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Are there differences in auscultatory pulse in total blood flow restriction between positions, limbs and body segments?

Existem diferenças no pulso auscultatório da restrição total de fluxo sanguíneo entre as posições, membros e segmentos corporais?

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Abstract – Verification of the auscultatory pulse in total blood flow restriction (BFR) has been a limiting factor in studies due to the way in which it is evaluated and prescribed, as hemodynamic measurements can be directly affected by gravity. The aim of the present study was to compare the auscultatory pulse in BFR between positions, genders, limbs and body segments in healthy young individuals. A total of 156 subjects participated in the study, 76 of whom were male and 80 of whom were female (23.9±3.7 years, 66.5±11.5 kg, 1.67±0.07 m). After filling in registration data, anthropometry was evaluated, and BFR pressure was determined. BFR was evaluated in a randomized manner in both limbs (upper and lower) and in both segments (right and left) in the following positions: a) lying in the supine position; B) sitting with knees and trunk at 90°; and c) standing in the anatomical position. Significant differences were observed between the lying, sitting and standing positions ($p<0.05$), between genders ($p<0.05$), between limbs ($p<0.05$) and between the right and left segments in the lower limb in both genders [males ($p=0.014$) and females ($p=0.009$)] in the lying position. However, no significant differences were observed between the right and left segments in the upper limbs ($p>0.05$). The BFR point appears to differ between positions, genders, lower limbs and segments. Therefore, it is recommended that health professionals should check the BFR point in the position relating to the exercise that will be performed, taking into account gender, lower limbs and body segments.

Key words: Arterial pressure; Hemodynamics; Ischemia; Therapeutic occlusion.

Resumo – *A verificação do pulso auscultatório da restrição de fluxo sanguíneo (RFS) total tem sido fator limitante dos estudos devido à forma de avaliação e prescrição, já que as medidas hemodinâmicas podem sofrer influência direta da gravidade. O objetivo do presente estudo foi comparar o pulso auscultatório da RFS entre as posições, sexo, membros e segmentos corporais em jovens saudáveis. Participaram do estudo 156 sujeitos, sendo 76 homens e 80 mulheres (23,9±3,7 anos, 66,5±11,5 kg, 1,67±0,07 m). Após o preenchimento da ficha cadastral, foram avaliadas a antropometria e em seguida houve a determinação da pressão de RFS. A RFS foi avaliada de forma randomizada em ambos os membros (superiores e inferiores) e ambos os segmentos (direito e esquerdo) nas posições: a) deitada em decúbito dorsal; b) sentada com joelhos e tronco em 90°; e c) em pé na posição anatômica. Observaram-se diferenças significativas entre as posições deitado, sentado e em pé (p<0,05), entre os sexos (p<0,05), entre os membros (p<0,05) e entre os segmentos direito vs. esquerdo no membro inferior em ambos os sexos [homem (p=0,014) e mulher (p=0,009)] na posição deitada. Entretanto, observou-se não existir diferenças significativas entre os segmentos direito vs. esquerdo no membro superior (p>0,05). O ponto da RFS parece diferir entre as posições, sexo, membros inferiores e segmentos. Portanto, recomenda-se que os profissionais da área da saúde devam verificar o ponto da RFS na posição referente ao exercício que será realizado, levando em consideração o sexo, membros inferiores e segmentos corporais.*

Palavras-chave: *Hemodinâmica; Isquemia; Oclusão terapêutica; Pressão arterial.*

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INTRODUCTION

The practice of physical exercise has increased in recent decades due to its promotion as a way of improving quality of life and health[1]. In this regard, several guidelines have been developed on the premise of perfecting physical exercise prescription[1,2]. In regard to resistance exercise prescription, muscle strength and hypertrophy have been cited as perfecting in improving quality of life and health[1]. To increase these physical strengths, the American College of Sports Medicine recommends that loads of 65% or greater of one maximum repetition (1RM)[2] should be used. However, resistance[3] or aerobic[4] exercise combined with blood flow restriction (BFR) has been used to increase muscle strength and hypertrophy. The main characteristic of this training method is the use of cuffs or elastic bands with a combination of low load percentages (20-30% of 1RM), which allows such increases without promoting high mechanical stress[5]. This approach can offer an excellent intervention option for populations that do not tolerate high loads[6].

Scientific evidence has shown the importance of low-load training with BFR in increasing muscle strength[3,7], muscle hypertrophy[3,7], localized muscle resistance[8] and functional capacity[9]. In addition, it has been demonstrated that this method is safe in relation to hemodynamics[10,11]. However, the use of this technique when using high intensities does not seem to be effective in increasing muscle strength and mass[12] and in the acute performance of muscle strength immediately after exercise[13].

In this regard, studies have been developed to improve the application of this training method, analyzing factors such as cuff size[14], pressure used[15] and form of BFR application (continuous or intermittent)[10,16]. Additionally, a safe and effective form, considered to be the good alternative for evaluating the BFR point and prescribing the pressure to be used in training, is the technique proposed in Laurentino et al.[3]. This procedure consists of BFR verification by means of a vascular Doppler, with the individual lying in the supine position[3, 8, 11]. However, the vast majority of exercises are performed in different positions (sitting or standing), and because gravitational force causes direct variations in hemodynamics when the individual changes his position[17], establishing the BFR point in a lying position is a limiting factor when proposing the performance of exercises in other positions. Therefore, this manuscript is of great importance, as it overcomes the limitations mentioned in several studies that verified BFR in the lying position but that used exercises in different positions[3,8,9]. These findings demonstrate the importance of establishing the BFR point for the position in which the exercise will be performed. In addition, there is no scientific evidence regarding the difference in BFR point measurement between limbs and body segments.

Knowing whether there are any differences between positions, sexes, limbs and segments will be of fundamental importance for professionals working with this training method, as it will serve as a way to assist in the BFR point prescription safety procedures. Therefore, we hypothesize that there would be significant differences between positions, sexes and limbs but that there would be no significant differences between segments. Thus, the aim of this study was to compare the BFR point between positions (lying down, sitting and standing), sexes (male and female), limbs (upper and lower) and segments (right and left) in healthy young people.

METHODOLOGICAL PROCEDURES

Subjects

A total of 156 healthy subjects participated voluntarily in this study: 76 men and 80 women (Table 1). The sample calculation was performed using G*Power 3.1 software[18], based on the procedures suggested by Beck[19]. Based on an *a priori* analysis, an N of 73 participants was calculated, having adopted a power of 0.80, an $\alpha = 0.05$, a correlation coefficient of 0.5, a nonsphericity correction of 1 and an effect size of 0.15. It was found that 73 subjects would be sufficient to provide 80.0% of the statistical power. As the study ended with 156 subjects, the *post hoc* analysis showed that the sample size was sufficient to provide 98.8% statistical power.

Participants who were apparently healthy and between 18 and 35 years of age were included in the study. And people with hypertension or history of cardiovascular disease were excluded. After the risks and benefits of the study were explained, the participants signed terms of free and informed consent, prepared in accordance with the Declaration of Helsinki. The study was approved by the Federal University of Paraíba Research Ethics Committee (protocol number 0476/13).

Table 1. Participant characteristics

	Male (n = 76)	Female (n = 80)	Total (n = 156)
Age (years)	24.9±3.9	23.0±3.2	23.9±3.7
BM (kg)	73.8±10.4	59.6±7.6	66.5±11.5
Height (m)	1.73±0.07	1.63±0.04	1.67±0.07
BMI (kg/m^2)	24.5±2.3	22.3±2.5	23.4±2.7

Note. BM = Body mass; BMI = Body mass index.

Study design

Participants attended the laboratory on only one occasion, in which they signed a registration form. Anthropometry was then evaluated and the BFR point determined. BFR was performed on both limbs (upper and lower) and both segments (right and left) in one of the following positions, randomly selected for each participant (crossover): a) lying in the supine position; b) sitting with knees and trunk at 90°; and c) standing in the anatomical position. At first contact, prior to the laboratory visit, participants were instructed to avoid exercising for 12 hours and to avoid caffeine, chocolate, nutritional supplements and alcohol before the evaluations.

Anthropometric evaluation

An electronic scale (Soehnle® Professional 7755) with 100 g of precision was used to obtain body mass (kg). A portable wooden stadiometer (Cardiomed, WCS-WOOD COMPACT - 2010 Curitiba, PR, Brazil) with an accuracy of 0.05 mm was used for height (m). Body mass index (BMI) was calculated by dividing body mass by the square of the height (kg/m^2).

Description of the positions

Lying position: The participant lay in a supine position, with legs and arms extended and supported on the stretcher. He/she then stood erect with his/her face and eyes facing forward, upper limbs extended to the side of the trunk and with palms facing forward, lower limbs parallel, with the toes facing forward.

Sitting position: The participant was seated with the angles of the hips, trunk, knees and ankles kept at 90º, and his/her body weight was transferred to the seat of the chair by means of the ischial tuberosity, with the feet resting on the ground and parallel.

Standing position: The participant stood erect with his/her face and eyes facing forward, upper limbs extended to the side of the trunk and with palms facing forward, lower limbs parallel, with the toes facing forward.

Determination of the BFR point

Total BFR was obtained by vascular Doppler (MedPeg® DV -2001, Ribeirão Preto, SP, Brazil). The probe was positioned over the radial artery to determine the BFR points of both upper limbs and on the dorsalis pedis artery to determine the BFR points of both lower limbs. For the upper limbs, a standard sphygmomanometer (Riester Komprimeter pneumatic tourniquet for hemostasis in extremities) was used for both arms (width 60 mm) and was fixed around the most proximal portion and inflated to the point where the auscultatory pulse of the radial artery was interrupted. For the lower limbs, a standard blood pressure sphygmomanometer (Riester Komprimeter pneumatic tourniquet for hemostasis in extremities) was used for both legs (width 100 mm) and was fixed in the most proximal region and inflated to the point where the auscultatory pulse of the dorsalis pedis artery was interrupted[3].

These procedures were performed by only one experienced evaluator, on the same person, under three conditions randomly (crossover): 1) lying supine; 2) sitting with knees and trunk at 90°; and 3) standing in the anatomical position. After anthropometric evaluation, the subjects rested for 10 minutes in the allotted position. The BFR point evaluation procedure then began. The BFR evaluations in the three positions were performed initially for the right and left arms and right and left legs, respectively.

Statistical analysis

The data were analyzed using version 20 of the Statistical Package for Social Sciences (SPSS). Initially, an exploratory analysis was performed to verify normality (Kolmogorov-Smirnov test). In all variables the assumption of normality was rejected ($p < 0.05$), thus, Kruskal-Wallis ANOVA was used to compare the positions. The Mann-Whitney test was then used to find the significant differences between positions, sex and body limbs, and the Wilcoxon test was performed for comparisons of segments (right *vs.* left). Data are presented as means and standard deviations. The significance level adopted was $p < 0.05$.

RESULTS

In the comparative analysis of BFR points between upper limb positions, higher values were observed in the sitting position when compared to the lying position only for the right segment in both males ($p = 0.008$) and females ($p = 0.041$). There were higher values in the standing position when compared to the lying position in both the right and left segments in females ($p = 0.001$, $p = 0.001$, respectively). There were also higher values in the standing position when compared to the position lying in the left segment for females ($p = 0.040$). For the lower limbs, higher values were observed in the sitting position when compared to the lying position in both segments, right and left, in both males ($p < 0.001$, $p < 0.001$, respectively) and females ($p < 0.001$, $p < 0.001$, respectively). It was also observed that regarding the lower limb, there were higher values in the standing position when compared with the lying position in both segments, right and left, in both males ($p < 0.001$, $p < 0.001$, respectively) and females ($p < 0.001$, $p < 0.001$, respectively). It was also observed that there were higher values in the standing position when compared to the sitting position in both segments, right and left, in both males ($p < 0.001$, $p < 0.001$, respectively) and females ($p < 0.001$, $p < 0.001$, respectively), as shown in Table 2.

In the comparative analysis of BFR points between sexes in the lying position, higher values were found in men when compared to women in both segments, right and left, in the upper limbs ($p < 0.001$; $p < 0.001$, respectively). It was also observed that between the sexes in the sitting position, there were higher values in men when compared to women in both segments, right and left, in the upper limbs ($p < 0.001$, $p < 0.001$, respectively) and in the lower limbs ($p < 0.001$, $p < 0.001$, respectively). For the standing position, there were higher values in men when compared with women in both segments, right and left ($p < 0.001$; $p < 0.001$, respectively), as shown in Table 2.

In the comparative analysis of BFR points between the limbs in the lying position, the lower limbs showed higher values when compared with the upper limbs in both segments, right and left, in males ($p = 0.019$, $p < 0.001$, respectively) and in females ($p < 0.001$, $p < 0.001$, respectively). It was also observed that between the limbs in the sitting position, there were higher values for the lower limbs when compared with the upper limbs in both segments, right and left, in males ($p < 0.001$, $p < 0.001$, respectively) and in females ($p < 0.001$, $p < 0.001$, respectively). It was also observed that among the limbs in the standing position, there were higher values in the lower limbs when compared with the limbs in both segments, right and left, in males ($p < 0.001$, $p < 0.001$, respectively) and in females ($p <$

0.001, p < 0.001, respectively), as shown in Table 2.

In the comparative analysis of BFR points between segments, higher values were observed in the left segment when compared to the right in both sexes [male (p = 0.014) and female (p = 0.009)], but only in the lying position (Table 2).

Table 2. Comparative analysis of BFR points between lying, sitting and standing positions between sexes, limbs and body segments

	Lying		Sitting		Standing	
	Upper	Lower	Upper	Lower	Upper	Lower
Right Segment						
Male	125.1±14.7§	133.0±19.8£	131.3±12.7†§	157.1±19.1†§£	127.7±16.7	181.9±22.0‡*§£
Female	116.3±16.1	132.2±14.0£	120.8±15.6†	143.2±20.2†£	124.1±13.9‡	165.0±20.6‡*£
Left Segment						
Male	126.3±12.4§	135.9±18.2£¥	130.1±17.2§	159.4±16.4†§£	128.2±16.3	182.5±24.1‡*§£
Female	117.3±14.0	134.7±16.8£¥	119.7±15.0	145.8±18.4†£	124.7±12.9‡*	166.2±20.7‡*£

Note. † significant difference between lying and sitting positions; ‡ significant difference between lying and standing positions; * significant difference between sitting and standing positions; § significant difference between sexes (male *vs*. female); £ significant difference between limbs (upper *vs*. lower); ¥ significant difference between segments (right *vs.* left).

DISCUSSION

The present study compared the BFR points between positions (lying down, sitting and standing), sex (male and female), limbs (upper and lower) and segments (right and left) in healthy young people. To our knowledge, this study was the first to verify the BFR points in different positions considering sex, limbs and body segments in an attempt to improve BFR prescription quality for strength and aerobic training. Furthermore, the results of this manuscript will overcome the limitations already mentioned in several studies, that is, BFR being verified only in the lying position, thereby allowing prescriptions for exercises in different positions[3,7-9,11]. The main findings of the present study were I) there were differences in the BFR points between positions, sexes and limbs (upper and lower); and II) there were no differences in the evaluation of BFR points in the upper limbs (right and left), but there were in the lower limbs.

Although no study has compared the differences in BFR points between positions, sex, limbs and segments, Nakajima et al. study[20] compared hemodynamic responses between the head-down tilt (real simulation for astronauts) and the sitting position, with application of the BFR in the lower segment. These authors concluded that the effects of permanence in hemodynamic measures after the use of BFR appear to promote a similar stress only in the upside-down position and may be useful for astronaut training. Lida et al.[21] also corroborated the information that BFR may act as a potential strategy in promoting hemodynamic changes in a similar way in the lying position with the application of BFR and in the standing position. These two studies are not directly related to the objective of the present study; however, they do show the importance of evaluating BFR in different positions.

In this regard, when reviewing the literature, it is apparent that several studies to date have evaluated BFR points in the supine position on the upper limbs[11,22] and the lower limbs[3, 7-9,11, 22], even though they used exercises that were applied in different positions. In this regard, when analyzing those studies' methodologies, it can be seen that the BFR prescription is a limiting factor, as there were differences in the present study's results between positions, limbs and segments. These variations in BFR point values may be related to gravitational force, which causes variations when the individual changes his position[17]. Therefore, exercise position should be considered as an individual factor for BFR verification. Additionally, it should be noted that this difference in BFR pressure level, determined for each type of exercise, can directly affect gains in a particular ability being trained. This effect may be due to increased discomfort and subjective perception of exertion, which leads to a reduction in training volume, as greater pressure causes more discomfort[23,24]; therefore, the total training workload may be directly affected[24].

In this context, in the lower limbs, the BFR point was higher in the standing position than in the lying position, with differences of 48.9 mmHg in men and 32.8 mmHg in women in the right segment. These differences also occurred in the left segment. This pressure variation may be a determining factor in training volume, which may generate consequences for physical strength capacities, hypertrophy and muscular resistance. These data partially corroborate the findings of a study by Miranda et al.[25], who observed that there were no significant differences in hemodynamic measurements after performing a supine exercise in the lying and sitting positions, but the mean values were lower for the lying position. As a recommendation, Miranda et al.[25] suggested that studies should aim to analyze different body positions to guide procedures for the prescription of exercises. Upon analyzing this recommendation, it is observed that this guidance is for traditional strength training, where there is already a vast field of knowledge, yet little is known about the variation in BFR points between positions, sexes, limbs and body segment, further highlighting the need for the present study. The quality and safety of BFR application is of fundamental importance in increasing muscle strength and hypertrophy of the practitioners of this intervention modality, either without exercise or in combination with strength or aerobic training.

When analyzing the differences between sexes, it was found that males' mean BFR point values were higher than those of females, which was true regardless of position, limb and segment. Thus, the fact that there are such differences in BFR points between sexes, positions, limbs and segments demonstrates that several previously conducted studies[26, 27] that used both sexes with pre-established pressures may have been directly affected, as neither the principle of biological individuality nor any of the parameters analyzed in the present study were taken into consideration. In addition, this information is corroborated by Wernbom et al. findings[28], who mention that males require higher pressures than females to be able to achieve total BFR.

This information underlines the difference between sexes in the physiological control of blood pressure, which can also be directly affected by age[29].

Another point worth mentioning is that BFR prescription in the upper limbs can be performed by measuring only one segment, with the same value being used for prescription of the opposite segment, as there was no difference in BFR point evaluations between the upper limbs. However, this principle should not be followed for the lower limbs, as there were significant differences. This concern regarding appropriate prescription among limbs and segments is of paramount importance, as it is observed that the lower limbs promote higher concentrations of growth hormone (GH) than the upper limbs, which can have direct fundamental consequences on muscle hypertrophy[30].

Finally, the present study has some limitations. First, these results can be applied only to people with the study group's characteristics and may suffer variations in cases of athletic people, those with special needs and older people. Second, it was not performed a randomization of the limbs and body segments. Third, the BFR point was established with a 6-cm cuff for the upper limb and a 10-cm cuff for the lower limb, but it is believed that these variations may continue to occur because the main influencer in these hemodynamic changes is gravity[17]. However, as cuff size can directly affect hemodynamic measurements[14], it is suggested that studies be conducted using different cuff sizes and with people at different training levels, those with special needs and those of different age groups.

CONCLUSION

Blood flow restriction points appear to differ between positions, sexes, lower limbs and segments. Therefore, it is recommended that health professionals should check the BFR point in each position for the exercises that will be performed, for example, lying down (bench press), sitting (front pull ups) and standing (squats), taking sex, lower limbs and body segment into consideration.

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COMPLIANCE WITH ETHICAL STANDARDS

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Conflict of interest statement
The authors have no conflict of interests to declare.

Ethical approval

Ethical approval was obtained from the local Human Research Ethics Committee - Federal University of Paraíba, and the protocol was written in accordance with the standards set by the Declaration of Helsinki.

Author Contributions

Conceived and designed the experiments: GRN, JCGS, RKCU, MSCS. Performed the experiments: GRN, JCGS, RKCU, HGS, EAPN, LSOR, STB. Analyzed the data: GRN, JCGS, RKCU, HGS, EAPN, LSOR, STB, MSCS. Contributed reagents/materials/analysis tools: GRN, JCGS, RKCU, HGS, EAPN, LSOR, STB, MSCS. Wrote the paper: GRN, JCGS, RKCU, HGS, EAPN, LSOR, STB, MSCS.

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