ABSTRACT

Purpose: The aim of this study was to analyze whether the beneficial properties of sulfurous mineral water from Varna basin varied depending on the lifestyle.

Materials and Methods: Fifty healthy volunteers entered the 8-week intervention study with mineral water intake from selected sources. Plasma markers for lipid profile, inflammation and oxidative status were measured before and after the intervention period. Based on the self-reporting questionnaire, the participants were stratified into groups depending on their lifestyle habits related to nutrition, physical activity, cigarette smoking, and frequency of alcohol consumption. The levels of biochemical markers were analyzed in relation to the lifestyle variables.

Results: Significant anti-inflammatory and antioxidant properties of the Varna sulfurous mineral water were suggested, which seem to be independent of lifestyle habits. A potential of the water to improve the lipid profile in overweight subjects was also revealed.

Conclusions: Everyday consumption of sulfurous mineral water may affect metabolic processes and health in their crosstalk with lifestyle habits. In terms of precision medicine and personalized nutrition, we believe that the results from this study would be of interest to the society, policymakers, and healthcare professionals.

Keywords: sulfurous mineral water, lifestyle habits, human health, lipid profile, redox status, inflammation.

INTRODUCTION

The health effects of mineral water intake have been considered by traditional medicine since ancient times, as well as discussed, questioned and reconsidered in terms of new scientific discoveries. On the other hand, in our times, in which about one-third of the global population suffers periodically from severe water scarcity, half a million of them - all year round, mineral waters may become a strategic resource for the human race. Thus clarifying the effects of these waters on human metabolism and health becomes a priority task for scientists. Safe intake, individual responses to different mineral waters, personalized daily doses – these are questions still to be answered for every type of mineral water. While many people rely on the healing properties of mineral water as a remedy for various pathological conditions, and many others use it as everyday drinking water, it is not clear whether individual response to an intake of a certain type of mineral water would depend on lifestyle habits, and anthropometric and metabolic state.

Lifestyle habits are an important factor in the maintenance of health. Unhealthy nutritional and lifestyle habits could contribute to a shift in the markers for oxidative status and inflammation in pathological conditions. Healthy body weight and regular physical activity are considered important in the prevention of socially significant diseases, such as obesity, metabolic syndrome, and cardiovascular diseases [1, 2]. Smoking, alcohol abuse, and an unhealthy diet could be the reason for lowered levels of plasma thiols and vitamin C, and for increased lipid peroxidation product levels (such as MDA) [3, 4]. A study reported that smoking positively correlated with inflammation and atherosclerosis and, even after cessation of smoking, the CRP levels of former smokers remained higher for a longer period of time as compared to non-smokers [5]. Thus it would be interesting to follow whether the lipid profile and plasma markers of inflammation and oxidative status would be equally affected upon interventional mineral water intake in individuals with different lifestyles.

Recently, the scientific interest in sulfur-containing mineral water (SMW) has increased due to the new knowledge about the beneficial effects of the compounds dissolved therein [6]. The thermal waters from the Varna mineral basin are with low mineralization and, based on their physicochemical characteristics, are classified as sulfurous [7-10]. Many public springs on the territory of Varna town make this water freely accessible for thousands of people. It is reported that mineral waters with a composition similar to those of Varna mineral basin are used in liver,
gastrointestinal and kidney disease therapies [11, 12], dermatological problems [13], chronic respiratory diseases [14-15], and age-related degenerative diseases [16]. The healing effects of sulfurous waters are attributed to the antioxidant and anti-inflammatory properties of divalent sulfur compounds, such as hydrogen sulphide and other dissolved sulfides [6, 17,18].

**PURPOSE**

The goal of this study was to explore whether the beneficial properties of sulfurous mineral water from Varna basin varied depending on the lifestyle.

**MATERIALS AND METHODS**

**Subjects and Study Design**

A group of 50 healthy volunteers (men/women=7/43), aged 40-65 (mean 50.76±7.38), consumed mineral water from selected springs with known mineral content during the intervention period lasting 8 weeks. Exclusion criteria were chronic diseases (diabetes, renal, liver, gastrointestinal, cardiovascular, autoimmune oncological diseases, hypertonia, psychiatric disturbances), pregnancy, lactation, intake of specified drugs (diuretics, antidepressants, thyroid and steroids hormones, antihypertensive drugs, steroid anti-inflammatory drugs), or supplements containing magnesium, calcium, iron, or selenium.

Physical status and anthropometric data were measured, and BMI (kg/m²) was calculated for each participant. The individual amounts of water were calculated according to the body weight (20 mL/kg), but they were not less than 800 mL per 24 hours. Furthermore, participants were asked not to change their dietary habits and lifestyle throughout the intervention period.

**Ethical Issues**

The study was approved by the Ethics Commission at the Medical University of Varna (Protocol No. 62/04. 05. 2017). Before entering the study, all selected subjects signed an informed consent.

**Blood Samples**

Fasting venous blood samples were collected in heparin vacutainers at two-time points: before (T0) and after (T1) the intervention. The blood samples were conditioned for 15 minutes at room temperature and centrifuged at 3500 rpm for 15 min. Blood plasma aliquots were stored at -80°C for analyses of biochemical markers.

**Biochemical Analyses**

Total cholesterol (TC), triacylglycerols (TAG), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C) and high-sensitivity C-reactive protein (hs-CRP) were routinely measured in a clinical laboratory by methods approved by the International Federation for Clinical Chemistry (IFCC). Commercially available kits were used for measurement of plasma malondialdehyde (MDA) (Northwest Life Science Specialties, Vancouver, Canada) and of plasma total thiols (TSH) (Diacron International, Grosseto, Italy), following the instructions of manufacturers.

**Lifestyle Variables**

Before the intervention, all participants completed specially designed questionnaires for assessment of the social and health status, dietary habits, and lifestyle-related habits, including physical activity, smoking, and alcohol consumption.

In order to explore if the response to the mineral water healing effect is dependent on the lifestyle, we analyzed the changes of biochemical markers in the following groups:

1) Depending on BMI, the distribution of the participants was into two groups according to categories defined by the World Health Organization: group BMI<25 kg/m² (normal weight) and group BMI ≥ 25 kg/m² (overweight, pre-obese) [19].

2) Depending on physical activity: high physical activity (HPA) group and low physical activity (LPA) group.

3) Depending on tobacco consumption: non-smokers (NS) and smokers (S).

4) Depending on frequency of alcohol consumption: subjects who never or rarely consume alcohol (NA) and subjects who consume alcohol every day (A).

The effect of mineral water was assessed within the groups by comparing the levels of biochemical markers before (T0) and after (T1) the intervention and also between the groups of the related lifestyle factors.

**Statistical Analyses**

Statistical analyses were performed using a package of statistical programs for Windows, SPSS v. 16.0 (SPSS Inc., Chicago, IL, USA). Descriptive analyses were performed, and the quantitative data were expressed as mean±standard error of mean (SEM). Descriptive analyses were performed, and the quantitative data were expressed as mean±standard error of mean (SEM). The continuous variables were analyzed for normality in distribution by using the Kolmogorov-Smirnov (One-Sample Kolmogorov-Smirnov D-Test). The paired sample t-test was applied to compare the T0 and T1 marker levels with normal distribution within the groups. Student’s t-test was applied for comparison of continuous variables with normal distribution between the two independent groups according to their behavioural habits. Spearman’s correlation analysis was used to evaluate the relationship between the tested parameters. Values of p≤0.05 were considered statistically significant.

**RESULTS**

All enrolled subjects completed the study (n=50) without any complaints due to the intervention. The results presenting the link between the biochemical markers changes due to mineral water intake and lifestyle factors are summarized in Table 1:

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Table 1. Effects of Varna mineral waters on biochemical markers depending on the lifestyle factors and habits of 50 healthy volunteers.

<table>
<thead>
<tr>
<th>Markers</th>
<th>Body Mass Index</th>
<th>Physical Activity</th>
<th>Smoking</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;25 (T0), n=26</td>
<td>HPA (T0), n=24</td>
<td>NS (T0), n=33</td>
</tr>
<tr>
<td></td>
<td>≥25 (T1), n=26</td>
<td>HPA (T1), n=24</td>
<td>NS (T1), n=33</td>
</tr>
<tr>
<td></td>
<td>≥25 (T0), n=24</td>
<td>LPA (T1), n=26</td>
<td>NS (T1), n=17</td>
</tr>
<tr>
<td></td>
<td>≥25 (T1), n=24</td>
<td>LPA (T1), n=26</td>
<td>S (T1), n=17</td>
</tr>
<tr>
<td>Body Mass Index</td>
<td>P&lt; 0.05</td>
<td>P&lt; 0.05</td>
<td>P&lt; 0.05</td>
</tr>
<tr>
<td>TC (mmol/L)</td>
<td>5.29±0.017</td>
<td>5.55±0.18</td>
<td>5.39±0.14</td>
</tr>
<tr>
<td>TAG (mmol/L)</td>
<td>0.88±0.06</td>
<td>1.08±0.11</td>
<td>0.99±0.07</td>
</tr>
<tr>
<td>LDL-C (mmol/L)</td>
<td>2.40±0.09</td>
<td>2.58±0.10</td>
<td>1.69±0.06</td>
</tr>
<tr>
<td>HDL-C (mmol/L)</td>
<td>1.72±0.06</td>
<td>2.58±0.10</td>
<td>3.03±0.24</td>
</tr>
<tr>
<td>MDA (µmol/L)</td>
<td>2.70±0.17</td>
<td>1.63±0.08</td>
<td>3.28±0.28</td>
</tr>
<tr>
<td>hs-CRP (mg/L)</td>
<td>2.24±0.33</td>
<td>4.53±0.13</td>
<td>435±12.42</td>
</tr>
<tr>
<td>TSH (µmol/L)</td>
<td>431±15.56</td>
<td>515±12.70</td>
<td>497±9.48</td>
</tr>
<tr>
<td>Physical Activity</td>
<td>P&lt; 0.05</td>
<td>P&lt; 0.05</td>
<td>P&lt; 0.05</td>
</tr>
<tr>
<td>TC (mmol/L)</td>
<td>5.33±0.19</td>
<td>5.60±0.15</td>
<td>5.83±0.26</td>
</tr>
<tr>
<td>TAG (mmol/L)</td>
<td>0.85±0.04</td>
<td>1.45±0.14</td>
<td>1.56±0.11</td>
</tr>
<tr>
<td>LDL-C (mmol/L)</td>
<td>2.49±0.10</td>
<td>2.87±0.12</td>
<td>2.90±0.15</td>
</tr>
<tr>
<td>HDL-C (mmol/L)</td>
<td>1.67±0.07</td>
<td>1.56±0.08</td>
<td>1.56±0.11</td>
</tr>
<tr>
<td>MDA (µmol/L)</td>
<td>2.59±0.15</td>
<td>4.02±0.45</td>
<td>4.39±0.55</td>
</tr>
<tr>
<td>hs-CRP (mg/L)</td>
<td>1.48±0.10</td>
<td>2.31±0.33</td>
<td>2.16±0.31</td>
</tr>
<tr>
<td>TSH (µmol/L)</td>
<td>491±11.86</td>
<td>444±13.83</td>
<td>471±14.51</td>
</tr>
<tr>
<td>Smoking</td>
<td>S (T0), n=17</td>
<td>S (T1), n=17</td>
<td>S (T0), n=17</td>
</tr>
<tr>
<td>TC (mmol/L)</td>
<td>5.88±0.18</td>
<td>5.44±0.17</td>
<td>5.82±0.27</td>
</tr>
<tr>
<td>TAG (mmol/L)</td>
<td>1.32±0.12</td>
<td>1.19±0.10</td>
<td>1.50±0.20</td>
</tr>
<tr>
<td>LDL-C (mmol/L)</td>
<td>2.87±0.12</td>
<td>1.62±0.07</td>
<td>1.66±0.07</td>
</tr>
<tr>
<td>HDL-C (mmol/L)</td>
<td>1.56±0.08</td>
<td>3.52±0.41</td>
<td>3.38±0.40</td>
</tr>
<tr>
<td>MDA (µmol/L)</td>
<td>4.02±0.45</td>
<td>2.16±0.31</td>
<td>3.44±0.55</td>
</tr>
<tr>
<td>hs-CRP (mg/L)</td>
<td>2.31±0.33</td>
<td>0.022</td>
<td>1.58±0.12</td>
</tr>
<tr>
<td>TSH (µmol/L)</td>
<td>492±16.96</td>
<td>492±16.96</td>
<td>492±16.96</td>
</tr>
<tr>
<td>Strong alcoholic beverages consumption</td>
<td>ns</td>
<td>ns</td>
<td>ns &lt;0.0001</td>
</tr>
<tr>
<td>TC (mmol/L)</td>
<td>5.60±0.15</td>
<td>5.87±0.30</td>
<td>5.87±0.30</td>
</tr>
<tr>
<td>TAG (mmol/L)</td>
<td>1.26±0.23</td>
<td>1.26±0.23</td>
<td>1.26±0.23</td>
</tr>
<tr>
<td>LDL-C (mmol/L)</td>
<td>2.78±0.14</td>
<td>2.78±0.14</td>
<td>2.78±0.14</td>
</tr>
<tr>
<td>HDL-C (mmol/L)</td>
<td>1.68±0.13</td>
<td>1.68±0.13</td>
<td>1.68±0.13</td>
</tr>
<tr>
<td>MDA (µmol/L)</td>
<td>3.63±0.45</td>
<td>3.63±0.45</td>
<td>3.63±0.45</td>
</tr>
<tr>
<td>hs-CRP (mg/L)</td>
<td>1.46±0.14</td>
<td>1.46±0.14</td>
<td>1.46±0.14</td>
</tr>
<tr>
<td>TSH (µmol/L)</td>
<td>525±19.87</td>
<td>525±19.87</td>
<td>525±19.87</td>
</tr>
</tbody>
</table>

ns: not significant, T0: baseline, T1: after treatment, HPA: high physical activity, LPA: low physical activity, NS: no smoking, S: smoking
Effects of the Intervention Depending on BMI

The distribution of the participants depending on their BMI was as follows: 26 subjects in group BMI <25 and 24 subjects in group BMI ≥ 25. No changes in BMI after the intervention were estimated.

As presented in Table 1, the basic levels (T0) of TC, TAG, LDL-C, MDA, and hs-CRP were significantly higher for the group with BMI ≥ 25 compared to the normal-weight group. After the intervention, the average value of LDL-C concentration decreased significantly for the overweight group at T1 time point (2.70 ± 0.09 mmol/L), compared to the T0 time point (2.87 ± 0.12 mmol/L, p=0.04). Moreover, the differences between of LDL-C values measured at T1 were no longer statistically significant between the two groups. Slightly, although not statistically significantly reduced levels of TC in BMI ≥25 group were established after the intervention (TC (T0)=5.88 ± 0.18 mmol/L, vs. TC (T1)=5.60 ± 0.15 mmol/L, p=0.055). No differences in HDL-C levels were estimated between normal and overweight participants, and this marker remained unchanged up to the end of the study.

The mineral water intervention resulted in a significant decrease of hs-CRP values both for the group with normal BMI, and for the group of overweight subjects (p=0.032 and p=0.001, respectively). No differences in the basic levels of TSH were established between the groups in T0 point. However, after the intervention, TSH increased significantly in both groups: BMI<25 (p<0.0001) and BMI ≥ 25 (p=0.006). The MDA levels were significantly different between the individuals with normal and overweight both before (p=0.008) and after intervention (p=0.001). No significant change of this marker was observed after the intervention in either of the two groups (Table 1).

Effects of the Intervention Depending on the Physical Activity

The distribution of participants depending on their physical activity was as follows: 26 were with low physical activity (LPA) and 24 with high physical activity (HPA). This distribution was based on several self-report questions, as presented on Fig.1:

Fig.1. Distribution of participants depending on their physical activity.

In orange – the group of high physical activity (HPA, n=24); in blue – the group of low physical activity (LPA, n=26). In brackets – number of participants pointing specific activity according to the questionnaire.
As can be seen in Table 1, the physical activity as a lifestyle factor was not related to significant differences in plasma levels of lipids and MDA between groups at the two-time points, T0 and T1. Furthermore, the 8-week intervention with mineral water did not result in significant changes within the HPA and LPA groups.

On the other hand, significantly decreased levels of hs-CRP were determined after the intervention for both groups. This effect was more pronounced for the LPA group. After the intervention, the hs-CRP values measured at T1 point for this group were close to those of the HPA group (Table 1). Although no differences between the groups were estimated for the levels of TSH at T0, after the intervention, this marker increased significantly within the two groups (p=0.001 for HPA and for LPA) and also between the groups at T1 time point. Higher levels of TSH were measured for the HPA group compared to the LPA group after the intervention (p=0.028).

Effects of the Intervention Depending on the Smoking Habits

According to the data from the questionnaire, half of the participants (n = 25) had never smoked cigarettes. Together with 7 who had been non-smokers for more than 5 years and 1 non-smoker - for less than 5 years, they formed a non-smoker group (NS), n = 33. The rest of the participants (n=17) were distributed in the smoker (S) group (Fig. 2).

![Fig. 2. Distribution of participants depending on their addiction to smoking.](https://www.journal-imab-bg.org)

In orange – NS group, n = 37; in blue - S group, n = 13. The number of smoked cigarettes per day is indicated; in brackets: the number of participants.

The average levels of TC and TAG were significantly higher in the S group at the two-time points (Table 1). Interestingly, the LDL-C levels were significantly lower in this group compared to the NS one (p (T0)=0.018 and p (T1)=0.043). HDL-C remained unchanged both between the groups and within the groups after the intervention.

As could be expected, MDA levels were higher in smokers than in non-smokers in T0 and in T1. After the intervention MDA decreased in non-smokers and increased in smokers, but these differences were not statistically significant (Table 1).

A very interesting result has been obtained for hs-CRP. Prior to the intervention, the average levels of this marker in smokers were significantly higher in comparison with the NS group (p=0.033). After the intervention, the hs-CRP levels significantly decreased in both groups, more prominently in the S group. Thus, at T1 point the levels of the marker were almost equal between the groups.

No differences were estimated for TSH between the groups at T0 and T1 points. After the intervention, their concentration in plasma increased significantly only in the NS group (p<0.0001).

Effects of the Intervention Depending on the Alcohol Consumption

The group of non- or infrequently consuming alcohol individuals (NA) included 37 participants, and the remaining 13 formed the group of those frequently consuming alcohol (A). The groups were formed based on the frequency of strong alcoholic beverages consumption (Fig. 3).
According to the results in Table 1, alcohol consumption did not affect the lipid profile, with the exception of a slight non-significant tendency for increased TC at T1 time point for the two groups.

No significant differences in the hs-CPR levels between the groups were estimated in either T0 or T1 time points (Table 1). After the mineral water intervention significantly decreased levels of this marker were measured in T1 for both groups (p=0.003 for the NA group, p=0.019 for the A group).

The basic levels of TSH were significantly higher in the A group as compared to the NA one (p=0.003). After the intervention, only in the NA group significantly increased levels of plasma TSH were observed. Thus at the T1 point, no differences between the TSH levels of the two groups were estimated.

**DISCUSSION**

The aim of the present study was to assess the role of multiple lifestyle factors in the body response to the SMW intake for an 8-week period. The idea that the lifestyle habits could influence the healing effects of mineral water was based on the fact that the successful management of many diseases depends on the lifestyle behaviour and this is important not only for the prevention but also for the successful therapy [20, 21].

In our study, the basic levels of the markers for the lipid profile as well as the markers for the inflammation and oxidative status were significantly lower for groups with healthy lifestyle habits (subjects with normal weight, with regular physical activity, nonsmokers, never or rarely consuming alcohol).

The differences in lipid profile markers were more pronounced between groups stratified by their BMI. Significantly higher TC, LDL-C and TAG were found for the overweight group before the intervention (T0 time point) in comparison with the normal BMI group (Table 1). Similar were the results for the marker of lipid peroxidation, MDA, and for the proinflammatory marker hs-CRP. These results were not surprising. Diet is one of the most important lifestyle factors directly affecting human health [22]. Poor nutritional habits are positively associated with obesity, which nowadays is one of the most serious health problems worldwide [23]. Excess of adipose tissue correlates with dyslipidemia, elevated levels of proinflammatory cytokines, and also with dramatically changed redox status [24, 25]. None of the participants in our study was obese according to the definition of WHO, but for 24 of them the calculated BMI was in the range of 25 - 29.9 kg/m², which is defined as a pre-obese (overweight) status [19]. Although not as severe as obesity, the overweight status is considered to be a predictive factor for the future development of chronic pathological conditions [26].

Following the changes of the marker levels upon the intervention, we found that at T1 timepoint the lipid profile was partially improved for the overweight group. This was manifested by a significant reduction of LDL-C levels (p=0.04) and a slight, although not significant, decrease of TC (p=0.055).

After the intervention, a significant reduction of the levels of the proinflammatory marker and an increase in the concentration of TSH were found for all participants, independently of the BMI. We suppose that the active compounds dissolved in SMW might contribute to an improved anti-inflammatory and redox status. At this stage, we could suggest that the improved redox status after the mineral water intervention possibly promotes the amelioration of the lipid profile. Because of its long lifespan...
and specific metabolism, the LDL lipoprotein particles are very sensitive to oxidizing agents in the blood and are key players in atherogenesis and cardiovascular pathology.

The mineral water from the Varna basin used in this study is known to be slightly mineralized and to have a complex chemical composition of hydrogen carbonate, magnesium, calcium, silicon, hydrogen sulphide, and dissolved sulfur compounds [7-10]. Mineral waters with similar composition are reported to have antioxidant, anti-inflammatory, and cardioprotective properties [6].

Physical activity was another lifestyle factor included in the focus of our study. Regular physical activity is a beneficial lifestyle factor related to a reduced risk of metabolic disorders and cardiovascular diseases [27]. As can be seen in Table 1, no significant differences were detected for the base levels of the lipid profile markers and in MDA between the HPA and LPA groups. Also, the intervention did not result in changes of the above-mentioned markers. On the other hand, the base levels of serum hs-CRP were significantly higher in the LPA group in comparison with the subjects with regular high physical activity (p=0.022). This result is in accordance with other studies reporting that the concentration of serum hs-CRP and the physical activity as a lifestyle habit are in an inverse relationship [28, 29]. Interestingly, after the SMW intervention, the levels of this marker were markedly reduced and, even more, no statistically significant differences were estimated in the hs-CRP concentrations between both groups at T1 point.

No differences in the baseline TSH levels between LPA and HPA groups were found. However, after the intervention, the serum concentrations of this marker were significantly increased in all subjects, for the HPA group the values being significantly higher (p=0.028). This difference in the effects of SMW could be explained with the assumption that subjects who are physically active have better redox status. The chronic effects of physical activity are associated with improved antioxidant defence and consistently lower levels of proinflammatory cytokines [28, 30].

Smoking is considered a risk habit affecting negatively the overall health status [31, 32]. Comparing the lipid profile markers between the S and NS groups in our study, no differences were found in the baseline values of TC, TAG, and HDL-C between the two groups. After the SMW intervention, reduced TC levels were measured for both groups but this effect was more prominent for smokers. At the same time, increased TAG levels for the same group were assessed at T1. Another interesting finding was the lower LDL-C levels in the S group compared to the NS one, before and after the intervention (p=0.018 and p=0.043, respectively). The LDL-C levels measured for the S group at the two timepoints could be explained with the fact that all participants in the study were with a good health status and without any complaints during the study or any history of cardiovascular disorders. On the other hand, elevated levels of TAG at T1 for the same group are a result most probably due to the adverse effect of the compounds contained in cigarette smoke - it is known that smoking, even for a short duration, and a moderate number of cigarettes are associated with an altered lipid profile. Studies analyzing the effects of risk lifestyle behaviour on health have reported that the levels of TAG, LDL-C, and HDL-C are adversely affected in smokers compared to nonsmokers [27, 33, 34].

Regarding MDA levels, no differences between S and NS were observed at the beginning of the study. The intervention with SMW resulted in reduced MDA levels only for the NS group at T1 point, and the differences in the values between both groups were statistically significant (p=0.004). The low sensitivity of smokers to the antioxidant effect of SMW could be explained by the higher exposure of these subjects to the action of oxidants in cigarette smoke.

And, logically, serum hs-CRP measured at T0 was significantly higher in the S group. However, after the intervention, significantly reduced hs-CRP levels were measured for both groups and no differences between them were detected anymore at the end of the study (T1). Most likely, the anti-inflammatory potential of biologically active compounds dissolved in SMW plays a role in improving the levels of this marker, independently of the lifestyle variable.

The SMW intervention increased the levels of TSH in both groups but this effect was significant only for the NS group. A possible reason for this difference in the effect of the water could be the altered redox status of smokers. The proteins rich in sulfhydryl groups, known as thiols are very sensitive to changes in intracellular redox balance and play a central role in the antioxidant defense in the body. Obviously, SMW has the potential to contribute to improving the redox status thanks to the active compounds dissolved therein. The biological activity of the divalent sulfur compounds (hydrogen sulfide, polysulfides, hydrosulfides, thiosulfates) is manifested by post-translational protein modification, the so-called S-sulfhydration [35] Moreover, except as a signal molecule hydrogen sulfide could act directly as antioxidant by maintaining the thiols in their reduced form. We could hypothesize that the antioxidant effect of active compounds in SMW might be due to their direct antioxidant properties or to their potential to increase the production of thiol containing antioxidants. Increased TSH could lead to an increased resistance to oxidative challenges and thus contribute in the prevention of variety of diseases, such as CVD, metabolic syndrome, atherosclerosis, and many others. On the other hand, the antioxidant power of water may not be enough to meet the increased antioxidant requirements of smokers [36].

Like physical activity, the frequency of alcohol consumption did not change the markers for lipid profile and lipid peroxidation. No differences were found in the levels of serum hs-CRP between the groups of never or regularly drinking alcohol subjects before and after the intervention. However, within the two groups significantly reduced levels of this marker were measured after the intervention. Similarly to previous analyses, here we may
assume that this effect is due to the potential of SMW, although a possible contribution of alcohol to the results for the A group should not be excluded. There are scientific reports revealing that moderate alcohol consumption contributes to improved systemic markers of inflammation, including serum hs-CRP [37, 38].

As can be seen in Table 1, the baseline TSH levels for the A group were significantly higher compared to the NA group (p=0.03). This is an intriguing result since it has not been established for any of the other variables. It could be suggested that the subjects in this group have stimulated antioxidant defence. Alcohol consumption is usually associated with its toxic effects on the body due to increased reactive oxygen species and depletion of endogenous antioxidants. However, in a study from 2009, Chan et al. reported that regular moderate non-abusing alcohol consumption could contribute to improved biochemical markers and also to self-reported well-being quality [39]. After the intervention, the total thiols increased in both groups but this result was significant in the A group only.

CONCLUSION

In conclusion, the results discussed above suggested that everyday consumption of SMW from Varna basin could contribute to the good health status of subjects with different lifestyle habits. The potential of this water to improve the lipid profile was markedly expressed in overweight subjects. According to our results, smoking may have a negative impact on the beneficial effects of the water, especially with regard to lipid profile and markers for lipid peroxidation. The observed significant decrease of hs-CRP and increase of total thiols after mineral water intake in all analyzed groups revealed the potential anti-inflammatory and antioxidant properties of Varna basin SMW, which seem to be independent of the lifestyle habits. And to relate these results to health, from a consumer perspective when talking about precision medicine and personalized nutrition, we should envisage not only therapy and food tailored for them as individuals, but also water in its crosstalk with lifestyle that may affect metabolic processes and health.

List of abbreviations

BMI – body mass index;
SMW – sulphurous mineral water;
TC - total cholesterol;
TAG – triacylglycerols;
LDL-C – low-density lipoprotein cholesterol;
HDL-C – high-density lipoprotein cholesterol;
MDA - malondialdehyde;
hs-CRP – high-sensitivity C-reactive protein;
TSH - total thiols;
HPA -high physical activity;
LPA - low physical activity;
NS - non-smokers;
S – smokers;
NA - no alcohol consumption;
A - alcohol consumption

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