Proposal Intensity Adequacy of Expiratory Effort and Heart Rate Behavior During the Valsalva Maneuver in Preadolescents

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Abstract

Background: **When performing the Valsalva maneuver (VM), adults and preadolescents produce the same expiratory resistance values.**

Objective: **To analyze heart rate (HR) in preadolescents performing VM, and propose a new method for selecting expiratory resistance.**

Method: **The maximal expiratory pressure (MEP) was measured in 45 sedentary children aged 9–12 years who subsequently performed VM for 20 s using an expiratory pressure of 60%, 70%, or 80% of MEP. HR was measured before, during, and after VM. These procedures were repeated 30 days later, and the data collected in the sessions (E1, E2) were analyzed and compared in periods before, during (0–10 and 10–20 s), and after VM using nonparametric tests.**

Results: **All 45 participants adequately performed VM in E1 and E2 at 60% of MEP. However, only 38 (84.4%) and 25 (55.5%) of the participants performed the maneuver at 70% and 80% of MEP, respectively. The HR delta measured during 0–10 s and 10–20 s significantly increased as the expiratory effort increased, indicating an effective cardiac autonomic response during VM. However, our findings suggest the VM should not be performed at these intensities.**

Conclusion: **HR increased with all effort intensities tested during VM. However, 60% of MEP was the only level of expiratory resistance that all participants could use to perform VM. Therefore, 60% of MEP may be the optimal expiratory resistance that should be used in clinical practice. (Arq Bras Cardiol. 2014; 103(2):146-153)**

Keywords: **Child; Age Factors; Heart Rate; Valsalva Maneuvers; Exhalation.**

Introduction

The Valsalva maneuver (VM) is named for called Antonio Maria Valsalva (1666–1723), an Italian doctor who first described the maneuver in 1704. Valsalva instructed his patients to use VM to expel mucopurulent discharge from the middle ear to the nasopharynx[1,2]. In the late nineteenth century, a decreased heart beat sound was observed in individuals performing VM when they closed the glottis and increased expiratory pressure[3]. In 1944, VM was first used to assess cardiac autonomic function in a patient with congestive heart failure after a change in cardiovascular activity was detected in the patient during VM[4]. Since then, VM is often used with a range of other non-invasive examinations that assess autonomic modulation of the cardiovascular system in ill patients[5-9], healthy patients, and athletes[10,11].

VM is an abrupt and transitory increase in intra-thoracic and intra-abdominal pressures produced by a voluntary expiratory effort equivalent to 30 or 40 mmHg and maintained 15 or 20 s against resistance applied by a mouthpiece attached to a manometer[6,9,12]. The efficacy of VM depends on several factors, such as age, sex, body position, and the intensity of expiratory effort[13].

However, there are no reports in the literature regarding calculations or guidelines that account for individual differences, such as respiratory muscle strength. These factors might affect the magnitude of the cardiovascular responses observed during the VM, possibly causing errors in the data analysis or interpretation. As for age, children and preadolescents typically perform VM with the same expiratory effort as adults. Perhaps the similar expiratory efforts among age groups, in addition to difficulties in understanding the VM produced by some children, have led to a limited application of VM in children and preadolescents[14].

Although VM is an important test of cardiovascular functioning, it is rarely used with preadolescents. Considering these previous findings and presuppositions, we conducted a study in which the main objectives were to assess HR responses during VM and to propose the intensity of expiratory effort an individual should use during the VM.

Method

This prospective study was approved by the Human Research Ethics Committee of the Center of Life Sciences at *Pontifícia Universidade Católica* in Campinas (protocol n. 298/11) and conformed to the requirements of the Declaration of Helsinki.

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Participant selection

Forty-five preadolescents aged between 9 and 12 years, (33 male and 12 female participants) were selected from 75 students attending public schools in the northwest region of Campinas (SP), and who were assessed between 2011 and 2013. The participant's parents or guardian consented to their participation in the study.

The inclusion criteria were a sedentary lifestyle (no regular participation in physical activities or sports in the previous 6 months), not taking medications that could interfere with cardiovascular activity, and the absence of diseases that could affect cardiorespiratory functions. From the 75 potential participants, we excluded 25 because of a sedentary lifestyle and five because of disease or medication use. We selected sedentary preadolescents because of the concern that physical training can cause cardiovascular adaptation that might bias the data.

Anthropometric and clinical evaluation

We conducted an anthropometric evaluation to record the body characteristics of the 45 participants. For each patient, we used weight and height to calculate the body mass index (BMI, Table 1).

The clinical evaluation included anamnesis, HR records (HR – Polar heart frequency meter S810i®, Kempele, Finland), and blood pressure (BP) measured with a mercury column sphygmomanometer (WanMed®, São Paulo, Brazil) with cuffs adapted to fit the participants' arms and a cardiac and pulmonary auscultation (stethoscope Littmann Classic II SE®, Ontario, Canada). The evaluation was performed using techniques that are widely described in the literature (Table 1).

Participants were advised not to consume caffeine or cola soft drinks and not to participate in physical activities, except for those necessary for daily routines, at least 24 h before the procedure. The data were collected in a room with a constant temperature of 23ºC and between the hours of 1500 and 1700. They were also advised to eat light meals 2 h before the procedures, especially when the procedures were performed around lunch time[15].

Selection of expiratory effort intensity and execution of the Valsalva maneuver

To determine the participants' effort intensities for performing VM, we measured each participant's maximal expiratory pressure (MEP) using a manovacuometer (M120® - Comercial Médica, São Paulo, Brazil) with values available from 0 to 120 cm H_2O. During this procedure, the participants sat in a chair with their feet comfortably placed on the floor.

A nose clip was placed to avoid air escape through the nostrils, and participants were asked to breathe in as deeply as possible through the mouth, reaching the maximal inspiratory capacity. Immediately after the inspiration, the participants expired abruptly through the mouthpiece and against the resistance of the manovacuometer using their maximum force[16,17].

Three measurements were performed, and the highest value for these three attempts was considered MEP. After a minimum time of 5 min used to obtain MEP, each volunteer executed VM in three 20-s attempts and against three predicted resistances, 60%, 70%, and 80% of MEP. The participant's momentary expiratory effort was displayed by a red line shown on the manovacuometer display.

The examiner followed the participant's effort and carefully observed for pressure oscillations to instruct the participant to avoid them when they occurred. The maximum acceptable oscillation was ±5 cm H_2O relative to the predicted effort. The participants were allowed a rest period of at least 5 min between each VM to recover. The resistance values for the three maneuvers were presented in order. The participant's HR was recorded during VM with a HR monitor belt (Polar heart frequency meter, S810i®, Kempele, Finland) that the participant wore around the thorax. The HR data were sent to a computer via an infrared interface and were processed using the manufacturer's software (Polar Precision Performance®, Kempele Finland), which computed a HR graph (Figure 1) and a report for the cardiovascular measures.

When selecting the expiratory resistance for cardiovascular functional assessments that are appropriate for the participant's age group, we considered factors such as the magnitude of the

Table 1 – Mean values of anthropometric, clinical, and maximal expiratory pressure (MEP) data, as well as MEP percentages calculated in the first and second evaluations (E1 and E2)

Variables	First evaluation (E1) (n = 45)		Second evaluation (E2) (n = 45)		p
Weight (kg)	39.8	± 5.0	40.3	± 5.4	ns
Height (cm)	139.5	± 29.0	140.0	± 29.3	ns
Systolic BP (mmHg)	107.1	± 4.1	109.2	± 4.3	ns
Diastolic BP (mmHg)	71.5	± 6.6	70.1	± 5.9	ns
HR (bpm)	83.0	± 12.0	84.1	± 11.7	ns
Maximal expiratory pressure (cm H_2O)	70.1	± 5.7	70.4	± 5.9	ns
Expiratory pressure – 80% of MEP	55.0	± 7.1	56.4	± 6.6	ns
Expiratory pressure – 70% of MEP	51.0	± 5.8	53.1	± 6.3	ns
Expiratory pressure – 60% of MEP	36.5	± 11.0	36.2	± 10.7	ns

BP: Blood pressure; HR: Heart rate

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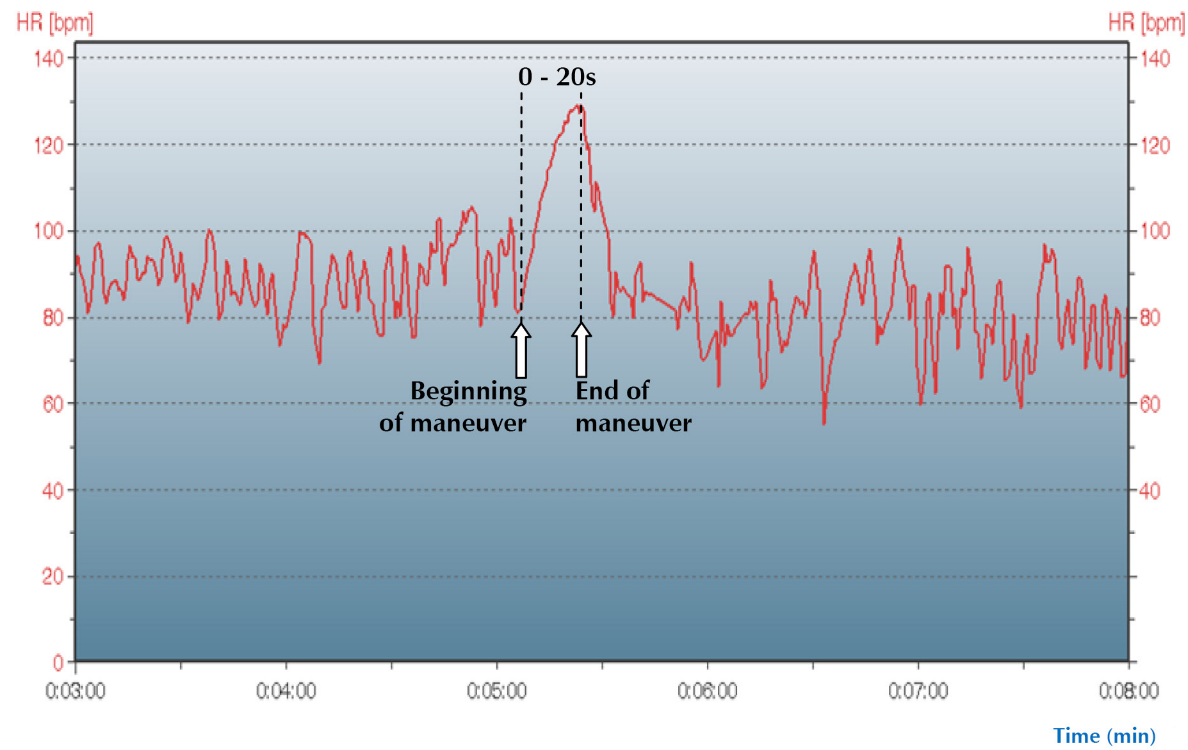

Figure 1 – *Heart rate (HR) tacogram (HR – bpm) recorded during the Valsalva maneuver (VM) performed by a 10-year-old preadolescent and with a resistance equivalent to 60% of MEP. Observe the beginning and the end of the emphasized maneuver effort and the respective 20 s time for the expiratory effort made with the closed glottis. Also, observe the sinus bradycardia after the maneuver.*

HR response, effort intensity needed to maintain the expiratory pressure for 20 s, and the number of participants who could properly complete the maneuver.

Replication of the results

According to Low[13], the VM should be repeated to ensure its reproducibility and the reliability of its results. Therefore, after the participants completed the first experimental session (E1), they were advised to return to the outpatient clinic 1 month later to repeat the session using the same predetermined effort intensities (E2). They were advised again to maintain their daily activities, but not to participate regularly in physical activities or sports during that period.

The procedure for collecting MEP and calculations for the percentage rates was repeated and monitored by the same examiner who monitored the first experimental session. The objectives for the E2 session were as follows:

a) to verify if the data obtained in the first evaluation (E1) were stable in the evaluation conducted one month later (E2)

b) to meet the essential requirements in processes involving new methodological proposals for evaluations, known as replication of the results

c) to determine whether a learning effect interfered with the data collection

Data analysis

The anthropometric and clinical data were tested with the Kolmogorov-Smirnov test, which revealed data normality. Therefore, a *t*-test was used to perform comparisons between the data collected in E1 and E2 (Table 1).

We analyzed the HR data recorded in three periods during VM. First, the median values of the HR deltas occurring in 0-10 s and 10–20 s were compared for maneuvers performed with the three expiratory effort intensities. Using a Kruskal–Wallis test, we determined the HR data were not normally distributed. The significance level was $p < 0.05$ for all statistical analyses (Figure 2).

Likewise, values for total delta (0–10 s and 10–20 s) were compared to determine HR increases between the beginning and end of the 20-s periods in stages E1 and E2, and with the same of expiratory effort intensities (Figure 3).

We also compared the median HR for the 45 participants before, during, and after they performed VM with a resistance that was 60% of MEP, which was considered the most adequate effort intensity. For this analysis, we used the Friedman test to compare HR recorded in four periods during VM: the pre-test, 0-10 s, 10-20 s, and HR after (Figure 4).

Statistical analyses were performed with Graph Pad Prism 6.0® software (San Diego, United States); HR values were obtained directly from the report generated by the Polar Precision Performance® software package.

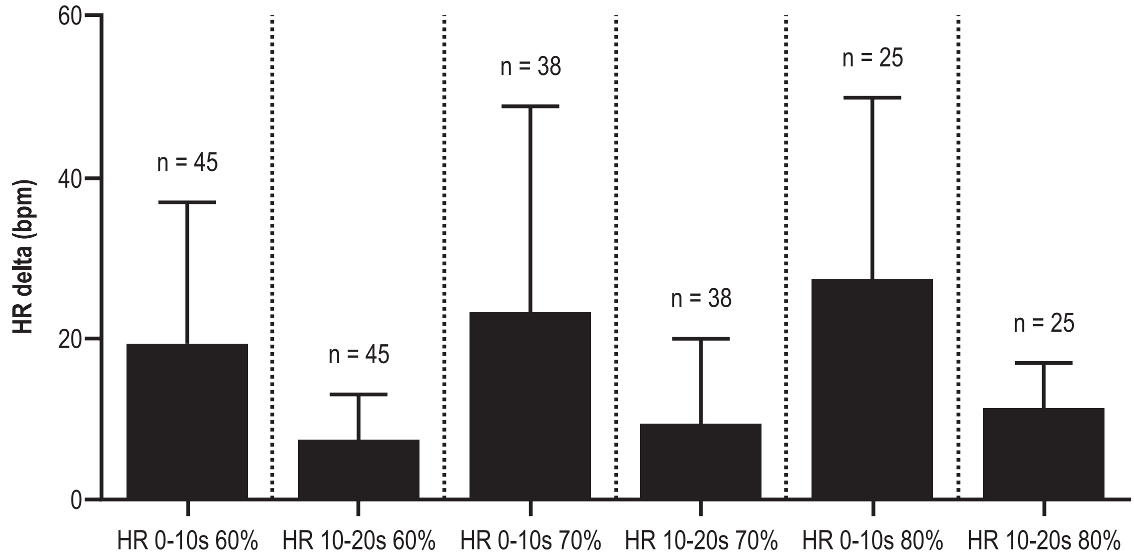

Figure 2 – *Mean values of HR deltas obtained during 0–10 s and 10–20 s of the Valsalva maneuver conducted with expiratory resistances of 60%, 70%, and 80% of MEP; data obtained during the first evaluation (E1). The presented values were significantly different ($p < 0.05$).*

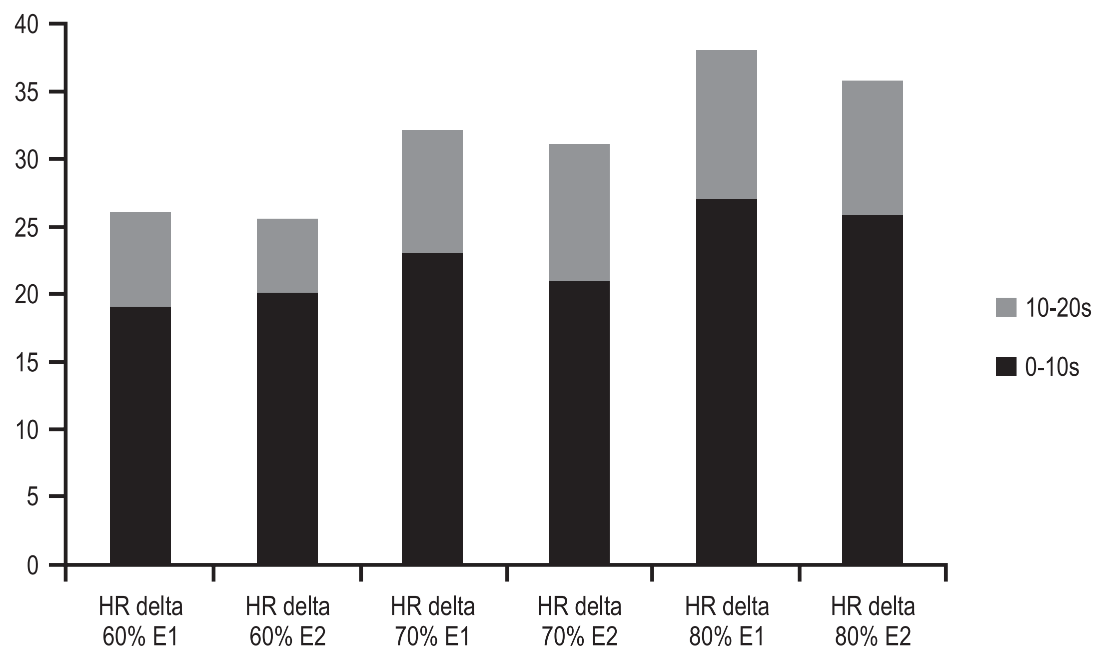

Figure 3 – *Overall medians of heart rate deltas (0–10 s and 10–20 s) recorded during the Valsalva maneuver performed with expiratory resistances of 60% (n = 45), 70% (n = 38), and 80% (n = 25) of MEP. Data collected during the two moments were compared (E1 and E2). E1 is the first evaluation, whereas E2 is the second evaluation. There was a significant difference ($p < 0.05$) between HR values in the three situations (60%, 70%, and 80% of MEP), however, there was no difference between moments E1 and E2 regarding each employed intensity.*

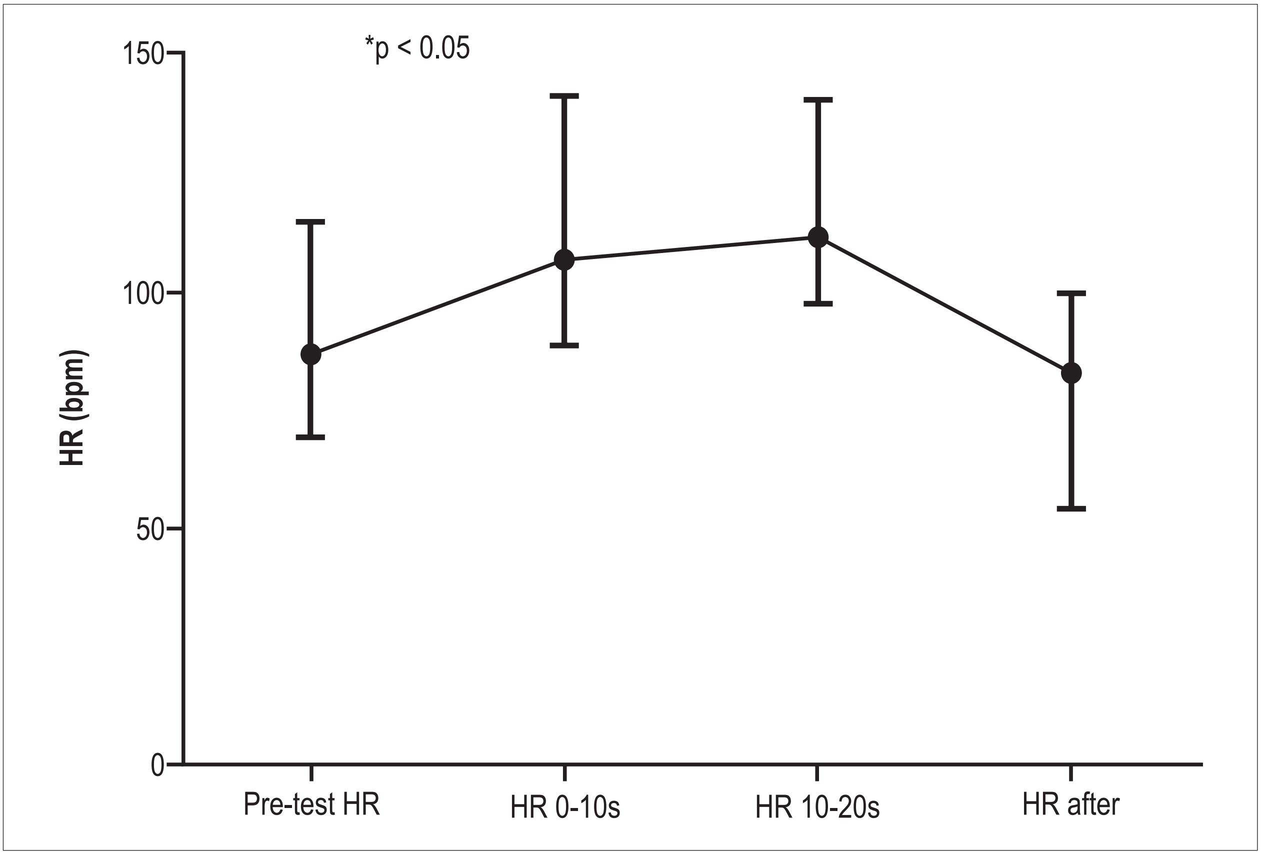

Figure 4 – *Mean HR values with their highest and lowest amplitudes recorded before (1-min HR mean – pre-test HR), during (values recorded at 0–10 s and 10–20 s), and after the Valsalva maneuver (1-min HR mean – pre-test HR) performed with an expiratory resistance equivalent to 60% of MEP. There was a significant difference ($p < 0.05$) among the HR values for all four periods.*

Results

Table 1 presents anthropometric and clinical values. As the data indicate, the participants' conditions were unchanged during moments E1 and E1 predicted for data collection.

Figure 2 presents the medians of the HR delta values for the 0–10 s and 10–20-s periods during VM and for the three effort intensities. For the 0–10 s period, the median HR at 60%, 70%, and 80% of MEP were 19 bpm (n = 45), 23 bpm (n = 38), and 27 bpm (n = 25), respectively. For the 10–20 s period, the median HR at 60%, 70%, and 80% of MEP were 7 bpm (n = 45), 9 bpm (n = 38), and 11 bpm (n = 25), respectively. All of the compared values showed significant differences, which indicates the HR response increased as the effort intensity increased.

Figure 3 presents the medians of the total HR deltas (0-20 s) when the expiratory effort was 60%, 70%, and 80% of MEP for stages E1 and E2. There was a significant difference among effort intensities in the same stage, but there was no difference in effort intensities between stages E1 and E2.

Figure 4 shows the median HR for all participants before, during (0–10 s and 10–20 s), and after the VM (n = 45) performed at 60% of MEP. HR responses are shown in detail for VMs conducted with a 60% resistance because all participants could perform VM at this intensity with minimal oscillations, and this is consistent with similar data reported in literature.

HR was significantly different among the four periods ($p < 0.05$). This finding reinforces the relevance of the maneuver as an instrument for assessing autonomic cardiac function.

Discussion

VM is widely used to assess autonomic cardiovascular function because it can identify vagal release, sympathetic actions, and cardiac vagal reactivation, in addition to being practical and having a low cost[6,18].

Even though standard protocols suggest VM should be performed for 15–20 s with 30–40 mmHg of pressure exerted on the mouth[19], no study has focused on a systematic method for using the VM that accounts for individual differences in respiratory capacity and strength. Whether body position or pulmonary volume affect expiratory effort also has not been considered, which makes it difficult to compare the results obtained in different studies[15,20].

These aspects, which were reported from previous studies with adults, become even more relevant when the individuals performing the VM are children or preadolescents. The expiratory effort intensities of children and preadolescents are not calculated according to their morphofunctional characteristics; therefore, they are examined under the same protocols and intensities as adults.

In the present study, we used a percentage of MEP because the expiratory effort depends especially on expiratory muscle strength[17,21], and when factors that are known to affect VM are under control, the individual performing VM will execute the maneuver with an adequate effort that is equivalent to the expiratory muscle strength.

In this context, weaker or smaller people would not have to exert major efforts to reach the predicted values, which are inadequate for the general population. Likewise, the maneuver could even be used in cases with pulmonary disease or other conditions that interfere with respiratory muscle strength, as these individuals would also be performing expiratory efforts that would be proportional to their functional capacities, after assessing the MEP.

One of the main findings of the present study was that 60% of MEP was the most adequate intensity, because at this effort intensity, all of the participants could conduct the maneuver with minimal pressure oscillation during the proposed time in both E1 and E2. The exception is the positive HR response, which reflects the cardiac vagal and sympathetic action[15]. The interesting aspect of this finding was that the effort used at 60% of MEP produced mean values of 36.5 and 36.2 cmH_2O for E1 and E2, respectively. These values are equivalent to 26.8 mmHg (E1) and 25.7 mmHg (E2) as mmHg is typically used to characterize VM. The data obtained in this study may be similar to those for the traditional VM; however, they are less than those proposed in other studies conducted with children or preadolescents[14].

For example, Van Steenwijk et al[14] examined the VM in children and preadolescents with the standard expiratory efforts of 30 mmHg and 40 mmHg and 15-s durations. Out of the 68 children analyzed, only 10 could execute VM with a minimal pressure oscillation (< 2 mmHg), when the effort intensity of the maneuver was 30 mmHg. For the remaining participants, the oscillations ranged from 15 to 55 mmHg and the duration ranged between 13 and 17 s.

After observing these results, the interest in using VM in children and adolescents as a clinical cardiac autonomic evaluation decreased, and discussions were raised regarding VM's reliability and feasibility. On the other hand, there is an increasing interest in finding reliable alternatives that are easy to apply and have unrestricted use.

With regard to HR during the VM, the magnitude of HR changes varied with the intensity effort (Figures 2–4), which demonstrates that higher loads imposed on the cardiovascular system activate arterial baroreceptors, chemoreceptors, and cardiopulmonary receptors, which are included in the central nervous system[7,14].

Activating these receptors allows modulation of the cardiovascular system. Such modulation results from sympathetic and parasympathetic nervous system activation, and both of these systems modulate HR and BP[18,22].

In practice, the increasing HR in the first 10 s of the VM (delta 0-10 s) depended on the vagal release, considering the actions of the cardiac parasympathetic nervous system are faster than those of the sympathetic nervous system. In the subsequent 10 s (delta 10–20 s of the maneuver), a supplementary increase in HR likely resulted from arteriolar sympathetic activation, which also modulates heart functions[2,6].

However, some authors[23] have not discriminated the periods of 0–10 s and 10–20 s; thus, only stating that the increased HR is mediated by the autonomous nervous system. Therefore, this system should modulate cardiac responses, such as HR, according to the stimuli provoked by the maneuver.

In order to consider the rate of the reflex activated during the maneuver, Pickering and Davies[24] suggested that the time of stimulus conduction from the baroreceptors to the heart of normal individuals, with a HR < 75 bpm, is around 473 ms. The registered HR response pattern enabled us to infer its normality, as HR increased during the entire maneuver (Figures 2 and 3), and was followed by bradycardia, produced by subsequent vagal activation[6,9,15].

Hohnloser and Klingenheben[6] showed that, among adults, HR deltas ≥ 15 bpm recorded during the maneuver indicated adequate or normal autonomic cardiac responses, whereas deltas between 11–14 bmp are considered borderline normal.

Abnormal responses were HR deltas ≤10 bpm, which is commonly found with heart failure, diabetes, post-acute myocardial infarction, mitral stenosis, and others that cause cardiac dysautonomia[9].

In the present study, for all of the three expiratory effort intensities, participants HR delta values greater than 15 bpm (Figure 3), thus suggesting that applying MEP percentages was efficient in causing an adequate HR response, and that the participants were without cardiac dysautonomia.

Considering the HR during an expiratory effort at 80% of MEP (55.0 cmH_2O in E1 and 56.4 cmH_2O in E2), there was a significant increase in HR, and the greatest increase occurred between the MEP percentages. This might suggest that this is an adequate expiratory resistance for future investigations. However, only 25 volunteers (55.5%) could execute the maneuver at this expiratory effort intensity while producing an oscillation less than 5 cm H_2O.

Likewise, when the expiratory resistance was 70% of MEP (51.0 cm H_2O in E1 and 53.1 cm H_2O in E2), the HR response was good, but 84.4% (38) of the individuals performed the maneuver perfectly. Therefore, the maneuver performed with major efforts confirmed what had been documented in other studies[14,15], which also revealed higher HR elevations when expiratory resistance was higher.

Figure 4 demonstrates bradycardia occurred after the expiratory effort concluded. After performing the VM for 20 s, HR was 113 bpm; 1 min after interrupting the expiratory effort, HR decreased by 32 bpm. Even though Figure 4 only demonstrates HR responses with an expiratory resistance of 60% of MEP, this HR response also occurred with the other expiratory resistances used in the study.

HR reduction during VM resulted from parasympathetic nervous system activation stimulated by the baroreceptor reflex. This reflex is sensitive to abrupt increases in BP (overshoot), which happened after the expiratory effort concluded[2].

According to Hilz and Dütsch[18], the resulting bradycardia is a measurement of the buffering capacity of the baroreflex system and the vagus nerve. Therefore, a decreasing HR at this time represents an adequate and expected action for a healthy population, as was observed in this sample. An analysis of this response can be used to investigate changes in the baroreflex system and vagal dysautonomia[20,22].

As for the study limitations, sedentary volunteers were selected according to questionnaire responses with information obtained from a parent or guardian. No tests or specific examinations were used to confirm the participant was sedentary, as the ones that were proposed by Luband et al[25]. Likewise, the study did not perform a simultaneous analysis of BP beats per beat, which could enrich the results and open new possibilities for analysis. However, the objective of the study was to assess HR, and especially because preadolescents were examined, it was believed that invasive methods could bias the study and HR measures.

As a final limitation, there were not enough comparisons between HR measured during the proposed and traditional methods, which would probably enable consolidation of the new methodology as a more adequate measurement, with greater reliability and clinical applicability.

However, it is possible to state that the other intensities used in this study (70% and 80% of MEP) were similar to those applied in clinical practice. Therefore, they may provide important information considering the traditional VM not only requires excessive effort from preadolescents, but it can prevent an adequate cardiac autonomic evaluation because it promotes oscillation in the oral pressure, and consequently, bias the results.

Conclusion

The present results suggest that 60% of MEP as an expiratory resistance during the VM performed by preadolescents is adequate for cardiac autonomic evaluation in this population. Besides being achievable for all volunteers, this expiratory effort intensity stimulated HR responses that allowed clinical-functional interpretations or analyses, both from vagal and cardiac sympathetic action during the VM.

Therefore, expiratory effort values that are calculated individually create conditions of balance and proportion between people with different biotypes and levels of respiratory muscle strength, without affecting the results or analysis. In addition, this enables a high number of people to be evaluated by this type of protocol.

Author contributions

Conception and design of the research, Analysis and interpretation of the data, Statistical analysis and Critical revision of the manuscript for intellectual content: Paschoal MA; Acquisition of data: Donato BS, Neves FB; Writing of the manuscript: Paschoal MA, Donato BS.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Study Association

This study is not associated with any thesis or dissertation work.

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