Determining the Arterial Occlusion Pressure for Blood Flow Restriction: Pulse Oximeter as a New Method Compared With a Handheld Doppler

Fernanda Lima-Soares,[1,2] Kassiana A. Pessoa,[1,2] Christian E. Torres Cabido,[1,3] Jakob Lauver,[4] Jason Cholewa,[4] Fabrício Rossi,[5] and Nelo E. Zanchi[1,2]

[1]Department of Physical Education, Federal University of Maranhão (UFMA), São Luís, Brazil; [2]Department of Physical Education, Federal University of Maranhão (UFMA), Laboratory of Cellular and Molecular Biology of Skeletal Muscle (LABCEMME), São Luís, Brazil; [3]Department of Physical Education, Federal University of Maranhão (UFMA), Physical Exercise, Health and Human Performance Research Group, Federal University of Maranhão (UFMA), São Luís, Brazil; [4]Department of Kinesiology, Coastal Carolina University, Conway, South Carolina, United States; and [5]Immunometabolism of Skeletal Muscle and Exercise Research Group, Department of Physical Education, Federal University of Piauí (UFPI), Teresina-PI, Brazil

Abstract

Lima-Soares, F, Pessoa, KA, Torres Cabido, CE, Lauver, J, Cholewa, J, Rossi, FE, and Zanchi, NE. Determining the arterial occlusion pressure for blood flow restriction: pulse oximeter as a new method compared with a handheld Doppler. *J Strength Cond Res* XX(X): 000–000, 2020—In laboratorial and clinical settings, the use of Doppler ultrasound equipment has been considered the gold standard method to determine arterial occlusion pressure (AOP). However, the use of Doppler equipment is inherently limited to the technical expertise needed to perform AOP measurements. To overcome the technical difficulties of the use of Doppler equipment use in the determination of AOP, a simpler and less subjective methodology would be helpful for blood flow restriction (BFR) practitioners. In this regard, portable pulse oximetry has been largely used in clinical practice for measuring systolic pressures, as well as loss or recovery of pulse, with results similar to those observed with the use of Doppler equipment. For such purposes, the AOP from young male and female subjects was evaluated after different body positions (standing, seated, and supine positions). Loss of capillary blood flow or AOP was readily determined by simple visual inspection for the pulse oximeter and loss of sound for the Doppler equipment. The results presented herein strongly suggest the use of the portable pulse oximetry equipment as reliable, when compared with the handheld Doppler (seated $\kappa = 0.962$, standing $\kappa = 0.845$, and supine $\kappa = 0.963$ and seated $rs = 0.980$, standing $rs = 0.958$, and supine $rs = 0.955$). Because AOP measurement by pulse oximetry is relatively easier to perform and financially more accessible than handheld Doppler equipment, BFR practitioners may benefit from this new methodology to measure AOP, thus determining individualized restriction pressures.

Key Words: blood flow restriction training, pneumatic cuff, kaatsu training

Introduction

Blood flow restriction (BFR) accomplished by the use of pneumatic cuffs is an effective method to induce muscle adaptations alone or in combination with exercise (7,15). Blood flow restriction programs performed with the appropriate application of pressure are effective in sparing the muscle mass during immobilization conditions or in inducing muscle hypertrophy when combined with resistance exercise (13,16,29). The most appropriate application of pressure requires measuring the pressure necessary to completely occlude arterial blood flow, referred to as arterial occlusion pressure (AOP). Therefore, the determination of an optimal cuff pressure is a 2-step process. The first step involves the determination of the AOP, which can be assessed through Doppler ultrasound. The second step is the determination of the optimal pressure to be applied by the cuff during exercise. In this regard, cuff pressures of 40–80% of AOP seem to be effective in producing optimal muscle adaptations, without incurring health risks to the individual (20).

Blood flow restriction cuff pressures have commonly been prescribed in relation to brachial systolic blood pressure or an absolute cuff pressure (24). Variables such as limb circumference (9,19), resting blood pressure (9,19), and the type of cuff (17) potentially affects AOP. Nonlaboratorial (e.g., gym) approaches do not consider individual AOP and, therefore, can result in different degrees of restriction during BFR exercise. As a consequence, cuff pressure prescribed for BFR exercise may also be erroneously determined, which in turn can influence chronic muscle adaptations after BFR exercise training.

In laboratorial and clinical settings, the use of Doppler ultrasound equipment has been considered the gold standard method to determine AOP (15,23,1,12). An alternative method to determine the AOP is through a sonographic handheld Doppler equipment (18,28); however, the use of Doppler equipment, even as handheld, is inherently limited to the technical expertise needed to assess AOP. In clinical settings, for example, training practice and regular use are required to acquire and maintain Doppler skills (26). In addition, the use of Doppler equipment is related to a certain degree of individual variability, which refers to the operator's skill in applying the probe to the artery, which auscultates the pulsatile blood flow (3). Lack of familiarity with Doppler equipment may be

---

Address correspondence to Dr. Nelo E. Zanchi, neloz@ig.com.br.

Journal of Strength and Conditioning Research 00(00)/1–5

another limitation in the assessment of AOP. Independent of the reasons, a vast majority of BFR practitioners do not perform any sort of measurement to determine individualized restriction pressures (25), which may impair chronic muscle adaptations after BFR exercise training or even increase health risks (17).

To overcome the technical difficulties of the use of Doppler equipment in the determination of AOP, a simpler and less subjective methodology would be helpful for BFR practitioners. In this regard, portable pulse oximetry has been largely used in clinical practice for determining systolic pressures, as well as loss or recovery of pulse, with results similar to those observed with the use of Doppler equipment (2). Although a handheld Doppler is capable of determining the arterial blood flow through auditory determination, pulse oximetry is capable of detecting it in the capillary circulation, through red and infrared light transmission (27). By using pulse oximetry, AOP could be determined by positioning the user's fingertip in the portable device while inflating the cuff. Loss of capillary blood flow (or AOP) would be readily determined by simple visual inspection (3). Although pulse oximetry would be very useful in determining the AOP for BFR purposes, to the best of our knowledge, a direct comparison with a handheld Doppler has not been performed in healthy individuals. Therefore, the purpose of this investigation was to compare the validity of a portable pulse oximeter with a handheld Doppler in the determination of the AOP in the upper limb of young, healthy subjects.

Methods

Experimental Approach to the Problem

To evaluate AOP using a Doppler and a pulse oximeter, the subjects reported to the laboratory once. Anthropometry (body mass, height, and arm circumference) and systolic and diastolic blood pressures were first measured. Body position (seated, standing, and supine) was then randomly assigned, and cuffs were applied to the most proximal portion of the right arm, whereas independent investigators simultaneously conducted Doppler and pulse oximeter measurements to determine AOP in a blinded manner.

Subjects

The sample was composed of 70 volunteers (mean ± *SD*: 33 men; 37 women; age 5 23.2 ± 3.5 years [age range: 18-33 years]). All subjects were normotensive and were not on stimulants or beta-blockers. Subjects were instructed to attend the laboratory after a minimum of 24 hours of absence of exercise, caffeine, and alcohol. All subjects provided written informed consent after having the purpose, experimental protocol, and possible risks associated with participation explained, and approval for this study was obtained from the Federal University of Maranhão - Brazil, under number 83219517.1.0000.5087.

Procedures

Anthropometric Measures. Body mass and height were measured by using a digital scale (Filizola PL 50, Filizzola Ltda, Brazil) and a standard stadiometer, respectively. The arm circumference was measured at half the distance between the olecranon and acromion process, using a tape (19).

Systolic and Diastolic Blood Pressure. Systolic and diastolic brachial blood pressures were measured using an appropriate-sized automatic blood pressure cuff (12.8 × 10.4 × 6.4 cm) (Omron, Model HEM-773) 30 minutes after all anthropometric measurements. The blood pressure was determined in duplicate, and if systolic blood pressure values were not within 5 mm Hg, a third determination was obtained. The average of the 2 values was taken as the resting blood pressure (19). The intraclass correlation coefficient (ICC) for blood pressure measurement was 0.848.

Arterial Occlusion Pressure. The BFR cuff used for AOP determination was 5 cm wide, made of nylon (Brazil JPJ-industry of hospital supplies, SP, Brazil), and this model has been previously used in a BFR study (14). After randomly determining the order of positions, subjects were placed in the first body position with the cuff positioned proximally on the right arm. For determination of AOP, the pulse was initially detected by an evaluator using a handheld Doppler probe on the radial artery (MEDMEGA, DV 610V, 10 MHz, Brazil). Auricular earphones were used to block the sound signals to the other evaluator. Simultaneously, the other evaluator was monitoring the pulse oximeter (Oxy control, Geratherm, Germany) placed on the index finger in a position that was not viewable by the Doppler evaluator. The cuff was then inflated to 50 mm Hg using a manual sphygmomanometer (13,10), and the pressure was gradually increased in steps of 10 mm Hg with 5 seconds between each value to allow for improved oximeter visualization. This was continued until the auscultatory pulse was no longer present (19,17). The lowest cuff pressure at which the pulse was absent was considered the AOP for each assessment. Beyond this point, the cuff pressure was gradually increased by 20 mm Hg, to completely assure lack of pulse recovery between the 2 different evaluators. This procedure was repeated for all body positions with 5-minute rest assigned between AOP determinations (28). In addition, because each investigator remained assigned to the same device, the ICC was calculated to illustrate the consistency between both investigators in determining AOP. The ICC for the Doppler investigator was 0.840, and the ICC for the oximeter investigator was 0.872.

Statistical Analyses

The normality of the data set was assessed using the Kolmogorov-Smirnov test. Based on the resulting parameters, nonparametric statistics were performed, and data are presented as median and interquartile range. The difference between the groups according to the median of Doppler's and pulse oximeter's AOP was tested by the Wilcoxon test. The correlations between measures were

Table 1

Characteristics of subjects.*†

Variable	*n* = 70
Gender	
Men	33
Women	37
Age (y)	23.26 ± 3.5
Height (m)	1.67 ± 0.1
Body mass (kg)	67.28 ± 13.53
Arm circumference (cm)	28.83 ± 4.04
BMI (kg/m^2)	23.91 ± 3.39
SBP (mm Hg)	120.13 ± 12.67
DBP (mm Hg)	71.17 ± 8.07
Heart rate	70.26 ± 11.48

**n* = number of subjects; BMI = body mass index; SBP = systolic blood pressure; DBP = diastolic blood pressure.

†Values are shown as the mean values mean ± *SD*.

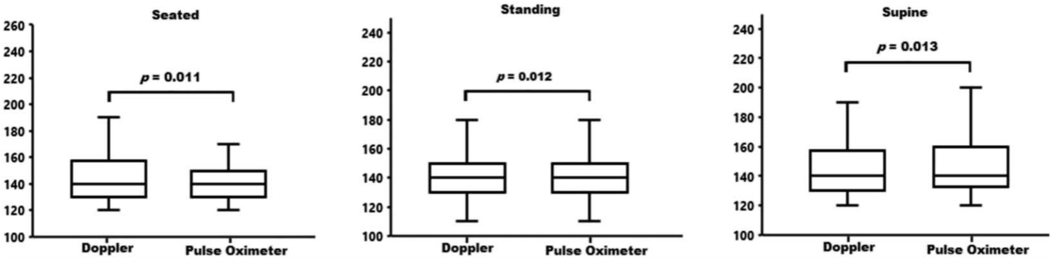

Figure 1. Comparison of the arterial occlusion pressure (mm Hg) in the Doppler and the pulse oximeter.

tested using the Spearman correlation. The groups were dichotomized by the 75th percentile (22) to separate AOP in 2 major categories of pressure (below and above the 75th percentile), and after that, their agreement was estimated by means of the Kappa coefficient. The strength of agreement for κ values were defined as follows: poor, 0–0.2; fair, 0.21–0.40; moderate, 0.41–0.6; good, 0.61–0.8; and excellent, 0.81–1.0 (4). Bland-Altman plots were also made to verify the level of agreement between the handheld Doppler and the pulse oximeter and the respective 95% limits of agreement (LoA). In the Bland-Altman graphs, their difference was plotted against the mean. All analyses were performed using the statistical software SPSS, version 17.0 (SPSS, Inc., Chicago, IL), and the statistical significance was set a priori at $p \leq 0.05$.

Results

All 70 subjects completed the study and were included in the analysis. Subject characteristics are provided in Table 1.

When comparing the pulse oximeter with the handheld Doppler, the same median (140 mm Hg) was observed between methods in the 3 body positions analyzed (seated, standing, and supine), as shown in Figure 1. The AOP median (interquartile) in the seated position was 140 (30) mm Hg in the Doppler group and 140 (23) mm Hg in the oximeter group with $p = 0.011$. In the standing position also, the AOP was also 140 (23) mm Hg in both groups with $p = 0.012$. Similarly, the AOP in the supine position was 140 (30) mm Hg in both methods with $p = 0.013$.

To summarize, all 70 subjects were evaluated by both the Doppler technique and pulse oximetry in regard to AOP determination. In the seated position, of the 70 subjects evaluated, 86% (60 subjects) showed the same AOP values for both methods. At the standing position, of the 70 subjects evaluated, 73% (51 subjects) reached the same AOP values for both methods. Finally, at the supine position, 81.5% (57 subjects) demonstrated the same AOP values, for both methods, in the same sample. In most cases, when some difference was observed, AOP's result was 10 mm Hg higher in evaluation using Doppler equipment.

Correlations between the handheld Doppler and pulse oximeter were positive and very strong (0.8–1) (Figure 2), with an rs of 0.980, 0.958, and 0.955 in the seated, standing, and supine position, respectively.

Bland-Altman plots for AOP in the 3 body positions are presented in Figure 3. Visual assessments of the plots show some points of the LoA in the 3 cases. It must be considered that the maximal difference found between the pulse oximeter and the Doppler was ±10 mm Hg.

Table 2 summarizes the results of crosstab analysis for the Doppler and the pulse oximeter. Both methods show good agreement in the classification of the subjects in the lower (below) or higher (above) 75th percentile, which means that both pieces of equipment were able to detect variations in the AOP for subjects showing either a lower or higher AOP. Data were classified as 0 when below the 75th percentile and 1 when above the same percentile. In seated and standing positions, the 75th percentile was 270 and 280 mm Hg, respectively. Minimal differences between pieces of equipment were seen in seated and supine positions. In seated versus supine position, for example, only one disagreement on classification between the Doppler and the pulse oximeter occurred, whereas in the standing position, both pieces of equipment totally agreed on the classification. The agreement was assessed using Cohen kappa statistics (κ). Our results reveal, for all positions, a high degree of K agreement (seated $\kappa = 0.962$; standing $\kappa = 0.845$; and supine $\kappa = 0.963$) with a $p = 0.000$.

Discussion

The main finding of the present investigation is that both the handheld Doppler and the portable pulse oximeter can be used interchangeably to determine upper limb AOP using a manual BFR cuff. Such measures were similar for both pieces of

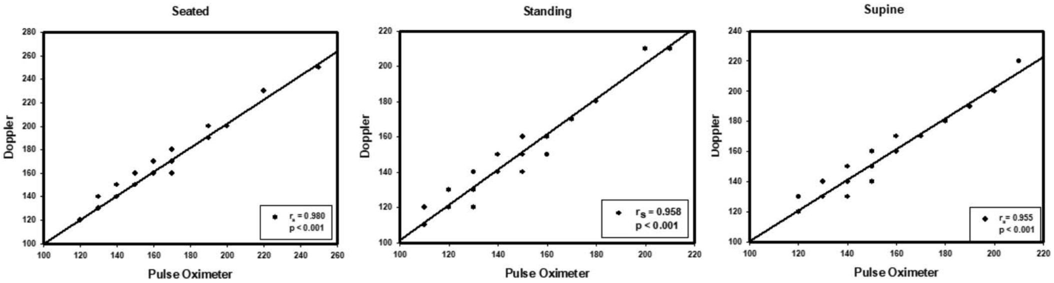

Figure 2. Spearman correlation between the arterial occlusion pressure measured by the Doppler and the pulse oximeter.

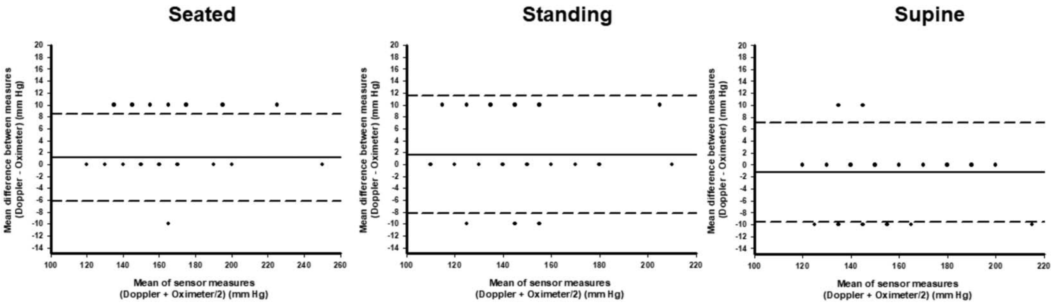

Figure 3. Bland–Altman plots of Doppler and pulse oximeter AOP. AOP = arterial occlusion pressure.

equipment at different body positions (standing, seated, and supine), in a cohort of young, normotensive and eutrophic, male and female subjects.

Although many studies have focused on the determination of the ideal pressure applied by the cuff during exercise with BFR, this is the first study to the best of our knowledge to evaluate the use of pulse oximetry to determine the AOP in young and healthy subjects. The importance in determining the AOP for BFR practitioners is very clear because optimal restriction pressures during exercise with BFR should be defined as a percentage of AOP. However, the determination of AOP itself has been limited to the use of Doppler equipment or direct palpation of an artery (21). In this study, we took advantage of the use of pulse oximeter equipment not to measure hemoglobin saturation or heart rate itself (the 2 most known functions of a pulse oximeter), but as an indicator of the presence of pulsatile blood flow in the capillary bed. For this endpoint, flattening or disappearance of the waveform on the pulse oximeter display or loss of the digital "pulse" display was described by Bianchi and Zamiri (3) as a methodology capable of measuring the arterial circulation in patients with venous disease of the leg. In the supracited study, however, because of the presence of venous disease, a linear association existed, but only a fair agreement between the handheld Doppler and the pulse oximeter was observed (3). In our population, considering the upper-limb determination, the correlations between both pieces of equipment were very high, suggesting that in normal healthy populations, AOP determination can be validly performed using portable pulse oximeter equipment.

Table 2

Cross-tabulation between Doppler and pulse oximeter AOP by the 75th percentile in all positions.*

	Doppler		
	≤P75, ≤270 mm Hg	**>P75, >270 mm Hg**	**Total (*n* = 70)**
Seated			
Pulse oximeter			
<P75	52 (74.3%)	1 (1.4%)	53 (75.7%)
>P75	0 (0%)	17 (24.3%)	17 (24.3%)
Total	52 (74.7%)	18 (25.7%)	
Standing			
Pulse oximeter			
<P75	51 (72.9%)	2 (2.9%)	53 (75.7%)
>P75	2 (2.9%)	15 (21.4%)	17 (24.3%)
Total	53 (75.7%)	17 (24.3%)	
	Doppler		
	≤P75, ≤280 mm Hg	**>P75, >280 mm Hg**	**Total (*n* = 70)**
Supine			
Pulse oximeter			
<P75	51 (72,9%)	0 (0%)	51 (72.9%)
>P75	1 (1.4%)	18 (25.7%)	19 (27.1%)
Total	52 (74.3%)	18 (25.7%)	

*AOP = arterial occlusion pressure.

It is not our intention to diminish or criticize the importance of the use of Doppler equipment in the determination of AOP, which is very precise and, in fact, is considered a gold standard method used in many studies (15,13,16,21). However, in the medical community, it has been described that nurses who had many duties in their daily professional activities did not use the Doppler equipment regularly to maintain their skills and confidence (5). In this regard, but in a different setting, a recent survey performed by Patterson and Brandner (25) has demonstrated that among BFR practitioners, individualized restriction pressures are not performed by most individuals, which led us to suggest that AOP determination through a handheld Doppler is not a trivial task for most individuals engaged in a BFR program. As recently proposed, if we consider that AOP determinations are now suggested to be re-evaluated during a BFR program (for purposes of readjustments) (11), then a simple methodology to determine AOP would be even more important. Our research advances in the direction of this question because through the use of a pulse oximeter, the practitioner has access to an easy-to-perform methodology, clear objective endpoints (cut off of the visual signal), which are financially feasible for most exercise practitioners.

As previously described, once the AOP is determined, calculating the optimal cuff pressure for an exercise session is a very easy task, based on the recent literature. When combined with resistance exercises of 30–40% of 1RM (repetition maximum), cuff pressures of 40% of AOP seems to be effective in inducing muscle hypertrophy (6). When the load applied is less than 30% of 1RM, a higher percentage of AOP, such as 80%, seems to lead to optimal muscle adaptations (8). Because our data show a maximal difference of 10 mm Hg between the Doppler or the oximeter method, when the relative pressure based on AOP is applied in the training protocol, this difference is likely negligible, especially during exercise, when some pressure oscillation during isotonic contractions are expected.

These results increase the possibilities for new BFR exercise and training studies; however, new studies are needed to validate this new methodology with different populations. We conclude that portable pulse oximetry is a valid method when compared with a handheld Doppler technique in the determination of upper-limb AOP. Such results were validated at different body positions (standing, seated, and supine), in a cohort of young, normotensive and eutrophic, male and female subjects. Future studies should evaluate this method in predicting AOP, not only in the upper limbs but also in the lower limbs, as well as in different populations.

Practical Applications

Determination of AOP is of ultimate importance for the success of BFR exercise training programs. In scientific settings, the Doppler equipment is highly used to determine AOP and then used to calculate the ideal pressure of training, which is usually 40–80% of AOP. In practical settings, however, most individuals use predetermined cuff pressures, without determining AOP. The employment of a fixed cuff pressure may lead to a greater variability between subjects, diminishing the effectiveness of BFR or BFR resistance training intervention. Here, we showed that AOP can be easily determined using the pulse oximeter equipment, without the need of technical expertise or previous experience with the equipment. Based on the supracited results, we propose the use of this methodology as an easy and reliable tool in the determination of AOP. Importantly, this methodology can be applied quickly and with minimal effort by rehabilitation professionals and coaches in the clinic and the field, respectively.

Acknowledgments

Research concept and study design: F. Lima-Soares, N.E. Zanchi, and K.A. Pessoa; literature review: F. Lima-Soares, N.E. Zanchi, and J. Cholewa; data collection: F. Lima-Soares, K.A. Pessoa, and C.E. Torres Cabido; data analysis and interpretation: N.E. Zanchi, J. Lauver, and J. Cholewa; statistical analyses: C.E. Torres Cabido, F. Rossi, and J. Lauver; and writing of the manuscript: N.E. Zanchi, F. Lima-Soares, F. Rossi, and J. Cholewa.

References

1. Bezerra de Morais AT, Santos Cerqueira M, Moreira Sales R, Rocha T, Galvão de Moura Filho A. Upper limbs total occlusion pressure assessment: Doppler ultrasound reproducibility and determination of predictive variables. *Clin Physiol Funct Imaging* 37: 437–441, 2017.
2. Bianchi J, Douglas WS, Dawe RS, et al. Pulse oximetry: A new tool in the assessment of patients with leg ulcers. *J Wound Care* 9: 109–112, 2000.
3. Bianchi J, Zamiri M, Loney M, et al. Pulse oximetry index: A simple arterial assessment for patients with venous disease. *J Wound Care* 17: 253–260, 2008.
4. Brennan P, Silman A. Statistical methods for assessing observer variability in clinical measures. *BMJ* 304: 1491, 1992.
5. Brown A, Bums W, Chalmers L, et al. Effect of a national community intervention programme on healing rates of chronic leg ulcer: Randomised controlled trial. *Phlebology* 17: 47–53, 2002.
6. Counts BR, Dankel SJ, Barnett BE, et al. Influence of relative blood flow restriction pressure on muscle activation and muscle adaptation. *Muscle Nerve* 53: 438–445, 2016.
7. Cruz RSO, Pereira KL, de Aguiar RA, et al. Effects of ischemic conditioning on maximal voluntary plantar flexion contractions. *J Electromyogr Kinesiol* 48: 37–43, 2019.
8. Dankel S, Jessee MB, Buckner SL, et al. Are higher blood flow restriction pressures more beneficial when lower loads are used? *Physiol Int* 104: 247–257, 2017.
9. Graham B, Breault MJ, McEwen JA, McGraw RW. Occlusion of arterial flow in the extremities at subsystolic pressures through the use of wide tourniquet cuffs. *Clin Orthop Relat Res* 286: 257–261, 1993.
10. Gualano B, Neves MJr, Lima FR, et al. Resistance training with vascular occlusion in inclusion body myositis: A case study. *Med Sci Sports Exerc* 42: 250–254, 2010.
11. Ingram JW, Dankel SJ, Buckner SL, et al. The influence of time on determining blood flow restriction pressure. *J Sci Med Sport* 20: 777–780, 2017.
12. Jessee MB, Buckner SL, Dankel SJ, et al. The influence of cuff width, sex, and race on arterial occlusion: Implications for blood flow restriction research. *Sports Med* 46: 913–921, 2016.
13. Laurentino G, Ugrinowitsch C, Aihara AY, et al. Effects of strength training and vascular occlusion. *Int J Sports Med* 29: 664–667, 2008.
14. Laurentino GC, Loenneke JP, Teixeira EL, et al. The effect of cuff width on muscle adaptations after blood flow restriction training. *Med Sci Sports Exerc* 48: 920–925, 2016.
15. Lima-Soares F, Cholewa JM, de Araujo Pessôa K, et al. Blood flow restriction and blood flow restriction resistance training improves muscle mass, muscle strength and mobility in an older patient with osteoarthrosis carrying the ACTN3 endurance genotype: A case report. *Geriatr Gerontol Int* 19: 458–459, 2019.
16. Lixandrão ME, Ugrinowitsch C, Laurentino G, et al. Effects of exercise intensity and occlusion pressure after 12 weeks of resistance training with blood-flow restriction. *Eur J Appl Physiol* 115: 2471–2480, 2015.
17. Loenneke JP, Fahs CA, Rossow LM. Effects of cuff width on arterial occlusion: Implications for blood flow restricted exercise. *Eur J Appl Physiol* 112: 2903–2912, 2012.
18. Loenneke JP, Thiebaud RS, Fahs CA, et al. Effect of cuff type on arterial occlusion. *Clin Physiol Funct Imaging* 33: 325–327, 2013.
19. Loenneke JP, Allen KM, Mouser JG, et al. Blood flow restriction in the upper and lower limbs is predicted by limb circumference and systolic blood pressure. *Eur J Appl Physiol* 115: 397–405, 2015.
20. Loenneke JP, Kim D, Mouser JG, et al. Are there perceptual differences to varying levels of blood flow restriction? *Physiol Behavior* 157: 277–280, 2016.
21. Mattocks KT, Jessee MB, Mouser JG, et al. The application of blood flow restriction: Lessons from the laboratory. *Curr Sports Med Rep* 17: 129–134, 2018.
22. McClelland RL, Chung H, Detrano R, Post W, Kronmal RA. Distribution of coronary artery calcium by race, gender, and age: Results from the multi-ethnic study of atherosclerosis (MESA). *Circulation* 113: 30–37, 2006.
23. Mouser JG, Laurentino GC, Dankel SJ, et al. Blood flow in humans following low-load exercise with and without blood flow restriction. *Appl Physiol Nut Metab* 42: 1165–1171, 2017.
24. Nielsen JL, Aagaard P, Bech RD, et al. Proliferation of myogenic stem cells in human skeletal muscle in response to low-load resistance training with blood flow restriction. *J Physiol* 590: 4351–4361, 2012.
25. Patterson SD, Brandner CR. The role of blood flow restriction training for applied practitioners: A questionnaire-based survey. *J Sports Sci* 36: 123–130, 2018.
26. Ray S, Srodon PD, Taylor RS, Dormandy JA. Reliability of ankle: Brachial pressure index measurement by junior doctors. *Br J Surg* 81: 188–190, 1994.
27. Ridlen G. Pulse oximetry: A historical perspective. *J Resp Care Pract* 11: 47–50, 1998.
28. Sieljacks P, Knudsen L, Wernbom M, Vissing K. Body position influences arterial occlusion pressure: Implications for the standardization of pressure during blood flow restricted exercise. *Europ J Appl Physiol* 118: 303–312, 2018.
29. Slysz J, Stultz J, Burr JF. The efficacy of blood flow restricted exercise: A systematic review & meta-analysis. *J Sci Med Sport* 19: p: 669–675, 2016.