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Technical Note

Limb Occlusion Pressure: A Method to Assess Changes in Systolic Blood Pressure

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ABSTRACT

International Journal of Exercise Science 13(2): 366-373, 2020. Although often used as a surrogate, comparisons between traditional blood pressure measurements and limb occlusion assessed via hand-held Doppler have yet to be completed. Using limb occlusion pressure as a method of assessing systolic pressure is of interest to those studying the acute effects of blood flow restriction, where the removal of the cuff may alter the physiological response. Purpose: We sought to determine how changes in limb occlusion pressure track with changes in traditional assessments of blood pressure. Basic Procedures: Limb occlusion pressure measured by hand-held Doppler and blood pressure measured by an automatic blood pressure cuff were assessed at rest and following isometric knee extension (post and 5 minutes post). Main Findings: Each individual had a similar dispersion from the mean value for both the limb occlusion pressure measurement and traditional systolic blood pressure measurement [BF10: 0.33; median (95% credible interval): 0.02 (-6.0, 5.9) %]. In response to lower body isometric exercise, blood pressure changed across time. The difference between measurements was small at immediately post and 5 minutes post. The Bayes factors were in the direction of the null but did not exceed the threshold needed to accept the null hypothesis. However, at 5 minutes post, the differences were within the range of practical equivalence (within ± 4.6%). Principal Conclusions: Our findings suggest that changes in limb occlusion pressure measured by hand-held Doppler track similarly to traditional measurements of brachial systolic blood pressure following isometric knee extension exercise.

KEY WORDS: Cuff method; blood flow restriction; cardiovascular response

INTRODUCTION

A common response to exercise is an increase in systolic blood pressure that is driven by the heightened demands of the cardiovascular system to support the working muscles (1). One method of exercise that increases demand on the cardiovascular system is low load resistance exercise in combination with partial blood flow restriction (4, 17). The blood pressure response to low load exercise in combination with blood flow restriction has been examined using more traditional methods of blood pressure measurements (4, 8, 20) as well as through changes in the limb occlusion pressure (lowest pressure required to occlude the artery) using the same pneumatic cuff that is applied during exercise (3). The limb occlusion pressure is most often associated with setting the relative pressure for exercise (14), however, the pre to post change in this pressure has also been used as an alternative method to measure systolic blood pressure (2, 3, 10, 13). It is of note that the use of the pre-post change in pressure as an alternative method to quantify systolic blood pressure is likely specific to pneumatic cuffs. This is because the pneumatic cuffs (as opposed to elastic wraps, or some devices that can only be inflated incrementally) allow the pressure to be changed without deflating.

Although used as a surrogate for changes in systolic blood pressure, direct comparisons between traditional blood pressure measurements and limb occlusion pressures have yet to be completed. This method of assessing pressure is of interest to those studying the acute effects of blood flow restriction, where the removal of the cuff may alter the physiological response. Previous studies using the limb occlusion method have noted that the cardiovascular response is augmented in the blood flow restriction conditions compared to traditional high load exercise (3, 7). However, when using the traditional blood pressure cuff method with the same exercise program, the augmentation in blood pressure with blood flow restriction is no longer observed (15, 18). There is also the potential to use this measurement as a non-invasive method to assess blood pressure during exercise, which cannot be done using automated-blood pressure cuffs. Therefore, the purpose of this study was to compare measurements of limb occlusion pressure and systolic blood pressure (via the traditional cuff) following a bout of isometric exercise. Diastolic pressure was determined with the traditional cuff method but was not able to be determined with the limb occlusion method.

METHODS

Participants

Eight resistance-trained males, between the ages of 18 and 35 years, were recruited by word of mouth for this study and completed one testing session. Resistance-trained was defined as consistently performing resistance exercise ≥3 times per week, for the previous 6 months. Exclusionary criteria included use of tobacco products (previous 6-months) or taking hypertensive medication. All participants were instructed not to consume alcohol or partake in exercise 24 hours before, consume food 2 hours before, or have caffeine 8 hours before their visit. This study was approved by the University's Institutional Review Board (Protocol # 18-063). Written informed consent was obtained from all participants before participation. This research was carried out fully in accordance to the ethical standards of the International

Journal of Exercise Science (19). Only a small group of men were tested because this was part of a larger study, which sought to investigate changes in blood pressure during multiple forms of resistance exercise. The data provided herein was used to determine justification for using limb occlusion pressure as a surrogate of brachial systolic blood pressure. Data for blood pressure changes during muscle contraction is not provided because it proved technically challenging and the data provided was of low quality. The assessment of limb occlusion pressure during the periods where the muscle was not contracting provided high quality assessments and that is the data provided within this manuscript.

Protocol
Following completion of paperwork, standing height and body mass were measured using a stadiometer (Seca 217, Hamburg, Germany) and a digital weight scale (Seca 769, Hamburg, Germany). Participants then had an appropriately sized traditional blood pressure (Omron #HEM-907XL) cuff placed on their right arm and a 12 cm wide nylon pneumatic cuff (SC12 Hokanson, Bellevue, WA) placed on their left arm. A single cuff width was used for limb occlusion pressure because this is what is common within studies investigating exercise in combination with blood flow restriction (5, 6, 11). Participants rested quietly for 10 minutes while seated on the knee extension machine (Hammer Strength, Iso-Lateral Leg Extension Life Fitness, Rosemont, IL). Traditional blood pressure was then measured first, followed by a measurement of limb occlusion pressure. Traditional blood pressure was measured every minute until two consecutive measurements were within 5 mmHg of each other. Multiple measurements of blood pressure were taken in order to be in line with traditional recommendations for assessing blood pressure. Immediately post exercise, however, only one measurement was taken in order to ensure the peak measurement was obtained. Following blood pressure, limb occlusion pressure in the left arm was determined. A bi-directional Doppler probe (MD6, Hokanson Inc., Belleview, WA, USA) was placed over their radial artery and a pulse was found through auscultation. The cuff was inflated using a rapid cuff inflator (E20, Hokanson Inc., Belleview, WA, USA) to a pressure of 50 mmHg, and then slowly increased until a pulse was no longer audible on the Doppler probe. The lowest pressure at which a pulse was not detected was recorded as the participant's limb occlusion pressure.

Next, participants rested for 5 minutes and then the same measurements were taken again. This was completed to help quantify the short-term stability of each measurement. Participants then completed 5 sets of 10-second bilateral isometric contractions on an overloaded knee extension machine. Each set was separated by 30-seconds of rest. Participants were allowed to hold onto the handles located on the side of the knee extension and were instructed to contract as hard and as fast as they could. Strong verbal encouragement was provided. Immediately following the final set, a single measurement of traditional blood pressure (right arm) and limb occlusion pressure (left arm) were taken simultaneously. Five minutes post exercise; limb occlusion pressure was measured again, followed by traditional blood pressure. The order of assessment at this time point was reversed because multiple measurements are recommended for the traditional cuff method but not the limb occlusion method. Given this, we decided doing a single inflation prior to potentially multiple (2+ inflations) inflations was the most appropriate approach for the measurement of blood pressure recovery.

Statistical Analysis
The width of the cuff has a large impact on the pressure needed to occlude an artery (9). Given this, we analyzed percent changes to account for any difference in cuff width between measurements. However, we also include results from the same analysis on the absolute raw values. A Bayesian one sample t-test was used to determine if the difference in the relative changes from baseline were different from zero (% change in traditional systolic blood pressure - % limb occlusion pressure) using a default Cauchy prior of 0.707 (centered on zero). An uninformed prior of 0.707 was chosen based on previous recommendations (21). We used the same analysis to demonstrate changes from baseline for each measurement. Bayes factors (BF10) were used to provide evidence for (BF10 of ≤ 0.33) or against the null (BF10 of ≥ 3.0) hypothesis. A BF10 of "3" means that the observed data are 3 times more likely under the alternative than the null hypothesis. Likewise, a BF10 of 0.33 means that the observed data are 3 times more likely under the null than the alternative hypothesis. We also included a region of practical equivalence to supplement our Bayes Factor analysis. To set the region, we compared the 5-minute reliability between traditional systolic blood pressure and limb occlusion pressure and chose the value that had the greatest variability. The % change in five minutes was -1.7 SD (2.0) % for traditional systolic blood pressure and -0.7 SD (3.9) % for limb occlusion pressure. The 3.9 SD for limb occlusion pressure was then multiplied by the critical t value of 2.365 to get the minimal difference value of 9.2%. Based on recommendations from Lesaffre (12) we halved the minimal difference value and set that as a confirmatory region of equivalence (i.e. ± 4.6%). For the raw values the boundaries were set to ± 5.4 mmHg (SD of 4.6 mmHg x 2.365 = 10.8 mmHg). We also determined how much each individual differed from the mean of each measurement to determine if the dispersion was similar across measurements. Statistical analysis was computed using the BayesFactor package (version 0.9.12-4.2) in RStudio version 1.1.414 (https://www.r-project.org/) (16). Bland-Altman plots were generated using jamovi (version.1.1.9) and ICC $_{(3,1)}$ were calculated using IBM SPSS Statistics 26.

RESULTS

Participant characteristics were as follows (mean ± SD): average age was 29 ± 1 years, height 1.7 ± 0.01 m, and body mass of 82 ± 13.5 kg. Each individual had a similar dispersion from the mean value for both the limb occlusion pressure measurement and traditional systolic blood pressure measurement [BF10: 0.33; median (95% credible interval): 0.02 (-6.0, 5.9) %].

In response to lower body isometric exercise, blood pressure changed across time (Figure 1). The difference between measurements was small at immediately post [mean difference of 1.1 (SD 11.8) %, $ICC_{3,1}$ of -0.125] and 5 minutes post [mean difference of -1.1 (SD 4.6) %, $ICC_{3,1}$ of 0.342] (Figure 2). The Bayes factors were in the direction of the null but did not exceed the threshold needed to accept the null hypothesis. However, at 5 minutes post, the differences were within the range of practical equivalence (Figure 3). This provides some support that the magnitude of difference in these changes are small and potentially not meaningful. Expressed as a relative change from pre [median (95% credible interval), diastolic was relatively unchanged immediately post exercise [-4.9 (-13.5, 2.8)%] and five minutes post exercise [1.9 (-

2.3, 6.9)]. For context, the minimal difference (%) calculated from the resting values of diastolic blood pressure was 12.1 %. Notably, all outcomes were similar when analyzing the raw absolute values (Figure 1B and Figure 2B).

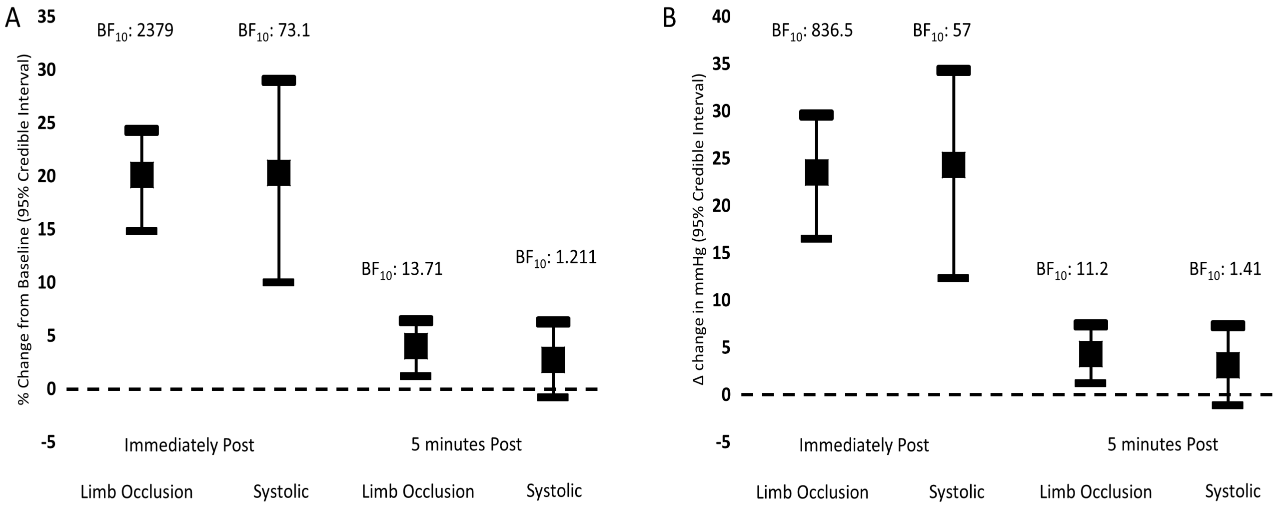

Figure 1. The relative (A) and absolute (B) change from Pre in limb occlusion pressure and systolic blood pressure following isometric knee extension exercise assessed prior to, immediately post and into recovery (5 min post). Bayes factors (BF_{10}) were used to provide evidence for (BF_{10} of ≤ 0.33) or against the null (BF_{10} of ≥ 3.0) hypothesis. The median [noted by black squares] represents the posterior density of the relative (or absolute) change under the alternative hypothesis and the 95% credible interval of that posterior density.

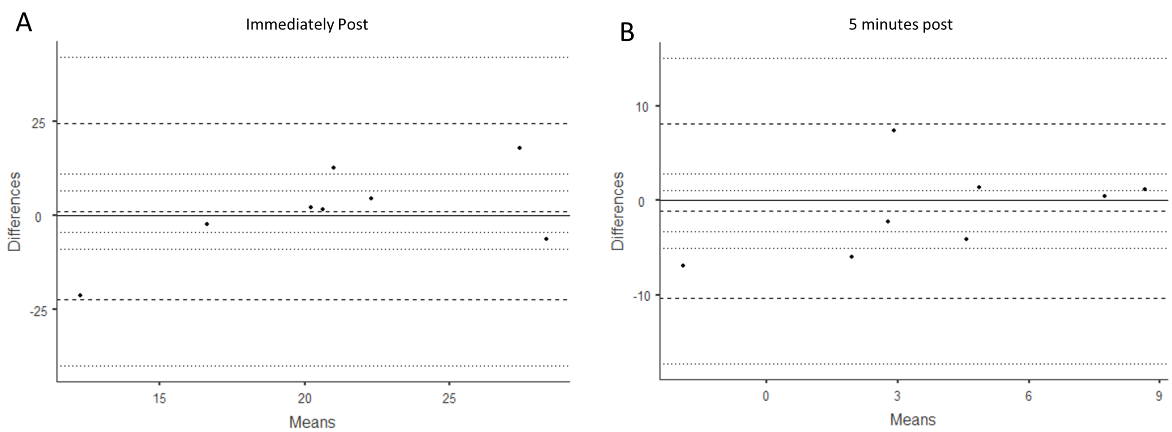

Figure 2. Bland Altman plots for immediately post (A) and 5 minutes post (B). The average change is on the x axis and the difference between measurements is on the y axis. The dashed line in the middle indicates the mean difference (systolic blood pressure – limb occlusion pressure) and the other two dashed lines represent the 95% upper and lower limits of agreement.

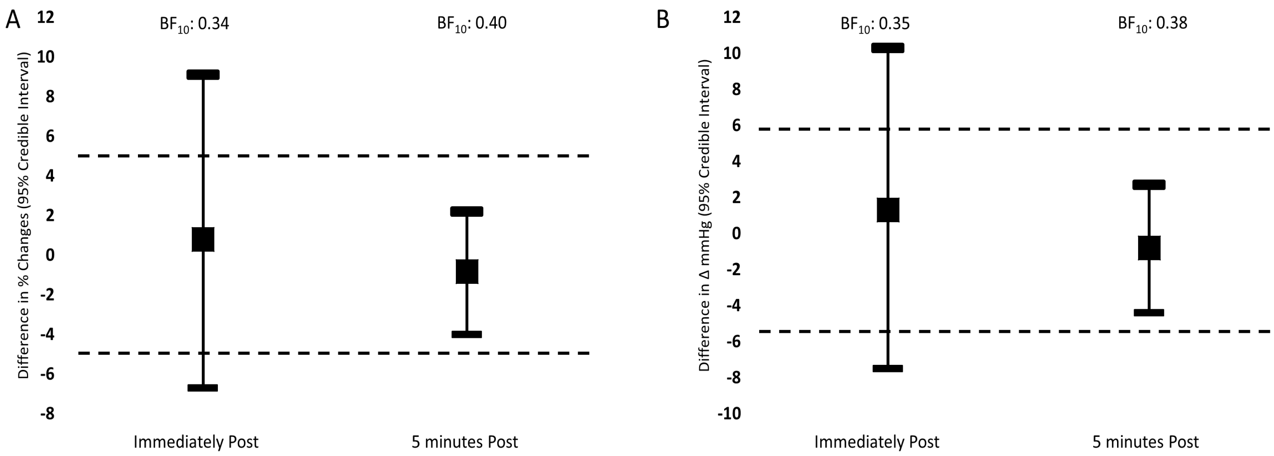

Figure 3. The differences in the acute relative change (from Pre) in limb occlusion pressure and systolic blood pressure following isometric knee extension exercise immediately post and into recovery (5 min post). Bayes factors (BF_{10}) were used to provide evidence for (BF_{10} of ≤ 0.33) or against the null (BF_{10} of ≥ 3.0) hypothesis. The median [noted by black squares] represents the posterior density of the relative (or absolute) differences under the alternative hypothesis and the 95% credible interval of that posterior density. The dotted lines across represent the range of practical equivalence calculated form the minimal difference of the resting limb occlusion value.

DISCUSSION

The primary finding of this study is that changes in limb occlusion pressure are similar (albeit not the same magnitude) to changes in brachial systolic blood pressure. To the best of our knowledge, this is the first research study to compare changes in limb occlusion pressure with changes in traditional measurements of systolic blood pressure. This study provides some evidence to support previous research that has utilized changes in limb occlusion pressure as an alternative measure for changes in blood pressure following exercise, with and without blood flow restriction (3, 10, 13). We elected to use the change in limb occlusion pressure in previous studies, because the cuff used for exercise is already on the participant's arm and can be progressively inflated immediately following blood flow restricted exercise. In other words, this measurement allows for a quicker, more efficient, assessment of the systolic pressure immediately post-exercise without having to deflate the cuff on the arm and apply and inflate a separate cuff. As noted earlier, the deflation of the blood flow restriction cuff may also impact the blood pressure measurement itself (15, 18); potentially underestimating the cardiovascular response to blood flow restricted exercise (3, 7). The results of the current study offers support for the utilization of limb occlusion pressure to quantify changes in systolic blood pressure following exercise. While the Bland Altman plots and equivalency tests provide support of reasonable absolute agreement, the ICC values were relatively low as a result of limited between participant variability in the cardiovascular response to exercise. As the purpose of this study was to see if limb occlusion pressure tracked similarly to systolic blood pressure, we do not feel it appropriate to make the results of our test dependent upon the heterogeneity in the sample recruited. Therefore, emphasis was placed on the results of the Bland-Altman plots and equivalency tests. Future work could build on this with a larger sample size, as this was a limitation with the current study. A noted strength, however, was the direct comparison between two estimates of systolic pressure taken in close proximity to each another.

In conclusion, this study supports the use of limb occlusion pressure measurements as a potential alternative measure of systolic blood pressure (when both cuffs are of similar widths). A notable consideration of this study is that the assessment of limb occlusion pressure can only provide information on the change in systolic blood pressure. Although diastolic pressure can change following resistance exercise, it is fluctuations in systolic pressure that are more commonly observed and considered after completion of physical activity. Nevertheless, this is a limitation of the limb occlusion method.

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