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Acute hemodynamic effects of salted potato chips in healthy people

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Short title: Acute hemodynamic effects of salted potato chips

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Introduction

Sodium chloride (salt) consumption causes water retention and thus affects many organs and systems. Excessive dietary salt intake is a risk factor for cardiovascular diseases such as hypertension, left ventricular hypertrophy, heart failure and stroke [1-3]. Salt is present in processed and seasoned food, including salty snacks consumed in huge quantities both by children and adults [3]. Frequently, a pack of salted snacks is eaten in a couple of minutes. Although the long-term cardiovascular consequences of excessive salt consumption have been known for years, [1-3], the acute effects of salted potato chips intake on the hemodynamic response in healthy people are unclear. In this physiological study, we assessed the transient hemodynamic response to the intake of salted potato chips by healthy adults.

Twenty-five healthy volunteers (15 women) at least 19 years old who were not taking any medication or using a low sodium diet were enrolled. The University Ethics Committee approved the study protocol (decision number 1144/05), and informed consent was obtained from all participants.

Participants abstained from salted snacks for at least 48 hours. During the study, subjects first rested in the supine position for 20 minutes, then the noninvasive recording of blood pressure and hemodynamic parameters was started. The first 5 minutes were taken for the baseline assessment (Pre-ingestion). During the next 15 minutes (Ingestion period), participants ate 110 grams of commercially available salted potato chips (Frito Lay, Poland) containing nearly 2.0 g of sodium chloride (plus app. 8 g proteins, 59 g carbohydrates, 35 g fats, and 6 g plant fibers) and drank 100 ml of water. After chips consumption (Post-ingestion), subjects continued signal recording for 40 minutes.
Beat-to-beat finger systolic blood pressure (SBP), pulse pressure (PP) and the rate pressure product (RPP) were measured by the volume-clamp photoplethysmographic method (Portapres 2, FMS, The Netherlands) [4,5]. Heart rate (HR) and stroke volume (SV), cardiac output (CO), systemic vascular resistance (SVR) and thoracic fluid content (TFC) were measured according to the modified Bernstein formula by cardiac impedance (Niccomo, Medis GmbH, Germany) [6].

All continuously measured parameters were averaged for every 5 minutes for the Pre-ingestion and Post-ingestion. The nonparametric ANOVA for repeated measures (Friedman's test) evaluated the changes in all parameters, and the post-tests compared measurements from the Pre-ingestion (R) with values recorded 5, 10, 15, 20, 25, 30, 35, and 40 minutes after chips consumptions. The relative maximal changes of all continuous data recorded during the Post-ingestion, compared with the Pre-ingestion baseline values, were presented as %. Only $P < 0.05$ was considered significant.

Median age of studied participants was 29.0 (25th-75th percentile: 28.0-32.0) years, body mass index 21.9 (20.3-23.8) kg/m$^2$, resting brachial SBP 110.5 (105.0-128.0) mmHg, diastolic blood pressure 61.5 (59.0-66.0) mmHg, and HR 66.5 (57.0-74.0) beats/minute. Figure 1 shows that except SV (panel E), the remaining hemodynamic parameters significantly changed ($P<0.001$) after chips consumption. Compared with the Pre-ingestion values, the maximal relative increases were observed for HR of nearly 16%, SBP of nearly 9%, in PP of 17%, in RPP of nearly 24%, in CO of 14%, and TFC of nearly 5%, and the maximal relative reduction in SVR of nearly 22%. The earliest changes triggered by chips intake were observed after 15 minutes for HR, CO, RPP and SVR; 20 minutes for PP; 25 minutes for TFC; and 40 minutes for SBP.

We demonstrate that the consumption of salted potato chips and drinking of only 100 ml of water cause significant acute hemodynamic changes in healthy individuals - values of HR, CO,
RPP, PP, SBP, and TFC increase while SVR decreases. It appears that increases of CO (HR x SV) and RPP (HR x SBP) were caused mainly by HR acceleration since the significant change was either not observed for SV or was very late for SBP. Compared to CO, the increase of TFC was delayed for 10 minutes. Both CO and TFC depend on the amount of fluid. However, CO reflects mainly changes in the whole intravascular space whereas TFC measures alterations in total, i.e. intravascular and extravascular, fluid amount but only in the chest. In other words, only TFC reflects alterations of fluid amount in the extravascular compartment. Therefore, the observed delay between increases of CO and TFC suggests that salted snacks cause hemodynamic changes first in the intravascular compartment and later in the extravascular space secondary to the shift of water and sodium.

Salted potato chips have different ingredients, including proteins, carbohydrates, fats and salt which are absorbed from the alimentary tract, transferred into the circulation and may trigger different hemodynamic effects. In general, different types of meals, for instance rich in proteins, carbohydrates or fats, cause an increase in CO and HR with a concomitant reduction in blood pressure and SVR [7-9]. Our observations are in agreement with others for HR, CO and SVR but different for SBP, which gradually increased. Because the relative content of salt in the 110-g chips pack is very high (nearly 2 g) and it corresponds to daily requirements for adults, we believe that an acute sodium overload in a matter of several minutes might overdrive blood pressure reduction observed after eating other nutrients, for example carbohydrates. The absorption of salt from the alimentary tract leads to a sudden shift of sodium (from the intestines) and water (from both intestines and the extravascular space) to the intravascular space and an increase in plasma osmolality [10,11]. The intravascular mobilization of fluid translates into an increased plasma volume, which needs faster HR to pump and lower SVR to contain it in the intravascular space. A
higher HR and gradually increasing SBP also cause a rise in the rate pressure product, which reflects myocardial oxygen and energy consumption [5].

This study has some limitations. First, this experimental study was designed to observe hemodynamic changes and not to search for the potential mechanisms, therefore, most of our physiological considerations are speculations only. Second, although we assume that salt is the main factor responsible for the hemodynamic changes, the potato chips have other active ingredients which contributed to final results, e.g. carbohydrates or proteins. Therefore, the observed hemodynamic consequences represent rather a mixed effect of all nutrients with some dominant influence of salt. One might also speculate that the observed hemodynamic changes were caused by water ingestion and not by the intake of chips [10,12]. However, the participants were allowed to drink only 100 ml of water. Very recently, we have reported a comparison of drinking 500 ml of beer and tap water by healthy people and found that there was no significant change in SBP even 60 minutes after was drunk [12]. Therefore we believe that drinking of 100 ml water had rather negligible physiological effects in our study. Further, we show the averaged hemodynamic response of all studied participants but some of the individual responses were different, i.e. flat or short lasting hemodynamic responses (data not shown). It might be caused by variant sodium sensitivity, which determines the blood pressure response to salt consumption [2,4]. To partially overcome this problem, we used the repeated measures tests in statistical analysis to partially limit the effects of interpersonal differences on final results. Finally, we used indirect hemodynamic measures by cardiac impedance and volume-clamp methods, which are commonly used in physiological and clinical studies. These methods are completely noninvasive and safe and allow to record cardiovascular signals in a continuous way [4,6].

In summary, the consumption of a pack of 110 g of salted potato chips containing nearly 2
g of sodium chloride triggers several significant acute hemodynamic responses in healthy people, including significant increases in blood pressure (SBP) retention of water in the extravascular space (TFC).

We hope that this study will contribute to the discussion on the role of excessive sodium in our diet as well as on the effects of dietary behavior, particularly the role of snacking during the day. Although the question of the role of dietary salt intake in hypertension is far from being answered, it seems necessary to underline that the consumption of salted snacks is not without effects on the cardiovascular system. A significant shift in the water amount in the lungs (TFC increase) caused by gradual retention of fluids in the extravascular space shows that other organs and tissues may be affected as well. It may partially explain an acute hemodynamic decompensation happening to patients with heart failure, renal failure or severe hypertension who do not follow the medical recommendation about the dietary restriction of salt intake [1-3].

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Figure 1. Acute changes of the hemodynamic parameters (box and whisker plots) before (R) and after (5-40) consumption of 110 grams of salted potato chips. P values come from the
nonparametric ANOVA test (Friedman test) for repeated measures. Asterisks indicate a significant difference in the post-tests analysis comparing the values measured at rest (R) and a specific point in time after the chips intake. Panel A shows changes in HR, panel B in SBP, panel C in PP, panel D in RPP, panel E in SV, panel F in CO, panel G in SVR, and panel H in TFC. The box and whisker plots present quartiles with the median value inside it, and the ends of the whiskers represent the 10th and 90th percentiles. Abbreviations: CO, cardiac output; HR – heart rate; \(P_{ANOVA}\) – \(p\)-value from nonparametric ANOVA test; PP, pulse pressure; RPP, rate pressure product; SBP, systolic blood pressure; SV, stroke volume; SVR, systemic vascular resistance; TFC, thoracic fluid content.