groups: SE+RE Group, RE Group, and a Control Group (CG) who had not been regularly training in resistance exercises (RE) for at least 6 months, as per Garber et al. (2011). In addition, participants who used anabolic steroids or any other medication were included as an exclusion criterion.

The study received approval from the Ethics Committee of the Barra Mansa University Center (53898516.8.0000.5236/2017). The following exclusion criteria were applied: a) use of medication; b) presence of any functional limitations that could affect test performance; c) any medical conditions that could influence the exercise program; d) use of drugs that could affect test outcomes; e) smokers, as per (G. da S. Araujo et al., 2019). Participants were fully informed about the research's risks and benefits and provided informed consent by signing an informed consent form (ICF). Additionally, participants were instructed not to engage in any other forms of physical activity during the research period.

Procedures

10 Repetition Maximum Test - The 10 Repetition Maximum (10RM) test aimed to reduce error margins through standardized instructions and familiarization prior to the test, ensuring all participants were acquainted with the data collection routines. Proper execution techniques for various resistance exercises, such as bench press (BP), front pull-up (FP), shoulder press (SP), leg press 45 (LP45), leg extension (LE), and leg curl machine (LC), were explained. Evaluators monitored participants' joint positioning during measurements to avoid activation of unintended muscles due to slight deviations. Verbal cues maintained motivation, while added weights were accurately measured. The exercise angle was visually controlled, and consistency in movement patterns was en-

sured across tests and training sessions for each participant (Monteiro et al., 2019) . To minimize muscle fatigue, three to five attempts per exercise were performed (Bentes et al., 2017), with a five-minute interval between attempts. After determining exercise load, a 20-minute interval preceded the next exercise. The 10RM protocol followed ACSM's (2007) recommendations, including a specific warm-up with 5 to 10 repetitions at 40% to 60% of perceived maximum before the first exercise. A load of 60% to 80% of perceived maximum was used for 6 repetitions after a one-minute interval. Another increase in load followed, leading to the 10RM weight. A re-test 48 hours later assessed 10RM load reproducibility.

Strength Training - The training protocol involved three sets at 80% of the 10RM for bench press, front pull-up, shoulder press, leg press 45, leg extension, and leg curl machine exercises. Exercise order was consistent across experimental conditions. Load adjustments were made if participants exceeded 10 repetitions in consecutive sets. A 120-second interval separated sets and exercises.

Stretching Exercises (SE) - Static passive stretching exercises included horizontal abduction of the glenohumeral joint with elbows flexed and hands supporting behind the head (chest), unilateral trunk tilt with extended elbow and flexed knees (dorsal), sitting glenohumeral horizontal adduction (deltoids), supported knee flexion (quadriceps), hip flexion with ankle dorsiflexion (hamstrings and glutes), and hip flexion with flexed and crossed knees (glutes)) (G. da S. Araujo et al., 2019). All protocols achieved mild discomfort (Garber et al., 2011), reaching an 8-point level on a 0-10 scale (McCully, 2010). Three series, each lasting 30 seconds, were performed, maintaining breathing patterns and avoiding the Valsalva maneuver. A 40-second interval separated series.

Blood Pressure Evaluation - Hemodynamic measurements occurred during a 10-minute dorsal decubitus rest period, utilizing a 24-hour ambulatory blood pressure monitoring device (Burdick 90217 Ultralite, USA) with the oscillometric technique (SBC, 2007). The cuff covered at least two-thirds of the upper arm. The equipment was used for blood pressure measurements in session 0, session 12, and session 24, following American Heart Association guidelines (Muntner et al., 2019) .

Heart Rate Evaluation - Heart rate data were collected using a heart rate monitor (Polar, RS 800 CX, USA). Electrodes were positioned moistened and towards the sternum's point at the xiphoid process. Data were transferred to a microcomputer via a Polar® infrared interface and analyzed using Polar Precision Performance® software (Finland). A 10-minute dorsal decubitus rest period was observed. The double product (DP) was computed as HR (bpm) x SBP (mmHg).

Oxygen Saturation Measuremen - Finger pulse oximetry (Nonin Onyx 9500, USA) provided SpO2 values. This indirect method correlated SpO2 with oxyhemoglobin (HbO2) at r = 0.98 (Martin et al., 1992). The probe was
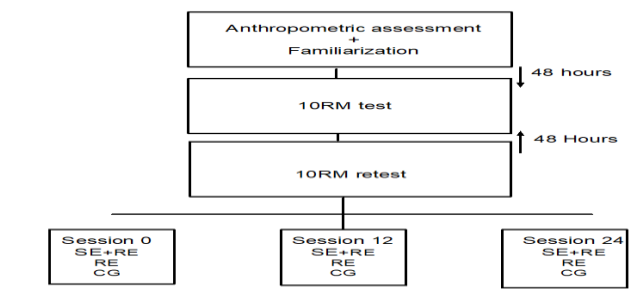
attached to the dominant hand's index finger, stabilized on a surface. SpO2 was measured for 10 minutes at rest (pre) in the dorsal decubitus position.

Figure 1. The study design

Statistical Analysis

At first, the normality of the distributions was tested by the formal Shapiro-Wilk normality test. The measures that had their normality rejected at this point were then already considered for non-parametric treatment, those that did not have their normality rejected followed for a more punctual analysis in relation to their distribution pattern having the Gauss curve as reference. Thus, analyses of symmetry, kurtosis, and visual analysis of histograms and Q-Q plots were performed. Finally, the non-parametric statistic was considered when a variable had its normality rejected in a comparison group. In all comparisons, this happened with one or more variables, so the descriptive values of the variables are presented as median and interquartile range as measures of central tendency and dispersion, respectively. Friedman test was applied for intragroup comparison of the repeated measures on the timeline and, for intergroup comparison of the different measurements on the timeline, the Kruskal Wallis test was applied. Whenever a significant difference was found in the multiple measures, for it to be scored a pairwise comparison-adjusted by Bonferroni correction was performed. For all inferential treatment, a significance level of 5% ($p < 0.05$) was accepted. All statistical treatment was performed in the Statistical Package for the Social Sciences (SPSS) version 21.0.

Results

In terms of intra-group comparisons of blood pressure values, SBP exhibited no significant differences at any time point on the timeline for the SE + RE group (p = 0.067), the RE group (p = 0.567), or the CG (p = 0.918).

DBP displayed no significant differences when comparing different intra-group moments in the SE + RE group (p = 0.67) or the CG (p = 1.0). However, in the RE group, DBP showed a significant difference in repeated measures (p = 0.006). Yet, when pairwise comparison was adjusted, this difference was attenuated for all time points ("session 0 x session 12 - p = 0.057"; session 0 x

session 24 - p = 0.057"; "session 12 x session 24 - p = 1.0").

MAP demonstrated no significant intra-group differences in the SE + RE group (p = 0.497) or the CG (p = 0.9). However, a significant difference emerged in the RE protocol (p = 0.016), with adjusted pairwise comparison revealing the difference between session 0 and session 24 (p = 0.022).

HR followed a consistent pattern with no significant differences in any of the repeated measures for either group ("SE + RE - p = 0.062"; "RE - p = 0.798"; CG - p = 0.973").

Similarly, DP exhibited no significant intra-group differences for any of the time points ("SE + RE - p = 0.301"; "RE - p = 0.9"; GC - p = 0.67").

Regarding SpO2, no intra-group differences were observed for RE (p = 0.062) and CG (p = 0.479). However, a significant difference emerged for SE + RE (p = 0.029), which was attenuated after adjusted pairwise comparison ("session 0 x session 12 - p = 0.656"; session 0 x session 24 - p = 1.0"; "session12 x session 24 - p = 0.221").

In intergroup comparisons, SBP showed no significant differences at any moment (session 0 - p = 0.85; session 12 - p = 0.689; session 24 - p = 0.258). DBP showed no significant differences in session 0 (p = 0.365) or session 12 (p = 0.075). However, a significant difference was noted in session 24 (p = 0.034), specifically between SE+RE vs. CG (p = 0.028). MAP showed no significant differences between session 0 (p = 0.423) and session 12 (p = 0.58). A significant difference emerged in session 24 (p = 0.032), with adjusted pairwise comparison revealing the difference between RE vs. CG (p = 0.026).

HR exhibited no significant differences at any time point when comparing the protocols (session 0 - p = 0.341; session 12 - p = 0.884; session 24 - p = 0.403).

Similarly, DP demonstrated a consistent behavior, with no significant differences at any time between groups (session 0 - p = 0.162; session 12 - p = 0.49; session 24 - p = 0.263).

SpO2 showed no significant differences between groups at session 0 (p = 0.393) or session 12 (p = 0.309). However, a significant difference emerged in session 24 (p = 0.0001), with adjusted pairwise comparison identifying significant differences between SE + RE vs. RE (p = 0.002) and SE + RE vs. CG (p = 0.002) groups.

Table 1.
SE+RE = stretching exercise + resistance exercise; RE = resistance exercise; CG = control group; SBP = Systolic Blood Pressure; DBP = Diastolic Blood Pressure; MBP = Mean Arterial Pressure; HR = Heart Rate; DP = Double Product; SpO2 = Oxygen Saturation; # = significant difference (p < 0.05) compared to control group; * = significant difference (p < 0.05) compared to session 0. Insignificant, Small and Moderate are the results of effect size.

	SE + RE			RE			CG		
	Session 0	Session 12	Session 24	Session 0	Session 12	Session 24	Session 0	Session 12	Session 24
SBP	128.5 (120-134)	124 (120-128) -0.63 Small	123 (115.5-125.75) -0.82 Small	126 (121-135.25)	123.5 (120.75-127.75) -0.30 Insignificant	123 (115.5-125.75) -0.50 Small	129 (121-134.75)	126 (121-135.25) -0.19 Insignificant	128 (117-137) -0.33 Insignificant
DBP	70 (66-74.5)	69 (63.75-75.25) -0.44 Insignificant	70.5 (67.5-73.5) -0.08 Insignificant	73.5 (68.5-77.25)	65.5 (60.5-72.25) -1.32 Moderate	#65 (60.5-72.25) -0.07 Insignificant	74 (68.75-78.25)	74 (68.75-78.25) 0 Insignificant	74 (68.75-78.25) 0 Insignificant
MAP	87.66 (85-95.33)	87.83 (84.5-91.41) -0.99 Small	88.5 (84.75-91) -0.86 Small	91.5 (87.83-94.5)	84,66 (82-91,25) -1.37 Moderate	#*84,5 (80.5-86.83) -0.32 Insignificant	91.66 (87.83-97.91)	92.5 (87.58-96.83-0.07 Insignificant	91.66 (85.75-97.33) -0.10 Insignificant
HR	62 (55.75-68.5)	66 (63.75-70.5) 0.75 Small	65.5 (60.5-70.75) 0.45 Small	65 (61.5-77.5)	68 (61.5-79.25) 0.20 Insignificant	72.5 (61.5-79.25) 0.15 Insignificant	68 (62.75-88.25)	68 (62.75-88.25) 0 Insignificant	68 (62.75-88.25) 0 Insignificant
DP	7778 (7093-8758)	8184 (8028.75-8882) 0.41 Insignificant	8062.5 (7260.5-8612.75) 0.03 Insignificant	8807.5 (7426.5-9694)	8677.5 (7548-10093) 0.10 Insignificant	8137 (7588.75-9798.75) -0.07 Insignificant	9091.5 (7681,2510914,)	8992 (7551.5-10702.75 -0.03 Insignificant	8640 (7617.25-10325.25) -0.10 Insignificant
SpO2	99 (98-99)	98.5 (94.75-99) -0.53 Small	#§99 (99-99) 0.37 Insignificant	98 (96.25-99)	97 (95.75-97.25) -0.36 Insignificant	97 (95.75-97.25) 0 Insignificant	98 (95.5-99)	97.5 (96-99) -0.39 Insignificant	96.5 (94.75-97.5) 0.13 Insignificant

Discussion

The objective of this study was to compare the impact of 24 sessions involving stretching exercises performed prior to resistance exercises (SE+RE) with sessions solely focused on resistance exercises (RE) on the responses of SBP, DBP, MAP, HR, DP, and SpO2 in untrained adults. The primary outcomes of this investigation reveal that SE+RE led to enhanced SpO2 in comparison to the control group (CG), while RE exhibited noteworthy enhancements in DBP relative to baseline and improvements in MAP compared to both baseline and the CG.

To the best of our knowledge, this is the first study to compare the effects of 24 sessions of stretching exercises performed before resistance exercises versus resistance exercise sessions on the hemodynamic response of untrained adults. Our study's findings indicate that while not displaying significant differences, the blood pressure (BP) response exhibited a reduction, which could potentially assist in managing BP responses through both resistance exercises (RE) and the combination of stretching exercises and resistance exercises (SE+RE). In our study, we evaluated the impact of 24 SE+RE sessions in comparison to RE sessions.

The two previous studies that assessed the acute effects of SE and SE+RE on hemodynamic responses were conducted by Da Silva et al. (2019) and Souza et al. (2019). Both studies involved a group of volunteers who performed 6 SE (pectoral, dorsal, deltoids, quadriceps, hamstrings, and gluteus) followed by 6 RE (bench press, front pull up, shoulder press, leg press 45, leg extension, and Leg curl machine) (Da Silva et al., 2019; Souza et al., 2019). In Da Silva et all.'s study (2019), the authors observed no significant increases in SBP and DBP responses in protocols that combined SE+RE or RE+SE immediately after the session. Additionally, in the protocol that included SE after the RE session, heart rate variability approached baseline values post-session without a significant increase in BP response. Souza et al. (2019) found significant increases in SBP response immediately after a SE+RE session, but these values returned to baseline after 15 minutes of rest.

Small reductions in BP responses can yield benefits for individuals engaging in exercise. Reductions of 3-4mmHg in SBP offer advantages by decreasing the risk of cardiovascular disease-related events (Pescatello et al., 2004). In our study, mean reductions of 4.5mmHg and 5.5mmHg were observed in SBP for the SE+RE protocol, and mean reductions of 2.5mmHg and 2mmHg were observed in the RE protocol during session 12 and session 24, respectively. Additionally, for the DBP response, reductions of 8mmHg and 7.5mmHg were noted for the RE protocol in session 12 and session 24, respectively. In a meta-analysis by MacDonald et al. (2016), the authors found SBP reduction values of 2-3mmHg in hypertensive adults. While our study did not involve a hypertensive sample, their findings align with the results observed in our RE protocol.

When assessing the immediate responses to the combination of Static Exercise (SE) and Resistance Exercise (RE), Costa e Silva et al. (2019) observed a notable increase in cardiac strain after exposing a group of volunteers to 2 sets of SEs followed by 3 sets of 10 repetitions in 2 REs (specifically, bench press and leg extension). The intensity of the REs was regulated to reach a rating of perceived exertion of 8 on a scale of 0 to 10 (McCully, 2010). The researchers noted that the amalgamation of SE and RE led to elevated values in Diastolic Pressure (DIP), Heart Rate (HR), and subjective perception of exertion. These outcomes might be attributed to the constriction of blood vessels caused by mechanical obstruction due to stretching during the SE, as described by Farinatti, Brandão, et al., 2011; Farinatti, Soares, et al., 2011. Araújo et a. (2018) reported significant increases that endured for 45 minutes subsequent to executing 6 SEs followed by 6 REs. The results from Costa e Silva et al. (2019) and Araújo et al. (2018) stand in contrast to the findings of Silva et al. (2019), Araujo et al. (2019), and Souza et al. (2019).

The last three studies employed similar methodologies by varying the sequences of Static Exercise (SE) and Resistance Exercise (RE). In Silva et al. (2019) study, participants were subjected to SE targeting the pectoral and quadriceps muscles, followed by the performance of RE exercises, namely bench press and leg extension. The SE+RE protocol exhibited significant increases in Heart Rate (HR) and Diastolic Pressure (DIP) responses in comparison to the baseline measurements. This acute elevation in HR and DIP responses might have been a response to the heightened physiological demands of the exercise to sustain performance (Nobrega et al., 2014) .The influence of SE on cardiovascular responses can extend for up to 15 minutes (Farinatti, Brandão, et al., 2011) , which could shed light on our findings. In our investigation encompassing 24 sessions, there might not have been a significant acute change in Systolic Blood Pressure (SBP) during the SE+RE training sessions. This absence of notable SBP elevation could potentially be attributed to an insufficient rise in physiological demand required to induce cardiovascular adaptations. This could be due to the lack of metabolite accumulation or a low dose-response ratio (Figueiredo et al., 2014; MacDonald et al., 2016). This response might have transpired due to the relaxation effect brought about by SE before the RE session, contributing to improved venous return and reduced afterload (da Silva et al., 2019).

The response of Oxygen Saturation (SpO2) exhibited noteworthy disparities solely within the SE+RE protocol. In our study, subsequent to the completion of 24 training sessions, substantial distinctions emerged between the SE+RE protocol and the Control Group (CG), while no significant difference manifested in relation to the RE protocol. Static Exercises (SEs) possess the capacity to promptly modify oxygen delivery owing to the transient hypoxic environment engendered by SEs. This environ-

mental hypoxia, upon cessation of SE performance, facilitates reperfusion and augments oxygen supply to the engaged muscles (McCully, 2010). This phenomenon is associated with the enhancement of vascular endothelial function and peripheral circulation, as exemplified by improvements documented in studies such as (Hotta et al., 2013).

The combination of strength training with stretching exercises can influence cardiovascular responses through various physiological mechanisms. Strength training increases the metabolic demand of muscles, resulting in localized vasodilation and consequent increased blood flow, while stretching can also induce a vasodilatory response in stretched muscles. (Kruse & Scheuermann, 2017 ; Schroeder et al, 2019).

Additionally, both types of exercises activate the autonomic nervous system, with strength training associated with greater sympathetic activity and stretching promoting a parasympathetic response. The release of hormones such as catecholamines and steroid hormones is also triggered by both types of exercises, affecting cardiovascular function. Furthermore, the metabolic changes induced by strength training and stretching, such as oxygen consumption and lactate production, can directly modulate cardiovascular activity. Therefore, understanding these mechanisms is essential for prescribing exercise programs that optimize cardiovascular health benefits for individuals. (Stubenitsky & Duncker ,1998), (Merz et al. 2015; Barreto et al.; 2023)

Araujo et al. (2018) investigated the effects of three different acute exercise protocols involving Aerobic Exercise (AE) order combinations on a group of 20 volunteers: a) SE+RE, b) RE+SE, and c) SE between RE sets. The aim was to evaluate responses in terms of Oxygen Saturation (SpO2), Diastolic Pressure (DIP), and Heart Rate (HR). Notably, there were no significant differences observed in SpO2 across the various tested protocols. The sequence of Static Exercises (SEs) did not elicit a substantial acute alteration in SpO2 levels.

In our study, notable alterations were observed within the SE+RE protocol when comparing week 24 with week 0 of the Control Group (CG). This could potentially be attributed to the influence of SEs performed before the RE session, which might have impacted endothelial responses as demonstrated in studies like (Hotta et al., 2013). This influence could enhance pulse velocity through relaxation of vessel walls. SEs could potentially aid in the release of endothelial factors, thereby improving vascular wall function, potentially through an augmentation in nitric oxide release (Nobrega et al., 2014).

In summary, our pioneering study compared the effects of stretching exercise (SE) sessions followed by resistance exercise (RE) with sessions solely focused on RE in the hemodynamic responses of untrained adults. We observed significant improvements in oxygen saturation (SpO2) in the SE+RE protocol compared to the control group (CG), while the RE protocol demonstrated notable

enhancements in diastolic blood pressure (DBP) and mean arterial pressure (MAP). The observed of small reductions in blood pressure responses have significant clinical implications for cardiovascular risk reduction. Furthermore, the heterogeneous responses observed underscore the intricate relationship between exercise types and physiological adaptations. Our findings contribute to the understanding of exercise order impacts on cardiovascular health, providing valuable insights to guide personalized exercise strategies and promote heart health.

Practical Implications and Future Directions

The study provides valuable insights into the chronic hemodynamic responses to various exercise combinations in untrained individuals. The lack of significant differences in most parameters implies that the chronic cardiovascular effects of SE, RE, or their combination might be limited for untrained individuals. However, the findings of lower diastolic blood pressure (DBP) and altered mean arterial pressure (MAP) in specific scenarios (SE+RE vs. CG, RE vs. CG) highlight the potential for subtle variations in response.

Future research could explore these responses in a more diverse population, including individuals with varying fitness levels and health conditions. Additionally, investigating the long-term effects of these exercise protocols on cardiovascular health and adaptation would contribute to a more comprehensive understanding of their impact. Moreover, incorporating more comprehensive measurements, such as assessments of endothelial function or vascular reactivity, could offer deeper insights into the cardiovascular effects of these exercise combinations.

So, this study contributes to the existing literature by shedding light on the chronic hemodynamic responses to different combinations of SE and RE in untrained individuals. While the results suggest limited effects, they provide a foundation for further investigations into the potential cardiovascular benefits of combining stretching and resistance exercises, particularly over the long term. Fitness professionals can use these insights to design exercise programs that target not only muscular strength and flexibility but also chronic cardiovascular responses.

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