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Post-exercise hypotension in concurrent training: a systematic review

A hipotensão pós-exercício no treinamento concorrente: uma revisão sistemática

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Abstract – Physical exercise is capable to reduce blood pressure (BP) acutely in a phenomenon described as post-exercise hypotension (PEH). However, the acute effect of concurrent training on PEH needs clarification. The present review aimed to verify and summarize the acute effect of concurrent training on PEH in normotensive and hypertensive subjects. The search was carried out in the databases PubMed, Scielo, and Lilacs, and resulted in 3806 articles. Only 14 studies met the eligibility criteria and were selected. According to included studies, concurrent training can promote PEH regardless of the order, volume, and intensity prescribed, being an effective strategy in the control of arterial hypertension. There is no consensus in the literature regarding the best prescription strategy, as well as the order of execution of the types of exercis

Key words: Blood pressure; Exercise; Post-exercise hypotension; Systematic review.

Resumo – *O exercício físico tanto aeróbio como de força é capaz de reduzir a pressão arterial (PA) de forma aguda em um fenômeno descrito como hipotensão pós-exercício (HPE). Contudo, ainda não está claro o efeito agudo do treinamento concorrente na indução da HPE. A presente revisão teve por objetivo verificar e sumarizar o efeito agudo do treinamento concorrente na HPE em indivíduos normotensos e hipertensos. A busca foi realizada nas bases de dados, PubMed, Scielo e Lilacs e resultou em 3806 artigos. Somente 14 estudos atenderam aos critérios de inclusão e foram selecionados. Segundo os artigos incluídos, o treinamento concorrente é capaz de gerar HPE independente da ordem de execução, do volume e da intensidade prescritas, sendo uma eficiente estratégia no controle da hipertensão arterial sistêmica. Não há consenso na literatura em relação a melhor estratégia de prescrição, bem como ordem de execução dos exercícios.*

Palavras-chave: *Exercício físico; Hipotensão pós-exercício; Pressão sanguínea; Revisão sistemática.*

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INTRODUCTION

Cardiovascular diseases (CVD) are a major public health problem. According to recent data from the World Health Organization[1], CVD is the leading cause of death in the world. One of the main risk factors associated with the development of CVD is arterial hypertension, which increased prevalence in the past few years[2]. Arterial hypertension affects more than 32% of Brazilian adults[2] with high prevalence in the elderly and women[3,4].

Currently, arterial hypertension is characterized by a sustained elevation in blood pressure (i.e., systolic blood pressure ≥ 140 mmHg and/or diastolic blood pressure ≥ 90 mmHg)[2]. Arterial hypertension is considered the most treatable and preventable morbidity among risk factors for developing CVD. However, the arterial hypertension treatment costs generate a high impact on the loss of labor productivity and family income, estimated in Brazil at more than R$ 12 billion between 2006 and 2015[5]. Thus, preventing arterial hypertension is an important and urgent priority of public health.

Lifestyle changes (i.e., including a lower intake of sodium, alcohol and fat, smoke cessation, and physical activity) are the main strategy for the control and prevention of arterial hypertension[2]. Among the behavioral factors, physical activity has been widely investigated in arterial hypertension management. Both aerobic training[6-10] and strength training[11-14] are able to reduce blood pressure chronically, as well as acute effect know as post-exercise hypotension (PEH)[15]. Although the literature addressed the efficacy of aerobic and strength training on hypertension treatment, the concurrent training (a combination of aerobic and strength training within the same session or in separate sessions) must be equally investigated.

Thus, it is necessary to summarize the existing literature that investigated the acute effects of concurrent training on blood pressure measurements. Also, it is important to explore whether aspects of concurrent training promote major PEH in comparison with other training models. Such information will help to provide an evidence-based for public health policy in order to recommend the concurrent training for prevention and treatment for arterial hypertension. The purpose of the present study was to review and synthesize the acute effects of concurrent on PEH in hypertensive and normotensive adults.

METHOD

Design and search strategy

This review follows the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement[16]. The search was performed in the following electronic databases: PubMed, Scielo, and Lilacs. We restricted to publications in English or Portuguese language until June 2019. The search strategy included a combination of keywords: post-exercise hypotension, post-exercise hypotensive response, blood pressure lowering, concurrent training, exercise training, exercise, as follows:

"Post-exercise hypotension" AND "Concurrent training" AND "Exercise training" AND "exercise"- "Post-exercise hypotensive response" AND "Concurrent training" AND "Exercise training" AND "exercise"- "Blood pressure-lowering" AND "Concurrent training" AND "Exercise training" AND "exercise"- "Post-exercise hypotension" OR "Post-exercise hypotensive response" OR blood pressure lowering.

Eligibility criteria

We included randomized clinical trials. Studies with human subjects over 18-yrs from both males and females were considered eligible. Studies that analyzed the acute effects of concurrent training compared to other training models on the blood pressure of hypertensive and normotensive subjects were also considered eligible. However, studies that did not present blood pressure measures before and after training for at least 30 minutes were excluded.

Data extraction

The screening in titles and abstracts was performed by one reviewer (DM) in order to identify potentially eligible studies. The full-texts were also assessed and considered according to the inclusion and exclusion criteria of this review. Then, the reviewer extracted data from included studies. Another reviewer (TLVPO) checked the information for completion and accuracy. The following information was extracted from the studies: sample size, mean age, rest blood pressure, training protocol, and main results.

Appraisal of study quality

Two independent reviewers (DM and TLVPO) assessed the methodological quality of the included studies by using the risk of bias Physiotherapy Evidence Database (PEDro) scale[17].

RESULTS

Initially, the search identified 3806 potential citations (Figure 1). After removing the duplicates, 2587 articles remained for analysis. Then, 2545 were excluded based on titles and abstracts. Another 28 citations were excluded, respectively 20 article reviews, 04 studies that did not evaluate acute effect on blood pressure, and other 04 that did not compare concurrent training with other training models.

Thus, fourteen studies met the inclusion criteria and were included in this review.

The articles included were published from 2011 to 2017. Ten studies were conducted with normotensive subjects. Also, four studies presented hypertensive subjects. The age group ranged from 20 to 65 years, 286 subjects participated in the studies, 122 men and 164 women, 177 normotensive, and 109 hypertensive subjects. All studies are randomized controlled trials that observed the acute effect of a single exercise session. Training

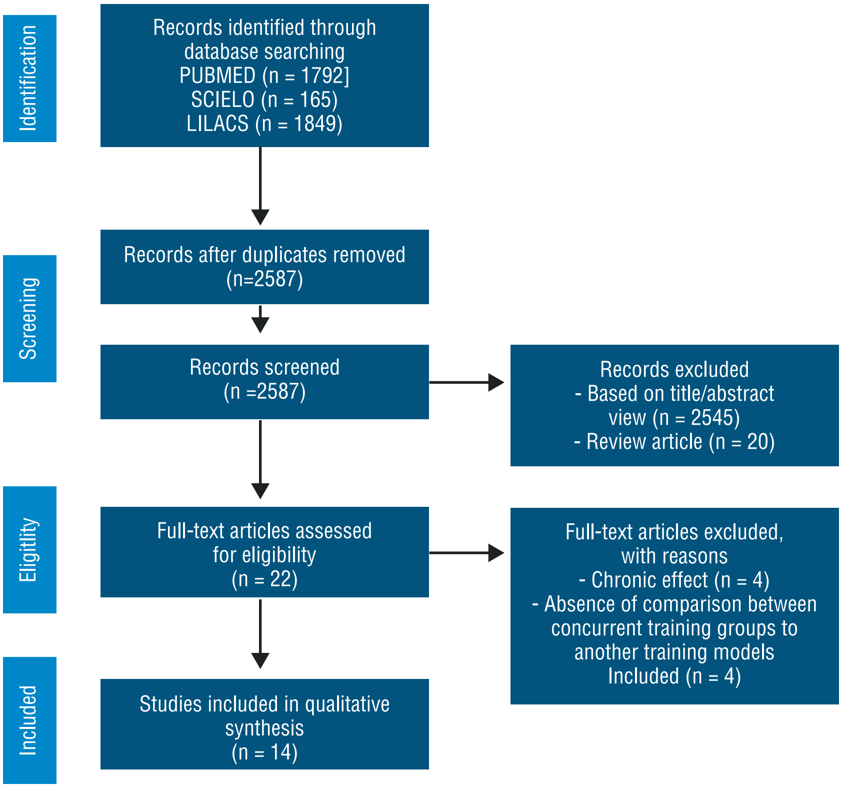

Figure 1. Flowchart of the systematic review.

protocol presented duration from 45 to 60 minutes. The aerobic training was performed at 40-80% of peak VO_2, 50-70% of heart rate reserve, 40-75% of maximal heart rate. The strength training was performed at 40-80% of 1 repetition maximum.

The blood pressure was measured after 30, 60, and 120 minutes of the end of the training, as well as 6 hours and 24 hours later. Systolic blood pressure ranged from 111 to 162 mmHg and diastolic blood pressure ranged from 68 to 95 mmHg.

The main characteristics of the studies included are available in Table 1.

The studies showed higher PEH when aerobic training was performed before strength training compared to the opposite[19,20]. However, the other four studies did not find differences regarding the order of execution of concurrent training[21-24]. When high intensity, great PEH[25,26].

The duration of PEH was longer after concurrent training in comparison to other training models[27-29]. Greater magnitude PEH was observed for aerobic training compared to concurrent training[27] and for concurrent training in comparison to strength training[11]. Saccomani et al.[22] found higher and longer PEH for concurrent training compared to aerobic and strength training. However, Ruiz et al.[30] did not observed any difference between groups (e.g., aerobic, strength, and concurrent). Results from Santos et al.[31] showed greater PEH when performed eccentric strength training prior to aerobic training in comparison to traditional strength training prior to aerobic training.

Table 1. Description of the selected studies on participants' characteristics, training protocol and post-exercise hypotension.

Study	Participants	Rest Blood Pressure		Training protocol	Duration	Results
		SBP	DBP			
Keese et al.[28]	21 normotensive men (20.7 ± 0.7 yr)	111.52 ± 2.56 mm Hg	73.86 ± 3.62 mm Hg	CG: 60 min rest AG: 60 min cycle ergometer at 65% $VO_{2\ peak}$ ST: 8 strength exercises in 3 sets of 6-8 rep at 80% 1RM CTG: 6 strength exercises in 2 sets at 80% 1RM + 30 min cycle ergometer at 65% $VO_{2\ peak}$	BP monitoring for 120 min	Magnitude reduction BP similar to AG, ST, CTG Longer PEH duration in SBP for AG, CTG. Longer PEH duration in DBP for AG.
Ferrari et al.[29]	20 hypertensive men (65.3± 3.3 yr)	120 ±13 mm Hg	71 ± 10 mm Hg	CG: 45 min rest AG: 45 min treadmill at 65-70% $VO_{2\ max}$ CTG: 4 strength exercises in 4 sets of 8 rep at 70% 1RM+ 25min treadmill at 65-70% $VO_{2\ max}$	BP monitoring for 60 min and 24-hour ambulatory monitoring	Magnitude reduction BP similar for AG and CTG Longer PEH duration in DPB for AG
Pinto et al.[23]	30 normotensive women (23.2 ± 4.6 yr)	110.3 ± 8.2 mm Hg	69.2 ± 7.0 mm Hg	SAG: 4 strength exercises in the water in 3 sets of 20s each + 18 min of aerobic exercises in the HR from LT ASG: 18 min of aerobic exercises in the HR from LT + 4 strength exercises in the water in 3 sets of 20s each	BP monitoring for 120 min	Similar reduction BP for GSA and GAS in 10 min for DBP and MBP
Tibana et al.[11]	30 normotensive women (33.1± 5.0 yr)	122.7 ± 9.2 mm Hg	77.8 ± 9.6 mm Hg	CG: 60 min rest SG: 6 strength exercises in 3 sets of 8 a 12 rep at 80% 1RM CTG: 30 min of treadmill at 65-70% HRR + 6 strength exercises in 3 sets of 8 a 12 rep at 80% 1RM	BP monitoring for 60min	Greater magnitude of BP for GCT
Lovato et al.[21]	9 normotensive men (24.8 ± 1.1yr)	119 ± 3.8 mm Hg	70.4 ± 2.65 mm Hg	SAG: 8 strength exercises in 3 sets of 10 a 15 rep at 60% 1RM + 50 min cycle ergometer at 60% $VO_{2\ peak}$ ASG: 50 min cycle ergometer at 60% $VO_{2\ peak}$ + 8 strength exercises in 3 sets of 10 a 15 rep at 60% 1RM	BP monitoring for 60min	Magnitude reduction BP and PEH duration equal between groups
Menêzes et al.[24]	19 hypertensive women (57± 2 yr)	130 ± 3.3 mm Hg	68 ± 2 mm Hg	CG: 50 min rest SAG: 7 strength exercises in 3 sets of 10 rep at 50 % 1RM + 30 min treadmill at 50-60% HRR ASG: 30 min treadmill at 50-60% HRR + 7 strength exercises in 3 sets of 10 rep at 50% 1RM	BP monitoring for 30 min	Magnitude reduction BP and PEH duration equal between groups
Saccomani et al.[22]	10 normotensive men (24.5 ± 1.1yr)	115.4 ± 1.7 mm Hg	70.8 ± 2.1 mm Hg	CG: 60 min rest AG: 50 min cycle ergometer at 60% $VO_{2\ peak}$ SG: 8 strength exercises in 3 sets of 12 rep at 60% 1RM ASG: 50 min cycle ergometer at 60% $VO_{2\ peak}$ + 8 strength exercises in 3 sets of 12 rep at 60% 1RM SAG: 8 strength exercises in 3 sets of 12 rep at 60% 1RM + 50 min cycle ergometer at 60% $VO_{2\ peak}$	BP monitoring for 60 min	Greater magnitude reduction BP and duration da PEH for GSA e GAS No differences in execution order

Continue…

Study	Participants	Rest Blood Pressure		Training protocol	Duration	Results
		SBP	DBP			
Ruiz et al.[30]	11 normotensive men (26.8 ± 2.9 yr)	122.4 ± 8 mm Hg	76.5 ± 8.4 mm Hg	SG: 8 strength exercises in 3 sets 12RM AG: 40 min cycle ergometer at 60-70% HHR ASG: 40 min cycle ergometer at 60-70% HRR + 8 strength exercises in 3 sets 12RM	BP monitoring for 60 min	Magnitude reduction BP and duration PEH equal between groups
Santiago et al.[19]	15 normotensive male and female (29.4 ± 7.3 yr)	117.5 ± 11 mm Hg	68.3 ± 7.7 mm Hg	ASG: 30 min treadmill at 80% HHR + 8 strength exercises in 3 sets of 8 rep at 75% 1RM SAG: 8 8 strength exercises in 3 sets of 8 rep at 75% 1RM + 30 min treadmill at 80% HHR	BP monitoring for 60 min	Greater magnitude reduction BP for GAS
Teixeira et al.[27]	20 normotensive male and female (26.1 ± 1yr)	111 ± 2 mm Hg	74 ± 1 mm Hg	CG: 60 min rest AG: 30 min cycle ergometer at 75% $VO_{2\,peak}$ SG: 6 strength exercises in 3 sets of 20 rep at 50% 1RM ASG: 30 min cycle ergometer at 75% $VO_{2\,peak}$ + 6 strength exercises in 3 sets of 20 rep at 50% 1RM	BP monitoring for 120min	Greater magnitude reduction BP and duration PEH for AG
Mazzoccante et al.[20]	10 normotensive men (22.6 ± 3.7 yr)	120 ± 4,5 mm Hg	68,5 ± 6,3 mm Hg	CG: 60 min rest SAG: 6 strength exercises at 90% 12 RM + 15 min treadmill at 90% LT ASG: 15 min treadmill at 90% LT + 6 strength exercises at 90% of 12RM CTAG: Alternate strength and aerobic exercises in sequence		Greater magnitude reduction BP for GSA Greater duration of PEH for GSA in comparison to GCT
Keese et al.[26]	21 normotensive men (20.7 ± 0.7 yr)	111.5 ± 2.6 mm Hg	73.9 ± 3.6 mm Hg	CG: 60 min rest SAG: 6 strength exercises in 2 sets of 6 to 8 rep at 80% 1RM + 30 min cycle ergometer at 50/65/80% $VO_{2\,peak}$	BP monitoring for 60 min	Magnitude equal BP reduction between groups regardless of intensity Longer duration PEH in 65% and 80% $VO_{2\,peak}$
Santos et al.[31]	60 hypertensive women (63.3 ± 6.2 yr)	162.15 ± 7.12 mm Hg	88.05 ± 4.22 mm Hg	CG: 60 min rest SEAG: 7 strength exercises in 3 sets of 10 eccentric rep at 100-120% 10 RM + 20 min treadmill at 65-75% HHR STAG: 7 strength exercises in 3 sets of 10 rep at 70-90% 10 RM + 20 min treadmill at 65-75% HRR	BP monitoring for 60 min	Greater magnitude BP reduction for GSEA
Faraji and Nikookheslat[25]	10 pre hypertensive women (37.6 ± 6.5 yr)	135-150 mm Hg	85-95 mm Hg	CG: 6 hours in rest CMEG: 22 min treadmill at 65% HRmax + 5 strength exercises in 3 sets of 12 rep at 65% 1RM CLEG: 22 min treadmill at 40% of HRmax + 5 strength exercises in3 sets of 12 rep at 40% 1RM	BP monitoring during 6 hours	Longer duration PEH for GCMI

Note. CG: Control Group, AG: Aerobic group, ST: Strength group, CTG: Concurrent training group, SAG: Strength aerobic group, ASG: Aerobic-strength group, SEAG: Strength eccentric-aerobic group, STAG: Strength traditional-aerobic group, CTAG: Concurrent training alternate group, CMEG: concurrent moderate exercise group, CLEG=Concurrent light exercise group. PEH=Post exercise hypotension. HR=Heart rate. LT= lactate threshold. HRR=Heart rate reserve. HRmax=Heart rate maximum. BP: Blood pressure, 1RM: 1 repetition maximum, SBP: Systolic blood pressure, DBP: Diastolic blood pressure, MBP: Mean blood pressure.

Table 2. PEDro scale quality assessment of the included randomized clinical trials.

Study	1	2	3	4	5	6	7	8	9	10	11	Score
Tibana et al.[11]	1	1	0	1	0	0	0	1	1	1	1	6/10
Santiago et al.[19]	1	1	0	1	0	0	0	1	1	1	1	6/10
Keese et al.[28]	1	1	0	1	0	0	0	1	1	1	1	6/10
Ferrari et al.[29]	1	1	1	1	1	1	1	1	1	1	1	10/10
Pinto et al.[23]	1	1	0	1	0	0	0	1	1	1	1	6/10
Lovato et al.[21]	1	1	0	1	0	0	0	1	1	1	1	6/10
Menêzes et al.[24]	1	1	1	1	1	0	0	1	1	1	1	8/10
Saccomani et al.[22]	1	1	0	1	0	0	0	1	1	1	1	6/10
Ruiz et al.[30]	1	1	0	1	0	0	0	1	1	1	1	6/10
Teixeira et al.[27]	1	1	0	1	0	0	0	1	1	1	1	6/10
Mazzoccante et al.[20]	1	0	0	1	0	0	0	1	1	1	1	5/10
Keese et al.[26]	1	1	0	1	0	0	0	1	1	1	1	6/10
Santos et al.[31]	1	1	1	1	0	0	0	1	1	1	1	7/10
Faraji and Nikookheslat[25]	1	1	0	1	0	0	0	1	1	1	1	6/10

DISCUSSION

The aim of this review was to summarize the acute effects of concurrent on PEH in hypertensive and normotensive adults. Our main results suggest that concurrent training is capable to induce PEH regardless of intensity and volume, as well as the order of execution of strength or aerobic training prior. The evidence pointed to a greater duration of hypotensive response induced by aerobic training when compared to concurrent and strength training. In comparison with strength training, the concurrent training led to greater duration and magnitude of the hypotensive response.

The effect of the order of execution, for example, aerobic training prior to strength training and vice versa was investigated by [19-24]. Santiago et al.[19] evaluated normotensive men after aerobic training (treadmill for 30 minutes at 80% of heart rate reserve) follow by strength training (3 sets of 8 repetitions of 8 exercises at 75% of 1RM. The PEH was greater when aerobic training was performed prior to strength training[19].

However, Mazzoccante et al.[20] analyzed normotensive young males and found greater BP reduction and longer PEH when strength training was executed before aerobic training. Previous studies that the order of execution does not affect the magnitude and duration of the hypotensive response in normotensive men[21,22], normotensive women trained in an aquatic environment[23] and hypertensive women[24]. The training protocols performed in the included studies vary widely in volume and intensity prescribed, and, hence, the literature still lacks evidence to state whether the order of execution, as well as the volume and intensity, influence the hypotensive response.

Faraji and Nikookheslat[25] submitted hypertensive women to perform an exercise on a treadmill for 22 minutes at 65% and 40% of HRmax, followed by 5 exercises in 3 sets of 12 repetitions at 65% of 1RM and the same exercises and sets but at 40% of 1RM. The authors observed that when high intensity, great magnitude, and duration of PEH.

Keese et al.[26] also investigated the effect of different intensities of aerobic training on PEH in young normotensives males. The training protocol consisted of 6 strength exercises performed in 2 sets of 6 to 8 repetitions at 80% of 1RM and 30 minutes of aerobic training in cycle ergometer at 50, 65, and 80% of VO_2 peak. All tested intensities promoted a similar decrease of BP, but PEH was longer when exercise prescribed at 65 and 85% of $VO_{2\ peak}$. In a recent review, Pescatello et al.[9] analyzed several studies that investigate aerobic or strength training and concluded that when higher intensity, more expressive the hypotensive response.

Teixeira et al.[27] compared the hypotensive response induced by concurrent training to other training models in young normotensive men and women. The group that performed aerobic training presented a greater reduction of BP and duration of PEH in 120 minutes after training when compared to strength training and concurrent training groups.

Keese et al.[28] found similar results in normotensives, young males. However, the authors observed longer duration of PEH for SBP in aerobic and concurrent training groups in comparison to strength training, and for DPB after aerobic training. Ferrari et al.[29] evaluated hypertensives older males 60 minutes after training, as well as 24h later, and also found BP decrease. The evidence suggests a longer duration of hypotensive response after aerobic training when compared to the strength and/or concurrent training. Similarly, the concurrent training-induced longer duration and magnitude of PEH in comparison to strength training. Tibana et al.[11] also reinforces that findings in a sample composed of women with metabolic syndrome.

In contrast, Saccomani et al.[22] evaluated the effect of different training models (i.e., strength and aerobic training and concurrent training both aerobic follow by strength training and vice versa) on the hypotensive response in normotensive young males. Although the concurrent training has led to the greatest magnitude of the hypotensive response compared to the other training models, the order of execution did not induce a long duration of PEH neither high BP decrease. Nevertheless, Ruiz et al.[30] found no difference between groups in similar study design and sample.

Santos et al.[31] enrolled and submitted hypertensive older women to the two training protocols that are composed, respectively, by 7 strength exercises (3 sets of 10 eccentric repetitions at 100-120% of 10 RM) plus 20 minutes of a treadmill at 65-75% of HRR, and 7 strength exercises (3 sets of 10 repetitions at 70-90% of 10 RM) plus 20 minutes of treadmill at 65-75% of HRR. The authors found a greater magnitude of BP reduction in the group that performed the eccentric strength training in addition to aerobic training. According to our strategy search, screening, and eligibility criteria, only the study of Santos et al[31] investigated the effect of different combination and methods of strength training combined with aerobic training on BP.

In addition, the studies included presented, on average, 6 points in a maximum of 11 in the PEDro Scale. The methodological quality may not compromise the findings of the present study since the PEDro score above 5 is considered good to high quality[18]. However, the majority of the studies included enrolled normotensives subjects and, hence, is an important limitation of this review that should be considered. Thus, it is necessary caution to generalize these findings in relation to hypertensive subjects.

CONCLUSION

In summary, the systematic review found that concurrent training can promote PEH regardless of the order, volume, and intensity prescribed in the studies. Thus, concurrent training may be an effective strategy in the control of arterial hypertension. Although PEH presented longer duration when performed aerobic training in comparison to strength or concurrent training, the literature lack consensus about the best prescription strategy, such as aerobic training prior to strength training or vice versa.

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Ethical approval
This research is in accordance with the standards set by the Declaration of Helsinki.

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

Author Contributions
Conceived and designed the study: DM. Performed the data extraction: DM. Analyzed the data: DM, TLVPO. Wrote the paper: DM, TLVPO.

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