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Alkaline-earth elements of scalp hair and presence of hypertension in housewives: A perspective of chronic effect

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HIGHLIGHTS

- Ca, Mg, Sr & Ba are typical alkaline earth elements (AEEs) related to human health.
- We aimed to investigate an association of hair AEEs with presence of hypertension.
- Our cross-sectional study was conducted among housewives in Shanxi Province, China.
- Lower levels of hair AEEs were associated with an increased hypertension presence.
- Hair AEEs concentrations were correlated with dietary habit of housewives.

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ABSTRACT

The relationship between population intakes of alkaline-earth elements (AEEs) and hypertension risk remains under discussion. Hair AEE concentrations can indicate their intake levels into human body. Thus, we aimed to investigate an association of hair AEE concentrations with hypertension risk, and the potential effect of dietary habit on this association. We recruited 398 housewives [163 subjects with hypertension (case group) and 235 subjects without hypertension (control group)] in Shanxi Province of north China. The scalp hair grown in the recent 2 years of each subject was collected and analyzed for the four concerned AEEs [i.e. calcium (Ca), magnesium (Mg), strontium (Sr), and barium (Ba)]. Our study results revealed that median concentrations (μg/g hair) of hair AEEs in the case group were systematically lower than those in control group [i.e. 701 *vs.* 1271 of Ca, 55.2 *vs.* 88.3 of Mg, 4.60 *vs.* 10.4 of Sr, and 1.02 *vs.* 1.68 of Ba]. Lower levels of the four individual AEEs of hair were associated with an increased presence of hypertension, respectively. Moreover, hair AEE concentrations were all positively correlated with the ingestion frequencies of meat, eggs, fresh vegetables, and fruits, while negatively with that of salted vegetables. A high ingestion frequency of fresh vegetables was associated with a lower prevalence of hypertension with or without adjusting confounders, while salted vegetables revealed a reverse tend. It was concluded that low hair AEEs, as markers of their long-term dietary intake, were associated with the presence of hypertension in a rural Chinese women.

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1. Introduction

Roles of major minerals or trace elements in the etiology of hypertension formation have been worldwide studied (Ekmekci et al., 2003; Taneja and Mandal, 2007). Some of them act as nutrients to prevent hypertension independently or with interaction

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effects between them (Taneja and Mandal, 2007). Alkaline-earth elements (AEEs), especially calcium (Ca) and magnesium (Mg), had been suggested to involve into blood pressure regulation or hypertension formation in human body (Sacks et al., 1995; Ekmekci et al., 2003). For example, Mg performed particularly in conjunction with other nutrients or metal elements to regulate human blood pressure (Agus and Agus, 2001; Zhang et al., 2016). Regulatory role of intracellular Mg on peripheral vascular resistance may affect extracellular Ca^{2+} uptake (Taneja and Mandal, 2007). Mainstream opinion suggested that deficiency of Ca or Mg was associated with increased prevalence of hypertension (Witteman et al., 1989; Takagi et al., 1991; Ascherio et al., 1992; Ekmekci et al., 2003; Panhwar et al., 2014; Choi and Bae, 2015; Kajale et al., 2016). However, some other studies didn't support this point of view. For instance, higher intake of Mg or Ca was observed in the hypertensive patients than that of the normotensive controls (Taneja and Mandal, 2007; Suliburska et al., 2011). Gonzalez-Munoz et al. (2010) observed that there were no significant differences of the four typical AEEs [i.e. Ca, Mg, strontium (Sr), and barium (Ba)] between the normotensive and hypertensive subjects in a postmenopausal women population (Gonzalez-Munoz et al., 2010). To our knowledge, the associations of population Sr and Ba intakes with hypertension risk were rarely reported. An animal study showed that Ba supplement could induce an increase of blood pressure of rats (Perry et al., 1989), indicating of the potential risk of Ba to hypertension. Therefore, it's worthwhile to provide more evidence to investigate the role of AEEs in hypertension risk.

Hypertension is a chronic disease induced by various factors (e.g. aging, obesity, imbalanced dietary intake of nutrients), so the concerned factors should be well assessed from a long-term perspective. Three biological samples have been used to indicate the intake levels of AEEs, including urine (Panhwar et al., 2014), serum (Takagi et al., 1991), and hair (Gonzalez-Munoz et al., 2010). Because AEEs in urine and serum were greatly affected by diet and had obvious variances among 24-hr monitoring, hair sampling was more preferred to use to indicate population long-term intake level of metals in the previous studies (Pereira et al., 2004; Gonzalez-Munoz et al., 2010; Suliburska et al., 2011; Ochi et al., 2013). In addition, hair sample can be noninvasively collected and stored at room temperature with low cost. Therefore, hair sampling was more suitable to assess population long-term intake level of AEEs.

Multiple studies had revealed that dietary factors were associated with blood pressure or hypertension, and dietary supplement of various nutrients has been considered as a most attractive strategy for treatment or prevention of hypertension (Resnick, 1999). Excessive sodium intake is a causal risk factor for hypertension, whereas high ingestion frequencies of fruit, vegetables, and low-fat dairy products and low in sodium and saturated fat are recommended to reduce hypertension risk (Zhao et al., 2011). Diet is the dominant route of population AEE intake, hence, ingestion frequencies of various food types may greatly modulate the AEE level in human body. We therefore proposed the hypothesis that intakes of the concerned four AEEs (i.e. Ca, Mg, Sr, and Ba) were associated with presence of hypertension, and this effect was modulated by population dietary habit. We planned to conduct our study among the housewives with long-term consistent living for at least 10 years in Shanxi Province of north China. The aims of this study were: 1) to determine the associations between the four AEEs of women's hair and presence of hypertension, as well as the association between diet habit and hypertension risk; 2) to investigate the correlations between hair AEE concentrations and frequencies of various ingested food types.

2. Materials and methods

2.1. Study population

Our cross-sectional study aiming to investigate the effects of environmental pollutants on hypertension risk in local housewives was conducted in Pingding County Hospital in Shanxi Province, China from Aug 2012 to May 2013. The detailed information about the recruitment was provided in our previous study (Wang et al., 2016). Briefly, the women who met the following criteria would be recruited: (1) residents of the study county (rather than immigrants), (2) aged 30 years or older, (3) no significant changes in their living conditions over the past 10 years. The questionnaire included information on age, education ("primary or lower", "junior high", "high school or junior college", or "above junior college"), occupation (farmer or non-farmer), and active or secondhand smoking (yes or no). The definition of passive smoking is staying in a tobacco smoking environment for more than 30 min. Frequencies ("<1 time per week", "1–3 times per week", "4–6 times per week", and "> 6 times per week") of the six concerned food ingestion were collected including meat, eggs, fresh vegetables, fruits, beans, and salted vegetables. Among them, fresh vegetables usually include celery, onion, cucumber, tomato, Chinese cabbage, eggplant, radish, etc., which are the freshly prepared for the local population. In most areas of Shanxi Province, consuming salted vegetables is a popular tradition. In the autumn, rural families salt their own Chinese cabbage, turnips, soybeans, and other vegetables in large ceramic containers for use during winter when fresh vegetables are not available. The vegetables are compressed by stones, filled with water, and allowed to ferment for several months. Blood pressure was measured three times by experienced physicians using an appropriate cuff with a standard mercury sphygmomanometer on the right arm at 2-min intervals following a rest period of at least 5 min. For each subject, hypertension was defined as systolic blood pressures of at least 140 mmHg and/or all diastolic blood pressures of at least 90 mmHg in all of the three-time measurements, as well as a self-reported diagnosis of hypertension requiring treatment with antihypertensive drugs. For self-reported diagnosis of hypertension, we will confirm it by checking their medical histories. A total of 405 housewives were recruited, while hair samples with at least 8 cm long were collected for 398 housewives of them, resulting in five invalid subjects. The study protocol was approved by the institutional review board of Peking University, and signed consent was obtained from all subjects.

2.2. Analysis of hair AEEs

Hair samples with length (as close to be 24 cm as possible) were used to represent their recent two-year intake levels of AEEs by assuming a consistent hair growth rate, i.e. 1 cm per month. Hair was cut into 0.5-cm segments and washed according to the internal standard operation procedure as the following: soaked in Triton X-100 (5‰, m/v) for 10 min, washed by ultrapure water (10 times), soaked in acetone for 5 min, and washed by anhydrous ethanol (1 time). About 80 mg of hair was weighed and transferred into a 15-mL Teflon® tube. Hair samples were digested by 1 mL HNO_3 in a microwave oven system for 60 min. Ca and Mg were measured using an inductively coupled plasma-atomic emission spectrometry [ICP-AES, Thermo iCAP 6000SERIES (USA)], and Sr and Ba using an inductively coupled plasma-mass spectrometry [ICP-MS, PerkinElmer, ELAN DRCII (USA). Quantifications of the four AEE concentrations of the standard hair samples (GBW09101b) purchased from the National Standard Material Center in China were 246.3 ± 6.2 μg/g hair (mean ± standard deviation) (Mg), 1606 ± 67 μg/g hair (Ca), 10.5 ± 0.4 μg/g hair (Ba), 8.8 ± 0.1 μg/g hair

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