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JSAMS-1441; No. of Pages 4
ARTICLE IN PRESS
Journal of Science and Medicine in Sport xxx (2017) xxx–xxx
Contents lists available at ScienceDirect
Journal of Science and Medicine in Sport
journal homepage: www.elsevier.com/locate/jsams

Original research

The influence of time on determining blood flow restriction pressure

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ARTICLE INFO

Article history:
Received 6 November 2015
Received in revised form 29 July 2016
Accepted 18 November 2016
Available online xxx

Keywords:
Arterial occlusion
Brachial systolic blood pressure
Brachial diastolic blood pressure

ABSTRACT

The influence of time, manifested in the oscillatory nature of physiology, has been documented in many processes. Within blood flow restriction literature, the restrictive stimulus is often applied based on a single arterial occlusion measurement, which is closely related to brachial systolic blood pressure (bSBP). Considering the oscillatory nature of bSBP, it is likely that time also influences arterial occlusion measurements.
Objectives: To investigate the influence of time, within and between days, on arterial occlusion pressure and to determine whether the variability resembles the oscillatory pattern of bSBP.
Design: Test-retest.
Methods: Twenty-two participants completed four testing sessions at 08:00 and 18:00 h, 48 h apart. Arm circumference, bSBP, and brachial diastolic blood pressure (bDBP) were measured at rest. Arterial occlusion pressure was determined using a cuff inflated on the proximal portion of the upper arm, with a Doppler probe placed over the radial artery.
Results: Significant differences [mean (SD)] were observed for arterial occlusion pressure between Morning Day 2 [132 (14) mmHg, $p < 0.05$], and all other visits [Morning Day 1: 138 (16); Evening Day 1: 139 (17); Evening Day 2 138 (14) mmHg]. A time effect was observed for bSBP, with a post-hoc test revealing that Morning Day 2 was different from all other visits.
Conclusions: Our findings suggest that arterial occlusion pressure is influenced by the time of day. As such, multiple occlusion measurements across an experiment may be necessary in order to account for potential oscillations in pressure and provide the intended relative restrictive stimulus.

1. Introduction

Low load resistance exercise in combination with blood flow restriction (BFR) is a potent stimulus, yielding similar increases in muscle size and strength as high load resistance exercise.[1–3] The stimulus applied by the compression cuff used in BFR exercise has been studied from an absolute (range: 50 mmHg[4]–300 mmHg[5]) and relative perspective, often prescribed as 1.3 times an individual's brachial systolic blood pressure (bSBP)[6] or as a percentage of arterial occlusion pressure[2,7,8] (range: 40%[8]–100%[9]). The applied pressure for BFR exercise has also been estimated from limb circumference and has been previously shown to explain a large portion of unique variance in arterial occlusion pressure for both the upper and lower body.[10,11]

Despite the various methods in which pressures are applied, the use of relative pressures (i.e. % of arterial occlusion) have been recommended[11] as this takes into account variables such as cuff width, limb circumference and bSBP, all of which have a large influence on the arterial occlusion at a single time point.[12] Commonly used BFR protocols often administer relative arterial occlusion pressures[13] that are determined by a single measurement obtained at baseline, despite the fact that there may be multiple visits over time (e.g., training study or acute study with different experimental conditions). bSBP increases within the first two hours of waking (i.e., morning BP surge[14]), peaking around 16:00–18:00 h or 12 h after waking[15–17] before decreasing (i.e. dipping pattern[14]) during the night time or sleep hours. Considering the variability in bSBP measurements over time and that bSBP explains a large amount of the unique variance in arterial occlusion pressure in the upper body,[11] it is plausible that similar variability would be observed with arterial occlusion pressure measurement. Diurnal variation in brachial blood pressure (bBP) has been well-documented[18] show-

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http://dx.doi.org/10.1016/j.jsams.2016.11.013
1440-2440/

ing distinct oscillatory patterns over the course of a day, less is known on how this diurnal variability may differ based on the smaller cuff and differing inflation device used for the arterial occlusion measurement. Methodological considerations of the BFR stimulus continue to evolve, however, little attention has been paid to the influence of time. BFR studies have hypothesized that there is an optimal pressure range for the restrictive stimulus applied during blood flow restrictive exercise.[19] However, if arterial occlusion measurements change over time, this will affect both high and low occlusive pressures, resulting in a less optimal pressure. Moreover, studies that measure arterial occlusion pressure in the morning but perform BFR exercise in the afternoon or evening may apply a lower relative stimulus than desired, and vice versa.

To our knowledge, no study has attempted to examine the influence of time on changes in arterial occlusion pressure. Therefore, the purposes of this study were to investigate the variability in arterial occlusion measurement within and between days, and determine whether the variability in arterial occlusion measurement within the same day oscillates in a pattern similar to that of bSBP. We hypothesized, based on the known oscillatory nature of most physiological variables including bSBP, the arterial occlusion measurement would vary within the same day. Considering that bSBP is a major predictor of arterial occlusion pressure, we hypothesized arterial occlusion measurements would oscillate in a pattern that mimicked diurnal variation in bSBP. More specifically, that arterial pressure measurements would be higher in the evening compared to morning hours.

2. Methods

Based on a previous study assessing the change in arterial occlusion after exercise among 28 individuals (effect size of 2.8),[7] a total of 24 participants were required to detect a more conservative 3 mmHg (effect size of 0.6) change in arterial occlusion pressure with 80% power at $p \leq 0.05$. Seven participants did not complete all of the testing sessions and their data was excluded from all further analyses. Twenty-two young participants (12 males, 10 females) with no known cardiovascular or metabolic diseases visited the laboratory for four separate testing sessions over two days. All participants were instructed to refrain from: (1) eating two hours prior; (2) consuming caffeine eight hours prior; and, (3) strenuous activity 24 h prior to testing. The study received approval from the University's Institutional Review Board and each participant gave written informed consent prior to participation.

All participants visited the laboratory on four occasions, at 08:00 and 18:00 h on two separate days, 48 h apart. Upon arriving for the first visit, the participants filled out the informed consent document and a brief health history questionnaire. Each participant's height and body mass were measured using a standard stadiometer and electronic scale. Mid-arm circumference of the right arm was measured using a standard tape measure at 50% of the distance from the acromion process to the olecranon process. Following the arm circumference measurement, the participants rested in a quiet seated position with legs uncrossed for 10 min. Following 10 min of seated rest the participants had heart rate and brachial blood pressure measured on the right arm using an appropriate sized blood pressure cuff and automated monitor (Omron, Model HEM-773). Blood pressure was taken twice with the arm at heart level and the average of the two measurements was used. If the second measurement differed by >5 mmHg, the measurement was repeated until two of the bSBP and bDBP measurements were within 5 mmHg. Each blood pressure measurement was separated by 15 s of rest. After a further five minutes of quiet seated rest, the participants were asked to slowly stand and arterial occlusion pressure of the right arm was measured using a 5 cm wide nylon cuff (Hokanson, Bellevue, WA). Pressure was regulated by the E20 Rapid Cuff Inflator (Hokanson, Bellevue, WA) system. The pulse at the wrist (arterial blood flow) was detected using a hand-held bidirectional MD6 Doppler probe placed on the radial artery. Both auditory and visual signals from the Doppler probe indicated if the pulse was present. The cuff was first inflated to 50 mmHg and pressure was progressively increased until the arterial flow was no longer detected. Arterial occlusion pressure was measured by the same researcher for all visits and was recorded to the nearest 1 mmHg as the lowest cuff pressure at which a pulse was not present. When arterial flow was no longer detected, the cuff was immediately deflated and removed from the arm. The measurements of arm circumference, brachial blood pressure and arterial occlusion pressure were performed in that order during all four visits.

The coefficient of variation (CV) was calculated for arterial occlusion pressure and bSBP across all four visits. A one-way repeated measures ANOVA was used to determine differences in arterial occlusion pressure, arm circumference, bSBP, and bDBP. If significance was found, a Fisher's least significant difference (LSD) test was used to reveal where the differences were. All data were computed using SPSS 22.0 and are presented as means and standard deviations (SD). Significance was set at $p \leq 0.05$ for all statistical tests.

3. Results

The mean age, height, and body mass for the participants (n = 22) were 24 (3) years, 176.6 (11.8) cm, and 76.9 (14.7) kg, respectively. The CVs for arterial occlusion pressure and bSBP were 5.0% and 4.8% respectively.

For arterial occlusion, there was a significant time effect ($p = 0.009$) with post-hoc analyses revealing that all time points (Morning Day 1, Evening Day 1, and Evening Day 2) were significantly different from Morning Day 2 (Table 1). Specifically, mean differences from Morning Day 2 were as follows: Morning Day 1 [5 (10) mmHg], Evening Day 1 [7 (10) mmHg], and Evening Day 2 [5 (7) mmHg]. There were no other significant differences in arterial occlusion. Similarly, there was a significant time effect for bSBP ($p = 0.027$) with post-hoc analyses revealing that all time points were significantly different from the Morning Day 2 (Table 1, $p < 0.05$). There was no time effect for bDBP ($p = 0.490$) arm circum-

Table 1
Summary of participant characteristics (N = 22).

Time of day (h)	Arm circumference (cm)	Arterial occlusion (mmHg)	bSBP (mmHg)	bDBP (mmHg)	Heart rate (BPM)
Day 1					
Morning (08:00)	32.8 (4.3)	138 (16)[a]	111 (12)[a]	65 (8)	65 (10)
Evening (18:00)	32.9 (4.3)	139 (17)[a]	112 (9)[a]	64 (7)	64 (12)
Day 2					
Morning (08:00)	33.0 (4.3)	132 (14)[b]	107 (10)[b]	63 (7)	66 (11)
Evening (18:00)	32.9 (4.3)	138 (14)[a]	111 (11)[a]	65 (7)	67 (13)

All data are expressed as mean (standard deviation). Visits with different letters represents significant difference between visits, notably only the arterial occlusion and bSBP measures on Morning Day 2 were significantly different than all other visits. Variability represented as standard deviations. bSBP: brachial systolic blood pressure; bDBP: brachial diastolic blood pressure. BPM: beats per minute.