

Acute hemodynamic responses are not different for mono and multiarticular exercises for the same muscle group

As respostas hemodinâmicas agudas não são diferentes para exercícios mono e multiarticulares para o mesmo grupo muscular

Las respuestas hemodinámicas agudas no son diferentes para ejercicios de articulaciones únicas y multiarticulares para el mismo grupo de músculos

Received: 06/09/2021 | Reviewed: 06/17/2021 | Accept: 07/04/2021 | Published: 07/07/2021

Leandro de Oliveira Sant'Ana

ORCID: <https://orcid.org/0000-0002-0156-4030>
Federal University of Juiz de Fora, Brazil
E-mail: losantana.ufjf@gmail.com

Fabiana Rodrigues Scartoni

ORCID: <https://orcid.org/0000-0002-0466-8193>
Catholic University of Petrópolis, Brazil
E-mail: fabiana.scartoni@ucp.br

Patrícia Panza

ORCID: <https://orcid.org/0000-0002-9683-0548>
Federal University of Juiz de Fora, Brazil
E-mail: paty_panza@yahoo.com.br

Bernardo dos Santos Coelho

ORCID: <https://orcid.org/0000-0002-7870-2446>
Estacio de Sá University, Brazil
E-mail: bernardogkcoelho@gmail.com

Tiago da Silva Ferreira

ORCID: <https://orcid.org/0000-0002-9900-0902>
Estacio de Sá University, Brazil
E-mail: tiagoakai@hotmail.com

Marcus Vinícius Vogel

ORCID: <https://orcid.org/0000-0001-7991-2763>
Salgado de Oliveira University, Brazil
E-mail: marcusvovogel@gmail.com

Bruno Soares de Oliveira

ORCID: <https://orcid.org/0000-0002-3632-2648>
Estacio de Sá University, Brazil
E-mail: bsoliveira84@gmail.com

Jeferson Macedo Vianna

ORCID: <https://orcid.org/0000-0003-1594-4429>
Universidade Federal de Juiz de Fora, Brasil
E-mail: jeferson.vianna@ufjf.edu.br

Abstract

Introduction: Different mechanical behaviors in resistance training can result in certain changes in the cardiovascular system. **Objective:** To verify the acute behavior of the main cardiovascular variables (heart rate, blood pressure, and double product) when performing resistance training with mono and multiarticular exercises. **Methods:** 10 male subjects participated in the study (26 ± 4 years; 81 ± 6 kg; 1.77 ± 2 m; 23 ± 1 kg / m²). They performed a test and retest for 8RM in the bench press and crucifix exercises on the machine. After the loads were outlined, they performed the intervention with the exercises, initially with a monoarticular activation containing two sets of 12 repetitions with 50% of the load acquired in the 8RM test of each exercise, using an interval of 60 seconds between one set and another. Additionally, three sets of 8 repetitions (80% 8RM) were performed with an interval between sets of 120 seconds. The execution speed was determined at a moderate level (2s for concentric, 2s for eccentric). It was measured before and during (series 1, series two, and series 3. Named as moments) heart rate exercises using POLAR, model RS800CX Multisport® and blood pressure using OMRON M6 (HEM-7001- E) ®. Then, the double product was calculated using the formula [HR (bpm) X SBP (mmHg)]. **Results:** In the heart rate analysis, there was an intra-condition difference for moments 1, 2, and 3 compared to rest ($p < 0.000$). In the inter-condition comparison, no differences were observed for rest ($p = 0.994$) and for moments 1, 2 and 3 ($p > 0.999$). In systolic blood pressure, intra-conditions, differences were observed for moments 1, 2, and 3 compared to rest ($p < 0.000$). In the inter-condition

comparisons, there were no differences between rest ($p > 0.999$), moment 1 ($p = 0.714$), 2 ($p = 0.999$) and 3 ($p > 0.999$). For diastolic blood pressure, intra conditions, for bench press no significant differences were found for moments 1 ($p = 0.331$), 2 ($p = 0.505$) and 3 ($p = 0.505$) when compared to rest. In the same way it was for the crucifix, wherein the comparison with rest, no difference was observed in moments 1 ($p = 0.849$), 2 ($p = 0.195$) and 3 ($p = 0.105$). In the same sense, no difference was also observed in the comparisons between conditions for rest ($p > 0.999$), moment 1 ($p = 0.999$), 2 ($p = 0.989$) and 3 ($p = 0.948$). Finally, the double product in intra-condition comparisons found differences between moments 1, 2, and 3 compared to rest ($p < 0.000$). However, in the inter-condition comparisons, no difference was observed at rest ($p = 0.999$), moment 1 ($p = 0.868$), 2 and 3 ($p > 0.999$). Conclusion: It is suggested that resistance training composed of mono and multi-joint exercises offers differences in hemodynamic responses but without differences between the types of mechanics applied by the exercises. Therefore, these results offer a partiality of what can happen with heart rate, blood pressure, and double product.

Keywords: Resistance training; Biomechanics; Heart rate; Blood pressure; Double product.

Resumo

Introdução Diferentes comportamentos mecânicos no treinamento resistido pode resultar em determinadas alterações no sistema cardiovascular. Objetivo: Verificar o comportamento agudo das principais variáveis cardiovasculares (Frequência cardíaca, pressão arterial e duplo produto) na realização de treinamento resistido com exercícios mono e multiarticulares. Métodos: 10 indivíduos do sexo masculino participaram do estudo (26 ± 4 years; 81 ± 6 kg; $1,77 \pm 2$ m; 23 ± 1 kg/m²). Realizaram teste e reteste para 8RM nos exercícios supino reto e crucifixo na máquina. Após o delineamento das cargas, realizaram a intervenção com os exercícios, inicialmente com uma ativação mioarticular contendo 2 séries de 12 repetições com 50% da carga adquirida no teste de 8RM de cada exercício, utilizando um intervalo de 60 segundos entre uma série e outra. Adicionalmente, foram realizadas 3 séries de 8 repetições (80% 8RM) com intervalo entre séries de 120 segundos. A velocidade de execução foi determinada em nível moderado (2s para concêntrica, 2s para excêntrica). Foi medida antes e durante (série 1, série 2 e série 3. Nomeadas como momentos) os exercícios a frequência cardíaca utilizando POLAR, modelo RS800CX Multisport® e a pressão arterial usando o OMRON M6 (HEM-7001- E)®. Adiante, foi calculado o duplo produto através da fórmula [HR (bpm) X SBP (mmHg)]. Resultados: Na análise da frequência cardíaca, houve diferença intra condições para os momentos 1, 2 e 3 quando comparado com repouso ($p < 0.000$). Na comparação inter condições não foi observado diferenças para rest ($p = 0.994$) e para os momentos 1, 2 e 3 ($p > 0.999$). Na pressão arterial sistólica, intra condições, foi observado diferenças para os momentos 1, 2 e 3 quando comparados com repouso ($p < 0.000$). Nas comparações inter condições, não foram observadas diferenças entre repouso ($p > 0.999$), momento 1 ($p = 0.714$), 2 ($p = 0.999$) e 3 ($p > 0.999$). Para pressão arterial diastólica, intra condições, para supino reto não foram encontradas diferenças significativas para os momentos 1 ($p = 0.331$), 2 ($p = 0.505$) e 3 ($p = 0.505$) quando comparado com repouso. Da mesma forma foi para o crucifixo, onde na comparação com repouso, nenhuma diferença foi observada nos momentos 1 ($p = 0.849$), 2 ($p = 0.195$) e 3 ($p = 0.105$). No mesmo sentido, nenhuma diferença também não foi observada nas comparações inter condições para repouso ($p > 0.999$), momento 1 ($p = 0.999$), 2 ($p = 0.989$) e 3 ($p = 0.948$). Por fim, o duplo produto nas comparações intra condições foram encontradas diferenças para os momentos 1, 2 e 3 quando comparados com o repouso ($p < 0.000$). Mas, nas comparações inter condições, nenhuma diferença foi observada em repouso ($p = 0.999$), momento 1 ($p = 0.868$), 2 e 3 ($p > 0.999$). Conclusão: Sugere-se que o treinamento resistido composto por exercícios uni e multi articular oferecem diferenças nas respostas hemodinâmicas, porém sem diferenças entres os tipos de mecânicas aplicadas pelos exercícios. Portanto, estes resultados oferecem uma parcialidade do que pode acontecer com a frequência cardíaca, pressão arterial e duplo produto.

Palavras-chave: Treinamento resistido; Biomecânica; Frequência cardíaca; Pressão arterial; Duplo produto.

Resumen

Introducción Diferentes comportamientos mecánicos en el entrenamiento de resistencia pueden resultar en ciertos cambios en el sistema cardiovascular. Objetivo: Verificar el comportamiento agudo de las principales variables cardiovasculares (frecuencia cardíaca, presión arterial y doble producto) en el entrenamiento de resistencia con ejercicios uni y multiarticulares. Métodos: participaron 10 individuos del sexo masculino (26 ± 4 años; 81 ± 6 kg; $1,77 \pm 2$ m; 23 ± 1 kg / m²). Realizaron una prueba y una nueva prueba de 8RM en los ejercicios de press de banca y crucifijo en la máquina. Tras delimitar las cargas, realizaron la intervención con los ejercicios, inicialmente con una activación mioarticular conteniendo 2 series de 12 repeticiones con el 50% de la carga adquirida en el test 8RM de cada ejercicio, utilizando un intervalo de 60 segundos entre una serie y otra. . Además, se realizaron 3 series de 8 repeticiones (80% 8RM) con un intervalo entre series de 120 segundos. La velocidad de ejecución se determinó a un nivel moderado (2 s para concéntrico, 2 s para excéntrico). La frecuencia cardíaca con el modelo POLAR RS800CX Multisport® y la presión arterial con el OMRON M6 (HEM-7001-E)® se midieron antes y durante (serie 1, serie 2 y serie 3. Nombrados como momentos). A continuación, se calculó el producto doble usando la fórmula [HR (lpm) X PAS (mmHg)]. Resultados: En el análisis de la frecuencia cardíaca, hubo una diferencia dentro de las condiciones para los momentos 1, 2 y 3 en comparación con el reposo ($p < 0,000$). En la comparación entre condiciones, no se observaron diferencias para el reposo ($p = 0,994$) y para los momentos 1, 2 y 3 ($p > 0,999$). En la presión arterial sistólica, intracondiciones, se observaron diferencias para los momentos 1, 2 y 3 cuando se comparó con el reposo (p

<0,000). En las comparaciones entre condiciones, no se observaron diferencias entre reposo ($p > 0,999$), momento 1 ($p = 0,714$), 2 ($p = 0,999$) y 3 ($p > 0,999$). Para la presión arterial diastólica, intracondiciones, para press de banca, no se encontraron diferencias significativas para los momentos 1 ($p = 0,331$), 2 ($p = 0,505$) y 3 ($p = 0,505$) al compararlos con el reposo. Lo mismo ocurrió con el crucifijo, donde en comparación con el reposo, no se observó diferencia en los momentos 1 ($p = 0,849$), 2 ($p = 0,195$) y 3 ($p = 0,105$). Del mismo modo, no se observó diferencia en las comparaciones entre las condiciones de reposo ($p > 0,999$), momento 1 ($p = 0,999$), 2 ($p = 0,989$) y 3 ($p = 0,948$). Finalmente, el producto doble en las comparaciones intra-condición se encontraron diferencias para los momentos 1, 2 y 3 en comparación con el reposo ($p < 0,000$). Pero, en las comparaciones entre condiciones, no se observaron diferencias en reposo ($p = 0,999$), momento 1 ($p = 0,868$), 2 y 3 ($p > 0,999$). Conclusión: Se sugiere que el entrenamiento de resistencia consistente en ejercicios uni y multiarticulares ofrece diferencias en las respuestas hemodinámicas, pero sin diferencias entre los tipos de mecánicas aplicadas por los ejercicios. Por lo tanto, estos resultados ofrecen una parcialidad de lo que puede suceder con la frecuencia cardíaca, la presión arterial y el doble producto.

Palabras clave: Entrenamiento de resistencia; Biomecánica; Frecuencia cardíaca; Presión arterial; Producto doble.

1. Introduction

Resistance training (RT) is an important way to intervene in health by improving muscle efficiency (Benito et al., 2020), causing muscle hypertrophy (Schoenfeld et al., 2019), and also enhancing all organic physiology (Amirthalingam, 2017; Vianna et al., 2014). Thus, studies important direct indicators to make the activity more efficient for any individual or group that comes to practice them (ACSM, 2011; Fragala et al., 2019). One of the most explored areas is resistance training, as many people today practice this activity, which has neuromuscular benefits and gains in muscle mass (Gualano & Tinucci, 2011; Terra et al., 2008).

Safety during this type of activity is essential. There are variables that, when measured, can establish a good relationship with the level of health (Fletcher et al., 2018) among these variables, we can highlight those that make up the cardiovascular system as blood pressure (BP) (Farinatti & Assis, 2000), heart rate (HR) (Leite & Farinatti, 2003) and the double product (SD) (Paccini et al., 2007; Polito et al., 2004). It is well established that the regular practice of resistance training leads to a favorable impact on the behavior of blood pressure (Araújo et al., 2018), both in the short and long term, due to a sequence of neurohormonal adjustments such as renin-angiotensin-aldosterone regulation and sites that generate the reduction in cardiac output values and peripheral vascular resistance (Ramos et al., 2019). Blood pressure is one of the most important indicators of cardiovascular health (Sant'Ana et al., 2020).

The observation of only one of these variables does not guarantee a significant level of reliability. However, the association between them can provide information that correlates with myocardial oxygen consumption (Ansari et al., 2012; Sant'Ana et al., 2020). In this case, the double product can be considered as an excellent indicator to assess myocardial work during rest or efforts, being quite efficient to demonstrate cardiac overload (Prisco & Salles, 2014). Double product is a variable closely related to exercise safety, giving parameters regarding the intensity of the exercise and its correlation with the preservation of the individual, thus providing subsidies to define which activities present the greatest risks of cardiac complications (Liborio & Raiol, 2015; Moreira et al., 2018). Reference values dictate that the double product values should not be higher than 30,000 mmHg/bpm (Powers & Howley, 2014).

Regarding the different ways to perform resistance training, few studies related to motor variations are available (Soares & Marchetti, 2013), especially training and cardiovascular functions (Figuroa et al., 2010). Therefore, the objective of the present study was to verify the acute behavior of the leading cardiovascular variables (HR, BP, and DP) when performing resistance training with mono and multiarticular exercises.

2. Methodology

Subjects

The study included ten male volunteers aged between 25 and 35 years (Table 1), practitioners of resistance training for at least six months and at most two years. According to resolution 196/96 of the national health council, all volunteers signed the consent form for experiments on humans. As an inclusion criterion, it was considered that the individual was fit for experimental intervention and without any osteoarticular restriction. On the other hand, existing osteoarticular lesions and the use of drugs to control and balance the cardiovascular system for psychological or neurological treatments or both, among others, were reasons for exclusion from the research. Finally, other factors that could negatively affect the intervention results, such as individuals with morbid obesity and chronic kidney disease, were considered exclusion criteria. The present study met the standards for researching human beings, resolution 196/96 of the National Health Council of 10/10/1996 and the Helsinki Resolution (Saif, 2000). All study participants agreed to sign the informed consent form containing the study objective, assessment procedures, voluntary nature of the subject's participation. In addition, an information term was prepared for the institution where the research was carried out, with the same items as the informed consent form and the filling out of the physical activity readiness questionnaire (PAR-Q). The research project of the present study was submitted to and approved by the Ethics Committee of Estacio de Sá University.

Table 1. Anthropometric characteristics and baseline variables of the participants.

Variables	Participants
	M±SD
Age (years)	26 ± 4
Weight (kg)	81,5 ± 6
Height (m)	1,77 ± 2
BMI (kg/m²)	23 ± 1

Source: Authors.

Experimental design

The present study was carried out through laboratory visits. The first visit was for individuals to sign the informed consent form, PAR-Q, and complete an anamnesis. The second and third visits, 24 hours later, were designated to perform the full load test (8RM) for the bench press and crucifix apparatus, respectively. After completing these tests, a break of 48 hours was given, and again, the tests (retest) were performed (fourth and fifth visits) to analyze the reproducibility of the loads acquired for each device. All conduct procedures for applying the 8RM tests were strictly respected to avoid possible bias in the results. Finally, the sixth and seventh visits were for experimental interventions.

Experimental intervention protocols

Participants performed two experimental conditions, the first (sixth visit) on the bench press and the second (seventh visit) on the crucifix on the machine. As the intervention consisted of only one exercise and the individuals were trained, a 24-hour interval between one session and another was stipulated, with both interventions being performed simultaneously to avoid discrepancies about the time interval and time of day.

The bench press (Technogym®) was performed with the bench at an angle of 180 degrees. The individual assumed the lying position, with the feet positioned on the floor. The individual performed adduction and abduction in the horizontal plane of the shoulder joint and flexion and extension of the elbow joint, returning to the initial position for a new repetition. In the pectoral crucifix (Technogym®), the individual sat in the device (90°), simultaneously performing an abduction and adduction movement of the shoulder joint.

For the exercises, initially, a myoarticular activation was performed with two sets of 12 repetitions with 50% loading acquired in the 8RM test of each exercise, using an interval of 60 seconds between one set and another. Additionally, three sets of 8 repetitions (80% 8RM) were performed with a break between sets of 120 seconds. The execution speed was determined at a moderate level (2 seconds for concentric, 2 seconds for eccentric). During the executions, the participants were monitored by two researchers, and the care with respiratory control (inspiration in the concentric and expiration in the eccentric) was fully requested to avoid the Valsalva maneuver and, thus, not to allow influences on the hemodynamic behavior.

Hemodynamic variables analyze

The hemodynamic evaluation was performed using the resting and exercising heart rate, the resting and exerting systolic and diastolic blood pressure, and finally the double rest and exercise product, this being calculated using the formula [HR (bpm) X SBP (mmHg)] (Ansari et al., 2012). For heart rate and blood pressure measurements, on the day the bench press was performed. The analyzes were performed with the individual lying down and, on the day of the crucifix on the apparatus, the measurements were performed with the individual seated. It is worth mentioning that both positions are plausible for the type of assessment (Schneider et al., 2018).

A POLAR watch, model RS800CX Multisport® (Quintana et al., 2012), was used for the heart rate measurement. And, for the evaluation of blood pressure, the OMRON M6 (HEM-7001- E)® digital device (Topouchian et al., 2006). Both heart rate and blood pressure were measured at rest, with heart rate for five minutes (considering the lowest HR). Blood pressure was measured twice with an interval of 1 minute, before the first execution (moment 1), the second (moment 2), and the third series (moment 3). For these last measurements, heart rate was measured for 1 minute (considering the lowest value), and the blood pressure twice with an interval of 1 minute between one analysis and another. For these assessments (HR and BP), the same researcher was always used to conduct the measurements for all participants.

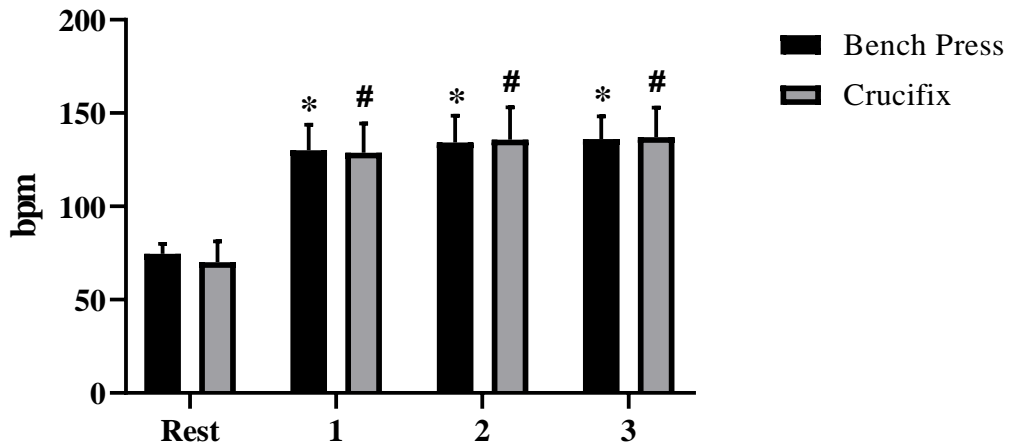
Statistical Analyzes

The Shapiro Wilk test did not reject the normality of the acquired data. The ANOVA (two-way) of repeated measures was applied for intra and inter conditions analysis (bench press and crucifix) at different moments of analysis (rest, 1, 2, and 3). When necessary, Tukey's test for multiple comparisons was applied. All statistical analyzes were performed using the Graph Prism software version 8.0.1, with a significance level of 5% ($p < 0.05$).

3. Results

In the heart rate analysis (Figure 1), a significant intra-condition difference was observed for moments 1, 2, and 3 when compared to rest ($p < 0.000$). In the inter-condition comparison, no differences were observed for rest ($p = 0.994$) and for moments 1, 2 and 3 ($p > 0.999$).

Figure 1. Heart rate behavior in the moment's analyses for bench press and crucifix.



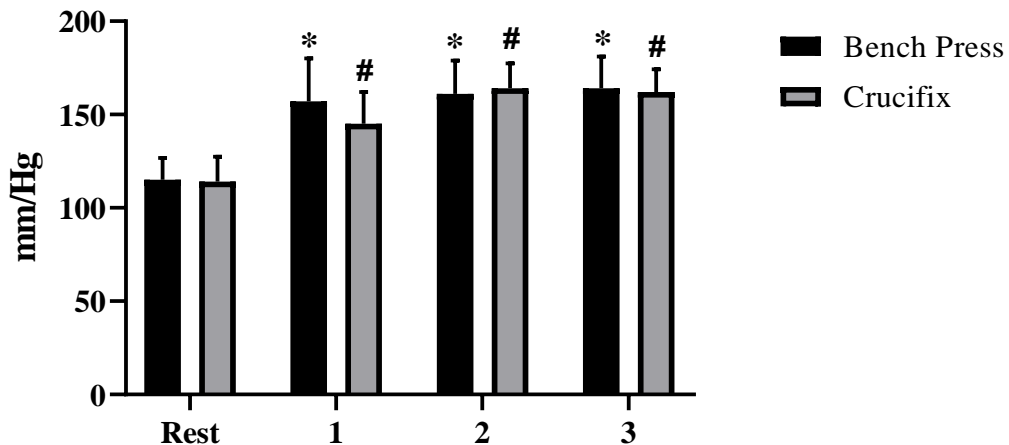
* Significant difference for analyse intra condition, compared with rest ($p < 0.05$).

Significant difference for analyse intra condition, compared with rest ($p < 0.05$).

Source: Authors.

In the systolic blood pressure (SBP) assessment (Figure 2), intra conditions, significant differences were observed for moments 1, 2 and 3 when compared to rest ($p < 0.000$). In the inter-condition comparisons, there were no differences between rest ($p > 0.999$), moment 1 ($p = 0.714$), 2 ($p = 0.999$) and 3 ($p > 0.999$).

Figure 2. Systolic blood pressure behavior in the moment's analyses for bench press and crucifix.



* Significant difference for analyse intra condition, compared with rest ($p < 0.05$).

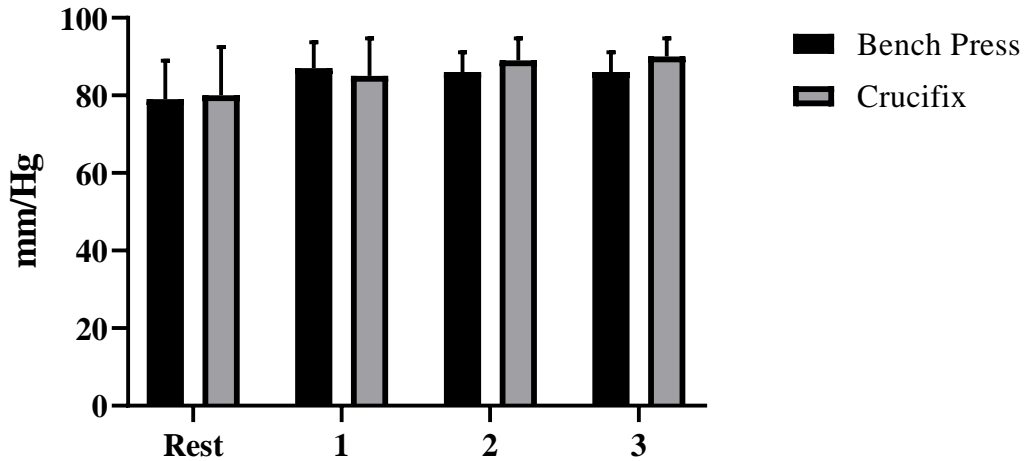
Significant difference for analyse intra condition, compared with rest ($p < 0.05$).

Source: Authors.

For diastolic blood pressure (BPD) in the Figure 3, intra conditions, for bench press no significant differences were found for moments 1 ($p = 0.331$), 2 ($p = 0.505$) and 3 ($p = 0.505$) when compared to rest. In the same way it was for the crucifix, where in the comparison with rest, no difference was observed in moments 1 ($p = 0.849$), 2 ($p = 0.195$) and 3 ($p =$

0.105). In the same sense, no difference was also observed in the comparisons between conditions for rest ($p > 0.999$), moment 1 ($p = 0.999$), 2 ($p = 0.989$) and 3 ($p = 0.948$).

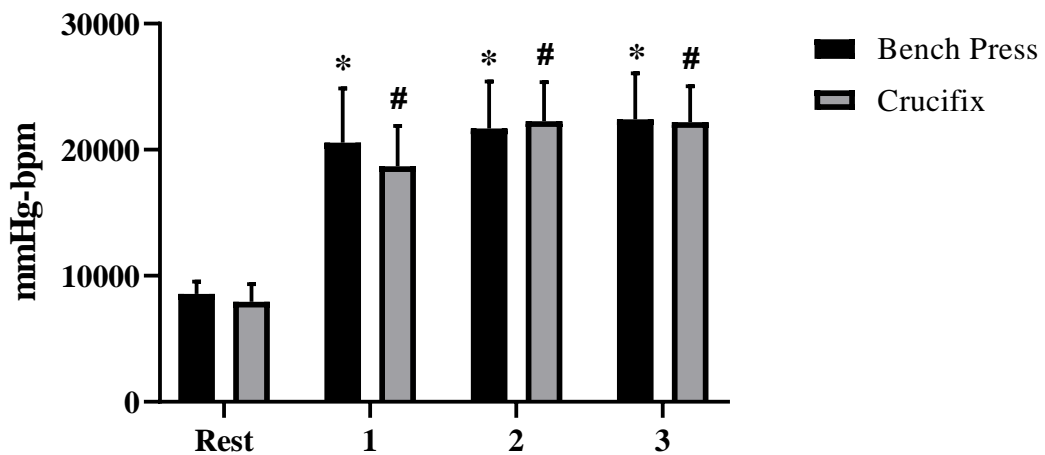
Figure 3. Diastolic blood pressure behavior in the moment's analyses for bench press and crucifix.



Source: Authors.

Finally, the double product as show in the Figure 4 was calculated [HR (bpm) X SBP (mmHg)] and, in intra-condition comparisons, differences were found for moments 1, 2 and 3 when compared to rest ($p < 0.000$). However, in the inter-condition comparisons, no difference was observed at rest ($p = 0.999$), moment 1 ($p = 0.868$), 2 and 3 ($p > 0.999$).

Figure 4. Double product (DP) behavior in the moment's analyses, for bench press and crucifix.



* Significant difference for analyse intra condition, compared with rest ($p < 0.05$).

Significant difference for analyse intra condition, compared with rest ($p < 0.05$).

Source: Authors.

4. Discussion

The present study aimed to investigate the acute hemodynamic responses (HR, SBP, DBP, and DP) in monoarticular (crucifix - chest) and multiarticular (bench press) exercises, using the 8 RM test in men (26 ± 4 years), active in resistance training. The hypothesis was that the intervention with multiarticular exercise would allow greater responsiveness of the analyzed hemodynamic variables when compared with the mono joint exercise for the same muscle group, this being the pectoral. This theoretical assumption was based on the principle that physiological responses would be more reactive in multiarticular actions due to the fact of two main factors, one due to the mechanical action interfering more gradually in the mechanoreceptors and the other due to the request for greater muscular territory, which would consequently result in greater hemodynamic response.

However, the findings demonstrated that the mono-articular and multiarticular exercises used in the present study interfered similarly in the cardiovascular responses, which were evaluated through HR, BP (systolic and diastolic), and DP. For HR, significant differences were observed for moments 1 (before the first series), 2 (before the second series), and 3 (before the third series) when compared to rest ($p < 0.000$). On the other hand, in the inter-condition comparisons, no difference was found ($p > 0.05$). In the assessment of BP, for SBP in intra-condition comparisons, there was a significant difference for moments 1, 2, and 3 compared to rest ($p < 0.000$). Regarding the inter-condition analyzes, no significant difference was observed ($p > 0.05$). For BPD, both intra and inter conditions, no difference was found ($p > 0.05$). Completing the hemodynamic evaluations, in the DP analysis, differences were observed for moments 1, 2, and 3 for both conditions when compared to rest ($p < 0.000$), but for inter condition comparisons, no difference was found ($p > 0.05$).

The scarcity of studies related to the theme of the present study makes discussions about our findings more restricted. Del Antonio and Assis, (2017) verified the hemodynamic behavior using intervention in an isokinetic device (knee extension and flexion) in adults and the elderly. They identified higher SBP, SD, and HR after activity but with greater significance for the elderly. ($p < 0.05$). PD is an important indicator of cardiovascular overload (Sant'Ana et al., 2020), and, therefore, its evaluation is essential for the midst of a training program. Domka-Jopek et al. (2018) evaluated 412 patients hospitalized for some cardiac dysfunction and, through a walk test, analyzed cardiovascular behavior through PD. They concluded that PD, using the walk test to assess individual inactivity, can be an important parameter for measuring the efficiency of the cardiac muscle (myocardium).

In resistance training, studies performed training interventions with tension and metabolic characteristics. Raiol et al. (2018) evaluated ten women using the 45° leg press exercises, the extensor chair, and the flexor chair found higher SD values in the 45° leg press exercises and the extensor chair in training tension characteristics ($p = 0.004$). Regarding BP, concerning systolic behavior, the values were significantly lower when exercising with an extension chair in training with tension characteristics ($p = 0.005$), and for the diastolic response, higher values were found when performing the 45° leg press exercise. Also, in training with tension characteristics. For HR, the exciting thing was that the importance of this variable was higher in training with metabolic factors ($p = 0.041$). Another study considering metabolic and tension training characteristics identified lower SD values for the leg press exercise with tension characteristics and higher values ($p < 0.05$) of this variable for the bench press exercise with metabolic traits in normotensive men (Zaniz et al., 2008).

Another study, however very limited (performed the intervention with only 4 individuals), evaluated the hemodynamic behavior in resistance training composed of four exercises (pectoral flying, pull-up front pulley, leg press 45° , and chair extension). The objective was to assess HR, BP (systolic and diastolic), and DP by performing the exercises at different speeds. They demonstrated a higher HR ($p < 0.05$) in the activities with a lower rate and higher values of the SBP and SD ($p < 0.05$) when the exercises were performed with more incredible speed (Santos et al., 2010). Our findings demonstrate a greater response for both movements (bench press and chest crucifix) for HR, PAS, and DP, as observed by Zaniz et al. (2008)

for the bench press exercise and by Santos et al. (2010) for FC, PAS and DP in a workout with pectoral joint action, but with different mechanics (pectoral flying). However, the present study used a protocol with a tension characteristic (3 x 8 repetitions with 80% of the 8 RM), with 2 seconds for the concentric phase and 2 seconds for the eccentric phase.

The related studies do not discuss possible mechanisms on the hemodynamic responses obtained in the face of the intervention with resistance training. But it is speculated that resistance training and aerobic training also stimulate hormonal actions related to renin-angiotensin, whose primary function is regulating blood pressure through baroreflex behavior (Sant'Ana et al., 2020). Changes in capillary density, endothelial function, and oxygen supply are also factors that can interfere with hemodynamic reactions during exercise (Adamson et al., 2019; Nemoto et al., 2007), but the physiological magnitude of these variables is not known for the intervention of resistance training. Another question is about the modulation (release and reuptake) of calcium (CA^{+}) in the cardiomyocyte, and this mechanism promotes cardiac efficiency, facilitating the entry and exit of blood in the heart (Sant'Ana et al., 2021). We can speculate that resistance training, because of its characteristic, offers greater tension on the blood vessels (arteries and veins) due to the contractile work, and with that, it affects greater peripheral resistance and arterial compliance, directly affecting cardiovascular responses.

The present study has some limitations and, therefore, it is worth mentioning that the results found may have been influenced by some methodological peculiarities. BP measurement during exercise is a limiting factor to the technique applied, and this situation has already been mentioned in other studies (Polito et al., 2003). The number of exercises used in the present study (two movements) also offers a limiting issue since, in practice, training with only two exercises is not prescribed. But here, we had the objective of evaluating the hemodynamic response in two exercises for the same muscle group with different mechanical actions (mono and multi-joint), thus offering parameters on the cardiovascular physiological behavior in an acute condition. The sample of the present study can also be considered a limitation ($n = 10$). However, there is a vast difficulty in selecting individuals of the researched modality (resistance training) for interventional performance. Finally, the number of existing studies on the theme presented can also be considered a limitation due to the restriction of discussions regarding the answers found here.

5. Conclusion

The present study's findings suggest that resistance training composed of mono- and multi-joint exercises offer differences in hemodynamic responses but without differences between the mechanics applied by the movements. Therefore, these results partially compare what can happen with heart rate, blood pressure, and double product. Consequently, it is suggested that more studies be carried out in this line of research, which is so essential to be considered in the training prescription. And with that, we have more information and indicators about the cardiovascular reaction under resistance training intervention.

Acknowledgments

Federal University of Juiz de Fora, Minas Gerais, Brazil. For the scholarship to the researcher and Ph.D. student in Physical Education Leandro de Oliveira Sant'Ana.

References

- ACSM. (2011). Quantity and Quality of Exercise for Developing and Maintaining Neuromotor Fitness in Apparently Healthy Adults: Guidance for Prescribing Exercise. *Med Sci Sports Exerc*, 1334–1359. <https://doi.org/10.1249/MSS.0b013e318213fefb>
- Adamson, S., Kavaliuskas, M., Yamagishi, T., Phillips, S., Lorimer, R., & Babraj, J. (2019). Extremely short duration sprint interval training improves vascular health in older adults. *Sport Sciences for Health*, 15(1), 123–131. <https://doi.org/10.1007/s11332-018-0498-2>

- Amirthalingam, T. (2017). *Effects of a Modified German Volume Training Program on Muscular Hypertrophy and Strength*. 31(11), 3109–3119.
- Ansari, M., Javadi, H., Pourbehi, M., Mogharrabi, M., Rayzan, M., Semnani, S., Jallatat, S., Amini, A., Abbaszadeh, M., Barekat, M., Nabipour, I., & Assadi, M. (2012). The association of rate pressure product (RPP) and myocardial perfusion imaging (MPI) findings: a preliminary study. *Perfusion*, 27(3), 207–213.
- Araújo, G. S., Behm, D. G., Monteiro, E. R., Fiuza, A. G. F. M., Gomes, T. M., Vianna, J. M., Reis, M. S., & Novaes, J. S. (2018). Order Effect of Resistance and Stretching Exercises on Heart Rate Variability and Blood Pressure in Healthy Adults. *J Strength Cond Res*, 33(10), 2684–2693.
- Benito, P. J., Cupeiro, R., Ramos-Campo, D. J., Alcaraz, P. E., & Rubio-Arias, J. A. (2020). A systematic review with meta-analysis of the effect of resistance training on whole-body muscle growth in healthy adult males. *International Journal of Environmental Research and Public Health*, 17(4), 1–27. <https://doi.org/10.3390/ijerph17041285>
- Del Antonio, T. T., & Assis, M. R. (2017). Duplo-produto e variação da frequência cardíaca após esforço isocinético em adultos e idosos. *Revista Brasileira de Medicina Do Esporte*, 23(5), 394–398. <https://doi.org/10.1590/1517-869220172305165363>
- Domka-Jopek, E., Jopek, A., Bejer, A., Lenart-Domka, E., & Walawski, G. (2018). The Importance of the Double Product in the Six-Minute Walk Test to Predict Myocardial Function. *BioMed Research International*, 2018. <https://doi.org/10.1155/2018/3082690>
- Farinatti, P. T. V., & Assis, B. F. C. B. (2000). *Estudo Da Frequência Cardíaca, Pressão Arterial E Duplo-Produto Em Exercícios Contra-Resistência E Aeróbio Contínuo* (Vol. 5, Issue 2, pp. 5–16). <https://doi.org/10.12820/rbafs.v.5n2p5-16>
- Figueroa, A., Hooshmand, S., Figueroa, M., & Bada, A. M. (2010). Cardiovascular baroreflex and aortic hemodynamic responses to isometric exercise and post-exercise muscle ischemia in resistance trained men. *Scandinavian Journal of Medicine and Science in Sports*, 20(2), 305–309. <https://doi.org/10.1111/j.1600-0838.2009.00927.x>
- Fletcher, G. F., Landolfo, C., Niebauer, J., Ozemek, C., Arena, R., & Lavie, C. J. (2018). Promoting Physical Activity and Exercise. *Journal of the American College of Cardiology*, 72(14), 1622–1639. <https://doi.org/10.1016/j.jacc.2018.08.2141>
- Fragala, M. S., Cadore, E. L., Dorgo, S., Izquierdo, M., Kraemer, W. J., Peterson, M. D., & Ryan, E. D. (2019). Resistance Training for Older Adults : Position Statement From the National Strength and Conditioning Association. *J Strength Cond Res*, 33(8), 2019–2052.
- Gualano, B., & Tinucci, T. (2011). Sedentarismo, exercício físico e doenças crônicas. *Revista Brasileira de Educação Física e Esporte*, 25(spe), 37–43. <https://doi.org/10.1590/s1807-55092011000500005>
- Leite, T. C., & Farinatti, P. T. V. (2003). Estudo da Frequência Cardíaca, Pressão Arterial e Duplo Produto em Exercícios Resistidos Diversos para Grupos Musculares Semelhantes. *Rev Bras Fisiol Exerc*, 2, 29–49.
- Liborio, H. B., & Raiol, R. A. (2015). Comportamento do Duplo Produto em Três Diferentes Exercícios Resistidos em Mulheres Normotensas. *RESC*, 5(2), 4–13.
- Moreira, S. O., Assis, A. P., Alves, V. H. S., Marcellini, P. S., & Silva, R. F. A. (2018). variação do Duplo Produto em Pacientes Pós Infarto Agudo do Miocárdio Submetidos ao Banho de Aspersão. *Rev. Pesq. Cuid. Fundam.*, 10(4), 1020–1025.
- Nemoto, K., Gen-n, H., Masuki, S., Okazaki, K., & Nose, H. (2007). Effects of High-Intensity Interval Walking Training on Physical Fitness and Blood Pressure in Middle-Aged and Older People. *Mayo Clin Proc*, 82(July), 803–811. <https://doi.org/10.4065/82.7.803>
- Paccini, M. K., Cyrino, E. S., & Glaner, M. F. (2007). Efeito De Exercícios Contra-Resistência na Postura De Mulheres. *Journal of Physical Education*, 18(2), 169–175. <https://doi.org/10.4025/reveducfisv18n2p169-175>
- Polito, M. D., Simão, R., Nóbrega, A. C. L., & Farinatti, P. T. V. (2004). Pressão Arterial, Frequência Cardíaca e Duplo Produto em Séries Sucessivas do Exercício de Força com Diferentes Intervalos de Recuperação. *Rev. Port. Ciências Desp.*, 4, 7–15.
- Polito, M. D., Simão, R., Senna, G. W., & Farinatti, P. T. V. (2003). Hypotensive effects of resistance exercises performed at different intensities and same work volumes. *Revista Brasileira de Medicina Do Esporte*, 9(2), 74–77. <https://doi.org/10.1590/s1517-86922003000200003>
- Powers, S. K., & Howley, E. T. (2014). *Fisiologia do Exercício: Teoria e Aplicação ao Condicionamento e ao Desempenho* (Manole (ed.); 8°).
- Prisco, L. F. N., & Salles, P. G. (2014). Respostas Agudas da Pressão Arterial , Frequência Cardíaca e Duplo Produto Após uma Sessão de Exercícios Resistidos. *Col Pesq Educ Fisica*, 13(3), 123–130.
- Quintana, D. S., Heathers, J. A., & Kemp, A. H. (2012). On the validity of using the Polar RS800 heart rate monitor for heart rate variability research. *European Journal of Applied Physiology*, 112(2), 4179–4180.
- Raiol, H. L., Barbalho, M., Almeida, I. C. T. S., & Raiol, R. (2018). Respostas Cardiovasculares Agudas ao Treinamento Resistido em Sessões de Treino com Características Tensionais e Metabólicas. *Rev Bras Presc Fisiol Exerc*, 12(80), 1101–1107.
- Ramos, A. M., Senna, G. W., Scudese, E., Dantas, E. H. M., Silva-Grigoletto, M. E., Fuqua, J. D., & Pardon, E. (2019). Cardiovascular and strength adaptations in concurrent training in hypertensive women. *Revista Brasileira de Medicina Do Esporte*, 25(5), 367–371. <https://doi.org/10.1590/1517-869220192505200493>
- Saif, M. (2000). World medical association declaration of Helsinki: Ethical principles for medical research involving human subjects. *Jama*, 284, 3043–3045.
- Sant' Ana, L. O., Machado, S., Ribeiro, A. A. S., Reis, N. R., Campos, Y. A. C., Silva, J. G. V., Scartoni, F. R., Brown, A. F., Monteiro, E. R., Novaes, J. S., Vianna, J. M., & Budde, H. (2020). Effects of Cardiovascular Interval Training in Healthy Elderly Subjects: A Systematic Review. *Frontiers in Physiology*, 11(July), 1–10. <https://doi.org/10.3389/fphys.2020.00739>

- Sant'Ana, L. O., Scartoni, F. R., Cruz, T. M., Ribeiro, A. A. S., Reis, N. R., Silva, J. G. V., Campos, Y. A. C., Araújo, G. S., Monteiro, E. R., Machado, S., Castro, A. P., Novaes, J. S., & Vianna, J. M. (2021). Acute Effects of Different Sprint Intervals on Blood Pressure, Heart Rate Variability, Lactate and Performance Responses in Physically Active Men. *The Open Sports Sciences Journal*, 14, 3–13. <https://doi.org/10.2174/1875399X0201401>
- Sant'Ana, L. O., Vianna, J. M., Reis, N. R., Ribeiro, A. A. S., Soares, B. O., Novaes, J. S., Scartoni, F. R., & Machado, S. (2020). Eight Weeks of Interval Training Led to no Improvement in Cardiovascular Variables in the Elderly. *The Open Sports Sciences Journal*, 13, 73–80. <https://doi.org/10.2174/1875399X02013010073>
- Santos, E. P., Costa, J. C. C. P., Silva, W. C., Navarro, A. C., & Silva, A. S. (2010). Duplo Produto em Exercícios de Força Realizados em Duas Velocidades Diferentes. *Rev Bras Presc Fisiol Exerc*, 4(21), 252–256.
- Schneider, C., Hanakam, F., Wiewelhoe, T., Döweling, A., Kellmann, M., Meyer, T., Pfeiffer, M., & Ferrauti, A. (2018). Heart Rate Monitoring in Team Sports — A Conceptual Framework for Contextualizing Heart Rate Measures for Training and Recovery Prescription. *Frontiers in Physiology*, 9(639), 1–19. <https://doi.org/10.3389/fphys.2018.00639>
- Schoenfeld, B. J., Contreras, B., Krieger, J., Grgic, J., Delcastillo, K., Belliard, R., & Alto, A. (2019). Resistance Training Volume Enhances Muscle Hypertrophy but Not Strength in Trained Men. In *Medicine and Science in Sports and Exercise* (Vol. 51, Issue 1). <https://doi.org/10.1249/MSS.0000000000001764>
- Soares, E. G., & Marchetti, P. H. (2013). Efeito Da Ordem Dos Exercícios No Treinamento De Força. *Centro de Pesquisas Avançadas Em Qualidade de Vida*, 5(3).
- Terra, D. F., Mota, M. R., Rabelo, H. T., Bezerra, L. M. A., Lima, R. M., Ribeiro, A. G., Vinhal, P. H., Dias, R. M. R., & Silva, F. M. (2008). Redução da pressão arterial e do duplo produto de repouso após treinamento resistido em idosos hipertensas. *Arquivos Brasileiros de Cardiologia*, 91(5), 299–305. <https://doi.org/10.1590/S0066-782X2008001700003>
- Topouchian, J. A., El Assaad, M. A., Orobinskaia, L. V., El Feghali, R. N., & Asmar, R. G. (2006). Validation of two automatic devices for self-measurement of blood pressure according to the International Protocol of the European Society of Hypertension : the Omron M6 (HEM-7001-E) and the Omron R7 (HEM 637-IT). *Blood Pressure Monitoring*, 6, 165–171.
- Vianna, J. M., Werneck, F. Z., Coelho, E. F., Damasceno, V. O., & Reis, V. M. (2014). Oxygen uptake and heart rate kinetics after different types of resistance exercise. *Journal of Human Kinetics*, 42(1), 235–244. <https://doi.org/10.2478/hukin-2014-0077>
- Zaniz, F. L., Lima, E., Parente Junior, E. V., Frota, P. B., Gonçalves, C. B. H., & Moraes, M. R. (2008). Análise do duplo produto no treinamento de força em séries com características metabólicas e tensionais. *Rev Bras Presc Fisiol Exerc*, 2(7), 55–58.