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Recommendations in Post-Exercise Hypotension: Concerns, Best Practices and Interpretation

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Abstract:	Post-exercise hypotension (PEH) is a clinically relevant phenomenon that has been widely investigated. However, the characteristics of study designs, such as familiarization to blood pressure measurements, duration of PEH assessments or strategies to analyze PEH present discrepancies across studies. Thus, identifying key points to standardize across PEH studies is necessary to help researchers to build stronger study designs, to facilitate comparisons across studies, and to avoid misinterpretations of results. Therefore, the goal of this narrative review about methods used in PEH studies was to gather and find possible influencers among characteristics of study design and strategies to analyze blood pressure. Data found in this review suggest that PEH studies should have at least two familiarization screening visits and should assess blood pressure for at least 20 min, but preferably for 120 min, during the recovery from exercise. Another important aspect is the strategy to analyze PEH, which may lead to different interpretations. This information should guide a priori study design decisions.

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Recommendations in Post-Exercise Hypotension: Concerns, Best Practices and Interpretation

For Peer Review

Abstract

Post-exercise hypotension (PEH) is a clinically relevant phenomenon that has been widely investigated. However, the characteristics of study designs, such as familiarization to blood pressure measurements, duration of PEH assessments or strategies to analyze PEH present discrepancies across studies. Thus, identifying key points to standardize across PEH studies is necessary to help researchers to build stronger study designs, to facilitate comparisons across studies, and to avoid misinterpretations of results. Therefore, the goal of this narrative review about methods used in PEH studies was to gather and find possible influencers among characteristics of study design and strategies to analyze blood pressure. Data found in this review suggest that PEH studies should have at least two familiarization screening visits and should assess blood pressure for at least 20 min, but preferably for 120 min, during the recovery from exercise. Another important aspect is the strategy to analyze PEH, which may lead to different interpretations. This information should guide *a priori* study design decisions.

Keywords: Blood pressure; aerobic exercise; resistance exercise; cardiovascular.

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Introduction

Many research groups have been investigating post-exercise hypotension (PEH), which is characterized as a reduction in blood pressure below the values observed either immediately prior to exercise or on a control day (e.g. same conditions but without exercise) [1]. Reasons to study this phenomenon include efforts to understand the capacity of an exercise session to predict the chronic effect and/or to understand the cardiovascular regulation during this window of opportunity [2-4]. Recent meta-analyses have demonstrated that PEH occurs with sufficient magnitude and duration to be clinically relevant [5,6]. Indeed, PEH has been observed for 16 hours after an exercise session [7], and the average blood pressure values for 24-hours post-exercise is lower compared with the same period after a control session [8-10]. However, the magnitude and duration of this response present with significant variability across studies [5,6], which might be attributable to differing methodological approaches for reporting PEH within these studies.

The existing literature on PEH is full of a wide range of varied protocols, methods, and analyses. Common variations include the number of familiarization measurements prior to the actual study; whether subjects are studied supine or, seated, or standing; employment of different types of arterial pressure monitors; and in clinic/lab (clinical) versus ambulatory monitoring. Protocols often vary for the type, duration, and intensity of exercise, and for the timing of post-exercise measurements. In addition, different comparisons are used for data analysis and interpretation: pre vs. post-exercise, exercise session vs. control session, or net effect comparisons of exercise vs. control session. All these conditions must be taken into account for the study design and interpretation of data in studies about PEH. If these characteristics of PEH studies create difficulty for comparisons across studies, then perhaps methodological recommendations about methodological concerns might help to standardize the study of PEH and increase the validity of comparisons. In this narrative review, these aspects are comprehensively discussed.

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Development

Concerns and approaches: from design to interpretation

Due to the exciting prospects for the clinical relevancy of PEH and the need for more research on this phenomenon, we were compelled to explore issues related to experimental design, methodology, and data collection, analysis and interpretation of the PEH studies that should be carefully considered to promote scientific rigor and high reproducibility on this topic. As the aim of this review was to stimulate a comprehensive discussion about methodological concerns in PEH studies, a narrative model was more appropriate and, thus, selected [11]. For this narrative review, literature search was conducted in PubMed database using the term "post-exercise hypotension", in reference lists of systematic reviews about this topic, and also in reference lists of the PEH studies. Moreover, this study followed all ethical standards [12]

Concerns with blood pressure measurements

An important aspect regarding any study of blood pressure measures is the fact that subjects should be sufficiently familiarized with the lab environment and blood pressure measurement procedures before the beginning of the experimental protocol.

Given the variability in blood pressure [13-15], clinical guidelines for assessing hypertension recommend the measurement of blood pressure on two or more visits to determine resting blood pressure, and in each visit, blood pressure should be measured at least twice [16-18]. This is based on studies comparing blood pressure changes between successive visits in which blood pressure decreases substantially from the first to the second visit [19-21], regardless of the interval between the visits (3 days or 14 days) or the initial level of blood pressure (normotensives or hypertensives) [21]. Values obtained on a third visit were similar to those observed on a second visit [21], highlighting the importance of screening visits that include the measurement of blood pressure to familiarize subjects. So that, a stable resting blood pressure can be recorded in the experimental protocol, allowing for greater rigor and reproducibility in the measure of PEH.

Despite the importance of familiarization visits to stabilize resting blood pressure in PEH investigations, some studies have relied on only one [9,22-47] or no [48-52] screening visit with blood pressure measurements before the experiments, and many studies simply have not reported if any blood pressure screening or familiarization had been performed [53-69] (Table 1). While study designs that incorporate both exercise and control session may mitigate this concern by showing no difference in pre-exercise blood pressure between the sessions, studies with a simple pre- versus post-exercise design (i.e. without a control session and/or one comparison session of exercise) are highly susceptible to this limitation [24,29,47,49].

Since post-exercise blood pressure reduction is influenced by its pre-exercise value [5,70], an "unreal" elevated pre-exercise value by the absence of adequate familiarization may inflate PEH. Thus, future studies where PEH is the main outcome should include, at least, 2 familiarization visits in which blood pressure is measured in accordance with reliability and familiarization studies [13-15]. Then, researchers may have more confidence in resting blood pressure obtained during subsequent experimental sessions.

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Timing of post-exercise measurements

The timing of blood pressure measurements after exercise may be one of the main causes for divergent results, impacting the magnitude and determinants of PEH across studies. The variability of experimental designs ranges from evaluating PEH during the first 5-min [67] to first 3-h [22] post-exercise, and extends to 24-h ambulatory blood pressure (ABPM) measurements after exercise. In fact, this variability has made it difficult to determine at what time after exercise the greatest PEH occurs and has introduced debate as to how long it lasts.

The magnitude of clinical PEH is important due to its strong correlation with the chronic hypotensive effect of exercise [39,71,72], allowing for the detection of responders and non-responders to training. Among 37 studies that analyzed blood pressure in the laboratory setting for at least 20 min after exercise [22,24-26,28,29,35,36,42,43,45,47,50-56,62,64-68,71,73-83], 3219 reported no decrease in blood pressure until that time (i.e. 20 min) [25,26,29,35,36,42-44,47,50-56,58,62,64-68,71,73-77,79-81], and the other 5 reported PEH was only at 15 minutes post-exercise [22,28,78,82,83]. Among 31 studies that followed blood pressure throughout the recovery period for at least 60 min [22,24-26,28-30,42,43,47,50,51,53,55,58,62,66,73,76-88], 19 reported the greatest blood pressure decrease after 30 min of recovery period [22,24,28,29,42,47,50,53,58,62,76-78,80,81,83,84,87,88], while 9 reported the same magnitude of PEH at all recovery times [43,51,55,66,73,79,82,85,86], and 3 studies reported the greatest PEH between 15-20 min after exercise [25,26,30]. Finally, all of the 8 studies that measured blood pressure for more than 1 h in the laboratory setting after exercise reported PEH lasting at least 120 min [22,40-42,62,83,84,88]. Taking into account the aforementioned information, future studies aiming to evaluate PEH should assess blood pressure between 20 and 120 min after the exercise to increase the chance for identifying PEH.

The duration of PEH is important to reveal whether the hypotensive effect can have a clinical impact reducing the subject's cardiovascular overload and risk for a long period of time [1]. Ambulatory blood pressure monitoring is the only adequate measure to evaluate this benefit. However, interpretations of ambulatory blood pressure recordings after exercise are sometimes confounded by the use of prolonged averaging periods (e.g. 12- or 24-h mean) [8,9,38,57,82,89,90]. While studies that report a reduction in mean 12- or 24-h blood pressure provide useful information related to the health benefits of exercise, this approach does not lend itself to a determination of the duration of PEH, which has erroneously been reported as lasting 24 h. The problem is that values early in a timeframe can generate the appearance of a blood pressure reduction which may be resolved by the end of the averaging timeframe. Thus, authors should opt for reporting hour-to-hour analysis, as

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demonstrated by Pescatello et al [91] where mean blood pressure stayed lower than pre-exercise values for 13 hours.

It is also important to note that post-exercise ambulatory blood pressure analysis allows for investigating the effects of exercise in real life conditions. However, some care is needed for comparing days with similar daily activities, such as conduct the experiment on the same day of the week (e.g. exercise and control sessions conducted on Monday) or at least to avoid conducting experiments on days with very different activities (e.g. a business day and a weekend day). Another important aspect is to start ambulatory blood pressure recordings at the same time of day in all experimental sessions, since average ambulatory blood pressure values are higher when monitoring was started in the morning than in the afternoon [92].

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Body position for blood pressure measurements

The body position of subjects before the exercise and during the recovery period after the exercise is an important experimental consideration for PEH studies and impacts the interpretation of the results, especially when considering hemodynamic mechanisms. An extensive review of the literature suggests that studying subjects in the supine position and in the seated position are both common [2], but some studies have not reported the adopted body position [93,94]. In addition, to our knowledge, no study has investigated PEH in the upright position. This inconsistency across studies limits comparisons. However, for some purposes, each position may be justified.

The supine position favors hemodynamic measurements without the interference of orthostatic stress [95]. However, it may decrease the generalizability of some findings, as outside of the construct of research studies, it is less common for individuals to recover from exercise in the supine position. In contrast, blood pressure measurements performed with subjects in a seated position may be more relevant, since many persons seat after exercise to rest, talk or do any other task in the sitting position. Actually, due to the orthostatic stress during sustained (1 h or more) promoted by seated position sitting after exercise, diastolic blood pressure increases over time when this position is sustained [95]. This is likely to be secondary to decreased venous return, which deactivates the cardiopulmonary reflex, increasing peripheral sympathetic nerve activity, systemic vascular resistance and diastolic blood pressure [96]. In the laboratory setting, this influence of body position is sufficient to flip the hemodynamics which underlies PEH, from a decrease of systemic vascular resistance when recovery occurs in the supine position to a decrease of cardiac output when recovery occurs in the seated position [43,67,68].

Therefore, there are valid rationales for studying subjects in either the supine or the seated position in PEH studies, depending on the experiment's objectives. However, authors should report which body position was used in the studies and should use the same body position pre- and post-exercise in both control and exercise sessions. Likewise, authors should discuss results within the context of the chosen body position. These steps may help avoid misinterpretations.

Method of blood pressure measurement

Due to the sometimes-small magnitude of relevant blood pressure reductions associated with recovery from exercise, rigorous methods of measuring blood pressure are essential in the study of PEH. While auscultatory measurement is the most common method for assessing blood pressure [97], manual sphygmomanometry, with its susceptibility to observer bias, two-digit preference and environmental noise, may not be so appropriate if it was not made by an experienced evaluator, which minimizes but do not exclude the observer bias. Thus, many researchers of PEH uses automated blood pressure monitoring [22,25,26,28,29,32,34,40,42,44,46,47,49-51,53,54,59,62,65,71,73,76,86,87,94,98-101].

While various groups have established criteria that such devices must fulfill to be validated (e.g. Association for the Advancement of Medical Instrumentation, British Hypertension Society, European Society of Hypertension), the criteria are focused on clinical testing and do not generally require testing specific to exercise or recovery from exercise. Thus, while there are validations of automated oscillometric devices at rest [16,18], to the best of our knowledge, no study has tried to validate oscillometric devices for use during exercise or the recovery after exercise. Nevertheless, oscillometric devices actually measure mean blood pressure and estimate systolic and diastolic blood pressure through algorithms based on the range of pulse pressure [97]. Thus, when pulse pressure changes, the algorithm is affected [102]. As blood pressure reductions after exercise are usually greater for systolic than diastolic blood pressure [5,6,70], pulse pressure decreases during exercise recovery, and this change may introduce bias into oscillometric-estimated systolic and diastolic blood pressures. Indeed, when assessed at the same time, auscultatory blood pressure showed a decrease in systolic and diastolic blood pressures after exercise, which was not detected by automated oscillometry that only reveals a reduction of mean blood pressure [87]. However, oscillometric method minimizes observer bias [102] and is less impacted

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by environmental noise than manual auscultation. Thus, when employing oscillometric devices, mean blood pressure should be considered.

In contrast, at least one automated auscultatory device has been validated for exercise [103] and such device is gaining use in PEH studies [40,42,47,94,101]. Finger monitors that rely on photoplethysmography (e.g., Finometer) have been validated for the study of PEH [78], and this has encouraged other research groups to use this technique [30,33,35-37,43,48,55,56,61,67,68,74,75,77,78,80]. However, while these devices can accurately track beat-to-beat changes in blood pressure, they have limitations for determining absolute values for blood pressure [104].

In brief, automated oscillometric measurements have advantages, mainly in mitigating investigator bias, but their validity is not as well established as automated auscultatory measurements for PEH studies. Considering that auscultatory is also widely used measurement in PEH studies, its limitation can be minimized by appropriate training and blinding of the observer.

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Different approaches to quantify PEH

Evaluating the occurrence of PEH and quantifying its magnitude requires a comparison of post-exercise blood pressure to some reference, and a variety of blood pressure measurements have been used as this reference value across studies (e.g. measurements taken immediately before the exercise bout, or from a control session without exercise). In addition, the magnitude of PEH has been calculated with different methods, with some incorporating changes over time determined from a control session [105], an example can be seen in the Figure 1.

In many studies [24,25,28-31,34,37,39,42,44,46-49,51,54,56,59,62-65,67-69,71,73,77,78,80,82,83,85-87,90,93,99,100,106-112] (shown in Table 1), PEH has been calculated as simply the difference between post- and pre-exercise blood pressures, what we will define as "PEH_I" (PEH_I = post-exercise blood pressure – pre-exercise blood pressure). Other studies which have included both an exercise and a control session, and have calculated PEH as the difference between post-exercise and post-control blood pressures, what we define as "PEH_II" (PEH_II = post-exercise blood pressure – post-control blood pressure) [7-9,22,25-28,30-33,35,38-40,44,50-52,55-57,60-65,67,68,77,78,80,82,84,87,89,90,94,98-100,107,109-112] (Table 1). Finally, some studies [23,25,30,36,37,43,45,46,48,53,58,66,74-76,79,81,87,88,90,100,101,106,107,110,112] (Table 1) have taken a more complex approach, calculating PEH as the net effect, i.e. the difference between responses observed in an exercise session and a control session, which we define as "PEH_III" [PEH_III = (post-exercise blood pressure – pre-exercise blood pressure) – (post-control blood pressure – pre-control blood pressure)].

Thus, researchers should consider the advantages and disadvantages for each approach to data analysis when they are designing their study. PEH_I has the advantage of demanding only one experimental session, with as few as two blood pressure measurements (pre- vs. post-exercise); however, we would strongly suggest the inclusion of more measurements over time rather than the bare minimum of two. In contrast, both PEH_II and PEH_III demand two data collection sessions, performed on different occasions (exercise vs. control). Per session, there is a minimum of one (post-exercise and post-control for PEH_II) or two (pre- and post-exercise/post-control for PEH_III) blood pressure measurements. Again, more measurements across time are desirable.

As studies using PEH_I require less time to execute and fewer data collection sessions, it is not surprising that this approach has been employed in many studies. However, PEH_I does not take into account possible changes in blood pressure that can happen across time independently of exercise (e.g., circadian effects), which can only be controlled by the inclusion of a control session in the study design, as done for PEH_II and PEH_III analysis. The inclusion of a control session as part of the experimental design and analysis in PEH mitigates against any overlying time effect. For example, some studies [8,81,90,106,107,109-111] observed no decrease in blood pressure after an exercise bout when relying on PEH_I analysis, but observed an increase in blood pressure from before to after a control session, showing that time alone is associated with increases in blood pressure under their specific experimental conditions. In such cases, PEH_II or PEH_III analysis can demonstrate that the exercise session had a measurable hypotensive effect, blunting the blood pressure increase that was observed with the control session [8,81,90,106,107,109-111]. Based on these arguments, whether or not a particular exercise session can promote PEH can only be clearly determined if time effects are controlled by a control session. Then, both PEH_II and PEH_III calculations can be employed to address this issue. On the other hand, if the objective is to compare expected PEH among different exercises protocols, instead of detecting its occurrence, PEH_I may be an option to save time.

PEH_II is often employed when studies rely on ambulatory blood pressure monitoring [7-9,23,27,38,57,82,89,90,109,112] because of the challenges in using an ambulatory blood pressure monitor for

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more than 24h (i.e., these studies do not include a pre-exercise 24-h recording, just a post-exercise and post-control recording). That said, there are also many studies using this analysis for laboratory-based blood pressure measurements [22,25,26,28,30,32,33,35,39,40,44,50-52,55,56,60-64,67,68,77,78,80,84,94,98,99,107]. The main limitation of PEH_II analysis is that it does not account for day-to-day variation in resting (pre-exercise) blood pressure [113]. Pre-intervention blood pressure might be different between the exercise and control session, confounding the results obtained with PEH_II analysis.

PEH_III analysis overcomes the main limitations of PEH_I and PEH_II, controlling for time effects and day-to-day variation in resting blood pressure. However, it demands two experimental sessions and at least two blood pressure measurements during each session (ideally more). In addition, there are some disadvantages beyond the obvious additional time requirements for conducting studies. The PEH_III value has more degrees of freedom, which decreases its reproducibility and increases the number of subjects needed in these studies [105]. This makes a prior sample size calculation even more important when designing protocols which will use PEH_III analysis.

Therefore, as stated before, all these procedures for calculating PEH are being used in the literature. All of them have advantages and disadvantages, and they may lead to contradictory outcomes. Thus, when designing, analyzing, and interpreting results about PEH, researchers should take into consideration these strengths and limitations. In addition, future research should relate these different approaches with meaningful clinical outcomes.

*** Insert the figure 1 here.**

Reporting results

Many studies include results for both systolic and diastolic blood pressure [22-24,27,31,38,39,45,52,62,65,66,68,69,71,73,76,80,83,89,94,109,110,112], whereas others report results for mean blood pressure [30,32,40,42,47,48,54,56,67,74,99,101]. It is possible that this is a reflection of researchers with a more clinical orientation versus those who focus on systemic hemodynamics and cardiovascular regulation. Based on the limitations exposed about oscillometric measurement, mean blood pressure should be reported in PEH studies employing this method of measurement. Using auscultatory method, systolic and diastolic represent the primary data, while mean blood pressure is secondary (calculated). Systolic and diastolic blood pressure have been more often related to risk for mortality and disease development [114], reflecting a clinical orientation, while mean blood pressure lends itself to discussions of the determinants of PEH. Thus, the best conduct would be to report all three blood pressure parameters in future studies with auscultatory PEH.

Another rationale for reporting all three parameters, is that some studies only report systolic [33,36,37,46,51-53,63,66,73] or diastolic blood pressure [64] reductions in response to exercise, rather than finding all blood pressure parameters following the same pattern. This is likely to be more than a statistical underpowering of studies (and a type II error) and may reflect some of the complicated physiology which underlies PEH in some contexts. For example, if one assumes, somewhat simplistically, that changes of systolic blood pressure are more related to cardiac output and changes of diastolic blood pressure are more related to systemic vascular resistance, divergent patterns of PEH between systolic and diastolic blood pressure become reasonable predictions. After performing aerobic exercise, PEH is most often mediated by a decrease of systemic vascular resistance, except in some special conditions in which cardiac output is reduced [2,3]. In contrast, resistance exercise generally causes PEH by a decrease in cardiac output [79,109] or a mixture of patterns across subjects [110,111]. However, studies which find decreased cardiac output can also report a decreased diastolic blood pressure [49,82,107]. Likewise for reductions in systemic vascular resistance and systolic blood pressure [33,34,36,43,44,58,60,63,75,79,81,84,94]. Thus, the “simple” attribution of isolated effects on systolic and diastolic blood pressure does not fit all observations. This is likely due to the more integrated nature of the responses, with cardiac and vascular changes being linked by physiological compensation, with superimposed baroreflex regulation of the heart [35] and peripheral vasculature [33]. Again, it is better to report all three blood pressure parameters in future studies on PEH, especially if they portray divergent profiles following exercise.

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Reporting individual responses: Do group means describe what is happening?

PEH can be observed in individuals with a broad range of characteristics [8] and after different exercise protocols, including aerobic, dynamic resistance, and isometric exercise [5,6]. However, within a given study, it is expected that not all subjects present a uniform blood pressure decrease after exercise (as shown in the Figure 2). As a further demonstration, consider the Figure 2, which shows how a study may find no change in mean systolic blood pressure after a session of aerobic exercise (panel a) despite the presence of PEH in the most of the subjects (panel b). Indeed, a previous study that evaluated ambulatory blood pressure after resistance and walking exercises in subjects with peripheral artery disease did not observe any difference in mean values, but individual responses revealed that many subjects presented clinically relevant blood pressure reductions [115].

Along these lines, Forjaz et al [8] observed no change in the group mean blood pressure for hypertensive subjects and a decrease in the group mean blood pressure for normotensive subjects, yet in both groups there were subjects who increased, decreased, or maintained blood pressure after the exercise session.

As in other realms of research, we are recognizing that these different individual responses may be of great importance. There may be a strong rationale to classify subjects as "responders" and "non-responders" [73,115]. However, similarly to what is debated for randomized control trials, there is still no consensus on how to define a true "response": whether it should be based on the presence of clinically relevant change [116] or on clearly measurable change [117]. In fact, the clinically relevant change for PEH has yet to be defined. An option might be when blood pressure response to exercise overcome the error of the blood pressure measurement [118]. However, clearly measurable change is still not clear, since very few studies have adequately investigated the reproducibility of individual PEH patterns [105].

Thus, this is an open area for future investigations that needs to be addressed. Studies employing analysis of group mean data revealed the clinical relevance of PEH, but individual response analysis may be necessary to advance comprehension of this phenomenon, and clarifying if there is a role for responders and non-responders.

*** Insert the figure 2 here.**

*** Insert the Table 2 here.**

Analysis of individual responses have been receiving highlight in the literature, and this approach shows great promise as a tool to identify who is responsive to a specific intervention based on an acute evaluation. However, the lack of standardization of how PEH is assessed creates a barrier for moving this approach forward.

Conclusions

Based on this narrative review, it is possible to recommend that rigor and reproducibility can be increased in PEH studies by inclusion of familiarization sessions for blood pressure measurements as well following some recommendations (Table 2). Investigators should be sure that screening visits are sufficient to familiarize subjects so that pre-exercise values are stable and representative of the individuals resting blood pressure. Apart from familiarization, authors who desire to observe blood pressure decreases are strongly

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encouraged to assess blood pressure at least for 20 min after exercise, but preferably for 120 min. They also should employ blood pressure measures considering their limitations. Finally, there are several statistical approaches for evaluating PEH, and the pros and cons of each must be considered in parallel to study design, and not after the study has been completed, since the choice impacts sample size determinations and can change the conclusion of study, illuminating or hiding the presence of PEH.

Finally, this is a narrative review that did not intend to completely explore the theme. Some important recommendations have been highlighted, but other researchers might have additional concerns/recommendations. Thus, a broad discussion by a panel of experts leading to a task force about the methodological concerns in PEH studies should be encouraged.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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Figure Legends

Figure 1 - Demonstrative of post-exercise hypotension (PEH) evaluated by different methods. Systolic blood pressure responses to exercise (continuous line) and control (dotted line) session. (Panel a) - PEH_I post-exercise blood pressure - pre-exercise blood pressure; (Panel b) - PEH_II: post-exercise blood pressure - post-control blood pressure; (Panel c) - PEH_III: [(post-exercise blood pressure – pre-exercise blood pressure) – (post-control blood pressure – pre-control blood pressure)].

Figure 2 - Hypothetical data of systolic blood pressure (mmHg) assessed pre and post an exercise session, demonstrating how group's means can mask important individual responses. Panel a): data presented by means; Panel b) data presented by individual responses.

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Table 1. Concerns and approaches in post-exercise hypotension studies.

Author and Year	Days of Screening	Time of Blood Pressure Measurements Post-exercise	Control or Comparative Session yes (y) / no (n)	Approach (I - Pre vs. Post) / (II - E vs. C) / (III - NE)
Angadi (2015)[22]	1	3hs / every 15min	Y	II
Aprile (2016)[98]	2	1h	Y	II
Augeri (2011)[23]	1	ABPM	Y	III
Azevêdo (2017)[53]	NR	1h / every 15min	Y	III
Birk (2012)[54]	NR	10min	Y	I
Bisquolo (2005)[99]	NR	45min	Y	I, II
Bonsu (2016)[24]	1	1h / every 10min	N	I
Brandão (2002)[82]	2	15;30;60;90min/ ABPM	Y	I, II
Brito (2014)[55]	NR	10;30;50;70;90min	Y	II
Brito (2015)[107]	2	45min	Y	I, II, III
Brito (2017)[89]	2	ABPM	Y	II
Carter III (2001)[56]	NR	5min	Y	I, II
Cavalcante (2017)[25]	1	1h / every 15min	Y	I, II, III
Ciolac (2009)[57]	NR	ABPM	Y	II
Cleroux (1992)[84]	3	30;60;90 min	Y	II
Coats (1989)[58]	NR	1h / every 10min	Y	III
Collier (2010)[48]	0	40;60min	Y	I, III
Costa (2016)[73]	2	1h / every 10min	Y	I
Cucato (2015)[106]	2	45min	Y	I, III
Cunha (2016)[26]	1	20;40;60min	Y	II
Dantas (2016)[27]	1	ABPM	Y	II
Dawson (2008)[59]	NR	60min	N	I
Dos Santos (2014)[119]	1	1h / every 15min	Y	II
Dujic (2006)[49]	0	30;60min	N	I

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Endo (2012)a[29]	1	1h / every 15min	N	I
Endo (2012)b[28]	1	1h / every 15min	Y	I, II
Esformes (2006)[60]	1	45min	Y	I, II
Figueiredo (2015)[50]	2	1h / every 10min	Y	I, II
Floras (1989)[85]	3	1h / every 5min	Y	I
Floras (1992)[93]	3	1h / every 5min	Y	I
Forjaz (1999)[86]	2	90min / every 5min	Y	I
Forjaz (2000)[8]	2	ABPM	Y	II
Forjaz (2004)[81]	2	15;30;60;90min ABPM	Y	II, III
Franklin (1993)[51]	0	1h / every 15min	Y	I, II
Gagnon (2012)[30]	1	10;30;50;70;90min	Y	I, II, III
Goessler (2015)[31]	1	ABPM	Y	I, II
Hagberg (1987)[83]	4	1h / every 10min	Y	I
Halliwill (1996)[33]	1	60min	Y	II
Halliwill (2000)[32]	1	1h	Y	II
Hamer (2006)[61]	NR	30min	Y	II
Harvey (2005)[34]	1	45;90min	Y	I
Headley (2008)[76]	2	1h / every 10min / ABPM	Y	III
Headley (2017)[100]	1	1h / every 10min / ABPM	Y	I, II, III
Hecksteden (2013)[71]	2	10min / 1h / 24h	N	I
Heffernan (2007)[35]	1	20min	Y	I, II
Isea (1994)[94]	NR	30min;1h;2h;3h;4h	Y	II
Jones (2007)[36]	1	20min	Y	III
Jones (2008)a[75]	1	5;10;15;20	Y	III
Jones (2008)b[74]	1	5;10;15;20	Y	III
Keese (2012)[62]	NR	2h / every 10min	Y	I, II
Lacombe (2011)[37]	1	60min	Y	I, III
Legramante (2002)[108]	3	60;90min	N	I

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Lehmkuhl (2005)[38]	1	ABPM	Y	II
Liu (2012)[39]	1	30min	Y	I, II
Lockwood (2005)[40]	1	30;60;90min	Y	II
MacDonald (1999)[78]	5	1h / every 15min	Y	I, II
Mac Donald (2000)a[77]	5	1h / every 15min	Y	I, II
MacDonald (2000)b[80]	5	1h / every 15min	Y	I, II
Mach (2005)[52]	0	30;60;90min	Y	II
McCord (2006)[101]	1	30;60;90min	Y	III
Moreira (2014)[72]	NR	60min	N	I
New (2013)[63]	NR	30;60;90min	Y	I, II
Notarius (2005)[64]	NR	10min	Y	I, II
Pricher (2004)[42]	1	2h / every 20min	N	I
Queiroz (2009)[87]	2	1h / every 5min	Y	I, II, III
		ABPM		
Queiroz (2013)a[109]	2	60min	Y	I, II
		ABPM		
Queiroz (2013)b[110]	2	60min	Y	I, II, III
Queiroz (2015)[90]	2	45min/ABPM	Y	I, II, III
Queiroz (2017)[111]	2	ABPM	Y	I, II
Raine (2001)[43]	1	1h / every 10min	Y	III
Rezk (2006)[79]	NR	15;30;60;90min	Y	III
Rossow (2010)[44]	1	30;60min	Y	I, II
Santaella (2006)[45]	1	30;60min	Y	III
Santana (2013)[46]	1	60min	Y	I, III
Somers (1991)[65]	NR	ABPM	Y	I, II
Souza (2016)[66]	NR	2h / every 10min	Y	III
Taylor-Tolbert (2000)[7]	4	ABPM	Y	II
Takahashi (2000)[68]	NR	10min	Y	I, II
Takahashi (2005)[67]	NR	5min	Y	I, II
Teixeira (2011)[88]	2	30;60;90;120min	Y	III

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Terblanche (2012)[112]	2	ABPM	Y	I, II, III
Tibana (2015)[120]	NR	10;30;60min	Y	II, III
Wallace (1997)[9]	1	ABPM	Y	II
Wilcox (1982)[69]	NR	30min	Y	I
Wilkins (2004)[47]	1	2hs / every 20min	N	I

AMBP – Ambulatory blood pressure; NR – non-reported; Pre vs. Post – Comparing pre values with post-exercise values; E vs. C – Comparing exercise with control sessions; NE – Evaluating net effect.

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Table 2. Recommendations to guide post-exercise hypotension (PEH) studies

- Perform, at least, two screening visits for blood pressure measurements before the first study day
- Track blood pressure for at least 20 min but preferably 120 min after exercise
- Determine the statistical approach before the study design
- If discussing mechanisms, include presentation of the mean blood pressure
- Avoid drawing conclusions on the duration of PEH from data averaged over long timeframes

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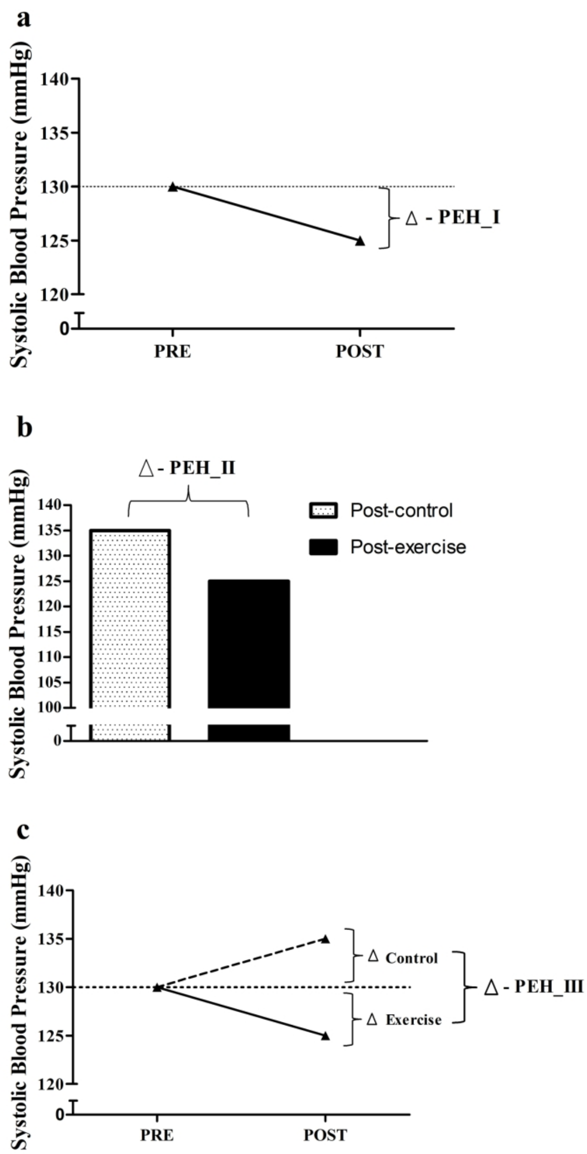

Figure 1

146x272mm (300 x 300 DPI)

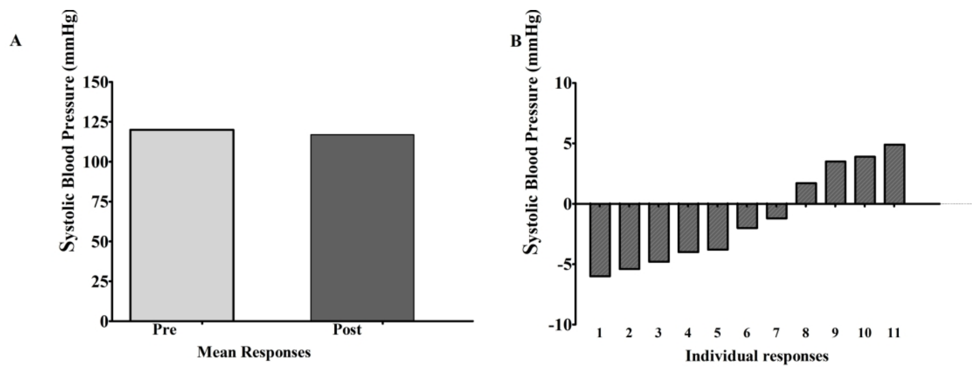

Figure 2

261x98mm (300 x 300 DPI)