Valsalva manoeuvre increases vagal baroreceptor unload reflex sensitivity in young healthy subjects

Próba Valsavy zwiększa czułość składowej przywspółczulnej odruchu spowodowanego odbarczeniem baroreceptorów u młodych zdrowych osób

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Abstract

Introduction. The objective was to verify the hypothesis that change in cardiovagal baroreceptor unload reflex sensitivity occurs between early phase 2 (VM2E) and phase 3 (VM3) of the Valsalva manoeuvre (VM). The study was performed on 29 volunteers between the ages of 25 and 40 (29.3 ± SE 4.0).

Material and methods. The experimental scheme was as follows: rest in sitting position, VM in sitting position maintaining an expiratory pressure of 20 mm Hg for 15 seconds, rest in sitting position. Changes in systolic blood pressure (SBP), diastolic blood pressure (DBP) and heart rate (HR) were measured using Finapres.

Results. In VM2E and VM3, HR increased (+51.76 ± SE 4.06 beats/min., $p < 0.001$; +37.77 ± SE 8.65 beats/min., $p < 0.0001$, respectively) in response to a fall in SBP (–47.55 ± SE 3.95 mmHg, $p < 0.001$; –29.66 ± SE 2.80 mmHg, $p < 0.0001$; respectively). Both events of baroreceptor unload have been observed within the very similar range of SBP and HR.

Conclusion. The slope of regression relating change in heart rate (ΔHR) and systolic arterial pressure (ΔSBP) was significantly higher in VM3 ($\Delta HR_2 = -1.063 \times \Delta SBP2 + 7.0986$) than in VM2E ($\Delta HR_1 = -0.4395 \times \Delta SBP2 + 30.862$), suggesting the increased baroreceptors' sensitivity toward SBP fall in VM3 compared to VM2E. VM increases vagal baroreceptor unloads reflex sensitivity.

Key words: Valsalva manoeuvre, baroreceptor reflex, vagal baroreflex sensitivity, vagal baroreflex unload

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Streszczenie

Wstęp. Celem badania było zweryfikowanie hipotezy, że zmiana czułości składowej kardiowagalnej odruchu z baroreceptorów występuje między wczesną fazą 2 (VM2E) a fazą 3 (VM3) próby Valsalvy (VM, *Valsalva manoeuvre*).

Materiał i metody. Badanie przeprowadzono w grupie 29 ochotników w wieku 25–40 lat (29,3 ± błąd standardowy średniej [SE, *standard error of the mean*] 4,0). Eksperyment przeprowadzono według następującego schematu: odpoczynek w pozycji siedzącej, VM w pozycji siedzącej, utrzymując ciśnienie wydechowe na poziomie 20 mm Hg przez 15 sekund, odpoczynek w pozycji siedzącej. Za pomocą urządzenia Finapres zmierzono zmiany wartości skurczowego ciśnienia tętniczego (SBP, *systolic blood pressure*), rozkurczowego ciśnienia tętniczego (DBP, *diastolic blood pressure*) i częstotliwości rytmu serca (HR, *heart rate*).

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Wyniki. W trakcie faz VM2E i VM3 nastąpiło zwiększenie HR (odpowiednio +51,76 ± SE 4,06 uderzeń/min; p < 0,001 i +37,77 ± SE 8,5 uderzeń/min; p < 0,0001) w odpowiedzi na zmniejszenie SBP (odpowiednio –47,55 ± SE 3,95 mm Hg; p < 0,001 i –29,66 ± SE 2,80 mm Hg; p < 0,0001). W obu przypadkach odbarczenie baroreceptorów obserwowano w bardzo podobnym zakresie SBP i HR.

Wnioski. Nachylenie linii regresji odnoszących się do zmiany częstotliwości rytmu serca (ΔHR) i skurczowego ciśnienia tętniczego (ΔSBP) było istotnie większe w fazie VM3 ($\Delta HR_2 = -1{,}063 \times \Delta SBP2 + 7{,}0986$) niż w fazie VM2E ($\Delta HR_1 = -0{,}4395 \times \Delta SBP2 + 30{,}862$), co wskazuje na zwiększenie czułości baroreceptorów w stosunku do spadku SBP w fazie VM3 w porównaniu z fazą VM2E. VM zwiększa czułość składowej przywspółczulnej odruchu wywołany odbarczeniem baroreceptorów.

Słowa kluczowe: próba Valsalvy, odruch z baroreceptorów, czułość składowej przywspółczulnej odruchu z baroreceptorów, odbarczenie baroreceptorów

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Introduction

Smith et al. [1], in a very elegant study, demonstrated that during the Valsalva manoeuvre (VM) the arterial pressure, transiently lasting only seconds, resets the relationship between arterial pressure and sympathetic and vagal neural outflows. This finding becomes very interesting in the context of recent reports that the baroreflex-induced tachycardia response following acute hypotension acts to stabilise cerebral blood flow [2]. The notion that the heart is highly intertwined in the regulation of cerebral blood flow is reinforced by data coming from our lab indicating that changes in cardiac output, under certain circumstances, may directly affect the brain's microcirculation [3].

In phase 3 of VM (VM3), firing of sympathetic motor neurons remains at a very low level despite the decline in arterial pressure [1]. Furthermore, the heart rate increase 60 seconds after the release of straining is less pronounced in spite of relatively lower arterial pressure values compared to the baseline [1]. These results clearly indicate baroreceptor reset [1]. Nevertheless, during the VM there are two rapid declines in arterial pressure, during early phase 2 (VM2E) and after the release of straining in VM3. We hypothesised that cardiovagal baroreceptor unload reflex sensitivity may increase between VM2E and VM3. To verify this hypothesis we performed a retrospective analysis of data from our previous study [4]. Baroreceptor-heart rate reflex gain was defined as the slope of the relationship of change in heart rate (ΔHR) to change in systolic arterial pressure (ΔSBP) during VM2E and VM3.

Materials and methods

Materials and methods were previously described in detail [8]. Briefly, the study was performed on 29 healthy volunteers (11 men and 18 women) aged 25–40 years, with a mean age of 29.3 ± SE 4.0. The volunteers were selected on the basis of a medical questionnaire, interview and blood pressure measurement. All of them gave informed consent to participate in the study. The experimental protocol was approved by the ethical committee of the Medical University of Gdansk. Subjects were free of any disorders and not taking any medication. No coffee, food or nicotine was permitted for 3 hours before the test. Additionally, prior to the test, the volunteers were asked to sit comfortably and rest for 30 min. Tests were performed within the following scheme:

— Rest sitting position (baseline),
— VM in sitting position maintaining an expiratory pressure of 20 mmHg for 15 s.

Each subject was studied once, with 30 min of rest after the study.

Changes in systolic blood pressure (SBP), diastolic blood pressure (DBP) and heart rate (HR) were measured using Finapres (Finapres, Ohmeda, Englewood, CO, USA). The Finapres sensor was mounted to the middle finger of the non-dominant hand, which was resting on the table. Beat-to-beat arterial pressure was transferred to a computer console continuously displaying SBP, DBP and HR. Then, the arterial pressure and HR responses were plotted to precisely delimit particular phases of VM, using the respective maximal and minimal values.

Shapiro-Wilk test has been used for the analysis of differences between average values and between male and female subjects. Because there were no discernible differences between men and women, data from the two groups were combined for statistical analysis. We compared changes in arterial pressure and HR responses between different phases of VM. Correlation and regression analysis was performed to assess interdependences between arterial pressure and HR.

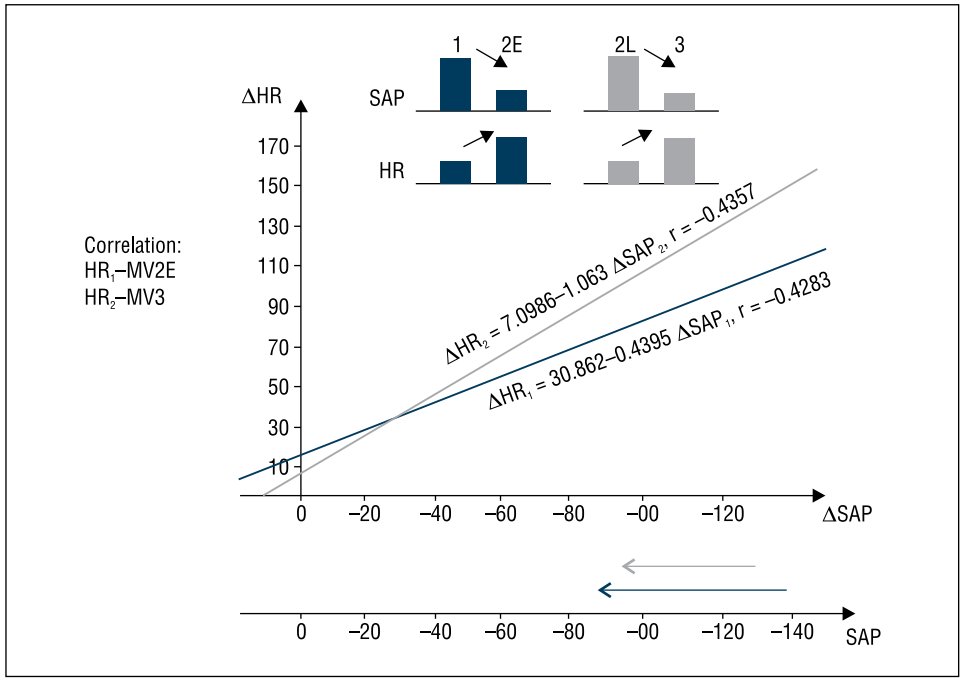

Figure 1. Regression lines for changes in heart rate (ΔHR) are plotted against changes in systolic arterial pressure (ΔSBP) for early phase 2 (VM2E) and phase 3 (VM3) of the Valsalva manoeuvre. The regression lines were not coincident ($p < 0.01$) and not parallel ($p < 0.01$). The regression equations including slope and the r values are provided for each line

Spearman's rank correlation coefficient was used to measure statistical dependence between two variables and multiple partial F-tests (tests of coincidence and parallelism) were performed to assess differences in relationships with two-tailed significance levels of 0.05. In addition, further analysis was performed to assess if the study was powerful enough to detect arterial pressure and HR differences. All statistical calculations were done using the Statistica for Windows 9.0 commercial package.

Results

In VM2E and VM3, HR increased (+51.76 ± SE 4.06 beats/min., $p < 0.001$; +37.77 ± SE 8.65 beats/ /min., $p < 0.0001$, respectively) in response to a fall in SBP (–47.55 ± SE 3.95 mmHg, $p < 0.001$; –29.66 ± SE 2.80 mmHg, $p < 0.0001$; respectively). There were no significant differences between sexes. Full descriptive statistics are available in our previous publication [4]. The arterial pressure and HR results were consistent with previous reports [1, 5].

Both events of baroreceptor unload were observed within a very similar range of SBP and HR. The slope of the regression relating ΔHR and ΔSBP was significantly higher in VM3 (ΔHR2 = –1.063 × ΔSBP2 + 7.0986) than in VM2E (ΔHR1 = –0.4395 × ΔSBP2 + 30.862), suggesting the increased sensitivity of baroreceptors toward SBP falls in VM3 compared to VM2E (Fig. 1).

Discussion

To the best of our knowledge, we are the first to report that during VM increase in the vagal baroreceptor unload reflex sensitivity occurs between VM2E and VM3. Our results represent a good fit with the earlier report by Smith at al. [1]. Smith et al. [1] described significant reset to lower pressure of the sympathetic arm of baroreceptor reflex in the first seconds after the release of straining. Furthermore, Smith at al. [1] suggested that vagal neural outflow reset to lower pressure 60 seconds after the release of straining. We found a greater baroreceptor-heart rate reflex gain immediately after the release of straining. Taken together, both studies suggest a significant shift from sympathetic toward the vagal arm of baroreceptor reflex immediately after the release of straining.

The study sample was sufficient to ensure that HR and SBP changes were detected with the adequate test power (at least 80%). A further advantage of our study was the involvement of a large group of female subjects, as the study by Smith et al. only had 3 female participants. Therefore, we

confirmed that the cardiovagal baroreflex sensitivity during the hypotensive stimulus is similar between sexes [6]. Variations in the menstrual cycle were not accommodated in our study; however, menstrual phase does not appear to affect the general pattern of cardiovagal unload responses [6]. Increases in sympathetic muscle-nerve activity triggered by VM are proportional to the level of straining [1]. Our study was initially designed to study changes in brain microcirculation during VM [4]. Therefore, we tried to minimise potential bias caused by simultaneous sympathetic activation, so the expiratory pressure was kept at 20 mmHg instead of the more commonly used 40 mmHg. Nevertheless, such design well suits this retrospective analysis which is focused on cardiovagal reflex responses.

We can only speculate about the physiological significance of the discussed phenomenon. The role of arterial baroreflex is to stabilise arterial pressure and most likely also cerebral blood flow on a moment-to-moment basis [2]. This and the previous study [1] demonstrate that arterial pressure transiently lasting only seconds changes the relations between arterial pressure and vagal neural outflows. However, it should be noted that VM is associated with significant changes in cerebral blood flow [7], brain microcirculation [4] and intracranial pressure [8]. Therefore, an input from the central nervous system into the baroreceptor reflex cannot be excluded. Actually, sensitisation of the vagal baroreceptor unload reflex seen in our study immediately after the release of straining may represent an attempt to maintain arterial pressure. In contrast, reset to lower pressure of the cardiovagal reflex described by Smith et al. [1] 60 seconds after the release of straining maybe seen as a protective mechanism to limit abundant cerebral blood flow [7] and associated risk when small arterioles dilated in VM3 are not able to quickly compensate huge blood volume gain caused by blood pressure increase in VM4 [4]. However, a well-designed experimental study is needed to verify this hypothesis and further assess the role of rapid baroreceptor reset and sensitivity change in the maintenance of brain circulation homeostasis.

To conclude, we demonstrated that:

1. During VM increase in the vagal baroreceptor unload reflex sensitivity occurs between VM2E and VM3,
2. The vagal baroreceptor unload reflex sensitivity during VM is similar between sexes.

Conflicts of interest: *None declared.*

References

1. Smith ML, Beightol LA, Fritsch-Yelle JM, et al. Valsalva's maneuver revisited: a quantitative method yielding insights into human autonomic control. Am J Physiol. 1996; 271(3 Pt 2): H1240–H1249, indexed in Pubmed: 8853364.
2. Ogoh S, Tzeng YC, Lucas SJE, et al. Influence of baroreflex-mediated tachycardia on the regulation of dynamic cerebral perfusion during acute hypotension in humans. J Physiol. 2010; 588(Pt 2): 365–371, doi: 10.1113/jphysiol.2009.180844, indexed in Pubmed: 19933752.
3. Frydrychowski AF, Wszedybyl-Winklewska M, Bandurski T, et al. Flow-induced changes in pial artery compliance registered with a non-invasive method in rabbits. Microvasc Res. 2011; 82(2): 156–162, doi: 10.1016/j.mvr.2011.05.005, indexed in Pubmed: 21658393.
4. Wszedybyl-Winklewska M, Frydrychowski AF, Michalska BM, et al. Effects of the Valsalva maneuver on pial artery pulsation and subarachnoid width in healthy adults. Microvasc Res. 2011; 82(3): 369–373, doi: 10.1016/j.mvr.2011.08.003, indexed in Pubmed: 21871464.
5. Hamilton WF, Woodbury RA, Harper HT. Physiological relationship between intrathoracic, intraspinal and arterial pressures. JAMA. 1944; 107: 853–856.
6. Fu Qi, Okazaki K, Shibata S, et al. Menstrual cycle effects on sympathetic neural responses to upright tilt. J Physiol. 2009; 587(Pt 9): 2019–2031, doi: 10.1113/jphysiol.2008.168468, indexed in Pubmed: 19237424.
7. Tiecks FP, Lam AM, Matta BF, et al. Effects of the valsalva maneuver on cerebral circulation in healthy adults. A transcranial Doppler Study. Stroke. 1995; 26(8): 1386–1392, doi: 10.1161/01.str.26.8.1386, indexed in Pubmed: 7631342.
8. Greenfield JC, Rembert JC, Tindall GT. Transient changes in cerebral vascular resistance during the Valsalva maneuver in man. Stroke. 1984; 15(1): 76–79, doi: 10.1161/01.str.15.1.76, indexed in Pubmed: 6229907.