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Human Nail Selenium and Cadmium Predict Perceived Stress

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KEYWORDS

Perceived stress;
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ABSTRACT: New Zealand has low levels of the essential trace elements selenium and a growing concern with increasing exposure to cadmium, one of the most toxic pollutants worldwide. Both elements are highly implicated in health and disease and have links with the central nervous system. Selenium levels have previously been shown to have a relationship with psychological stress and is also known to protect against cadmium neurotoxicity. We sort to examine the impact of selenium and cadmium as factors for perceived stress in a New Zealand population, with a high proportion of tertiary students. All participants completed a validated questionnaire for perceived stress and had nail clippings analysed for cadmium and selenium using inductively coupled plasma mass spectrometry. Factors for increased perceived stress are younger age, lower selenium concentrations and higher cadmium concentrations. Both selenium and cadmium are likely to be important considerations to reduce perceived stress levels in this population.

INTRODUCTION

Human health is a holistic term that includes three domains: physical, psychological, and social well-being [1]. Psychological stress (the perception an individual's capacity to adapt to environmental demands has been exceeded [2]) has associations with all three of these domains [2-4]. Psychological stress is associated with many physical diseases including cardiovascular disease, cancer, depression, infectious disease, autoimmune disease, obesity and wound healing (for reviews see [2, 5, 6]). The mechanisms for the associations between psychological stress and disease are not clear. However, increased inflammation in stressed individuals [7] and associations between chronic psychological stress and shortened telomere length and accelerated cell ageing [5], are likely factors. Lengthy time frames between the occurrence of psychological stress and future physical health have been identified in adults [8] and children [9].

Psychological stress may be influenced by the "gut-brain axis" a complex relationship of bidirectional communication involving the brain, the microbiome, and dietary nutrients [10]. The nutrient selenium is an essential component of several major metabolic pathways, including antioxidant defence systems (for review see [11]). Selenium deficiency has been associated with several adverse health effects, from subclinical manifestations to cardiovascular disease and cancer (for review see [12]). Low levels of selenium have also been linked to increased psychological stress [13]. Areas of selenium deficiency are widespread in New Zealand [14] Thus, New Zealand residents may be more likely to suffer adverse health effects from selenium deficiency.

Cadmium is one of the most commonly encountered heavy metals pollutants in the environment with serious dose-dependent toxicity risk for humans [15]. Compared with other known toxic chemicals, cadmium ranks in seventh place based on a combination of frequency, toxicity, and potential for human exposure [16]. This is because cadmium has the potential to accumulate in humans with a very long biological half-life of 20–30

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years, which is a factor in the many negative health implications (for review see [17]). Cadmium exposure is known to affect the central nervous system, and clinical symptoms may include neurological disturbances, learning disabilities and behavioural alterations in adults and children (for reviews see [17, 18]. Dietary metals play important roles in protecting against cadmium toxicity [17] and selenium specifically protects [19] against cadmium neurotoxicity. Cadmium is present in many foods, and diet is a significant source of human exposure [20]. The accumulation of cadmium in agricultural soils with subsequent adverse effect on food quality is of particular concern in New Zealand [21]. There is a lack of data on cadmium soil concentrations in New Zealand, and some foods have been shown to exceed local food standard maximum levels [21].

New Zealand has low levels of the essential trace elements selenium and a growing concern with increasing exposure to cadmium, one of the most toxic pollutants worldwide. Both elements are highly implicated in health and disease and both have strong links with the central nervous system. Selenium is known to protect against cadmium neurotoxicity. The aim of this study was to examine the impact of selenium and cadmium elements as factors for perceived stress in a New Zealand population,

MATERIALS AND METHODS

Residents of Hawkes Bay were invited to participate in this study via posters and social-media at the Eastern Institute of Technology, tertiary education center, Hawkes Bay, New Zealand. Participants with a current residential address other than Hawkes Bay were excluded.

All participants completed the ten-item Perceived Stress Scale (PSS) [22], a validated tool used to measure perceived psychological stress in many populations (Lee, 2012). The PSS was used to calculate a stress score as previously described [22]. After completing the questionnaire, participants provided nail clippings for trace element analysis. Sampling was performed using recommended procedures [23, 24]. Participants were asked in advance not to trim their nails for a minimum of two weeks. Nails were collected by clipping with a stainless steel clipper, obtaining as much nail as possible from both feet and hands. The nail samples were stored at room temperature in a labelled envelope until laboratory processing. At sampling, participants completed a nail questionnaire to obtain information on nail polish frequency and colors, nail medication use, stainless steel cooking materials use and socks and shoe use. The number of toe and fingernails cut from each participant was also recorded at sampling.

Nail samples were washed and prepared for analysis as follows. Visible dirt was removed by scraping with cotton. Each sample was then placed into a 50 mL beaker and washed with 0.5% Triton-X 100 (Sigma-Aldrich, NZ) followed by deionised water, and then acetone (Sigma-Aldrich, NZ). Each washing step lasted for two hours using a mechanical shaker which was followed by repeated rinsing with deionised water. After the washing procedure, samples were dried at 40^0 C overnight in an oven, weighed and sent for analysis.

Nail analysis was performed by Analytica laboratories (Ruakura Research Centre Campus, Hamilton, New Zealand). Nail cadmium and selenium was determined using inductively coupled plasma mass spectrometry (ICP-MS). Briefly, 10–20 mg of weighed nail samples underwent aqua regia digest. These were then diluted to 2% HNO3, 1% HCl. Rhodium was used as an internal standard for cadmium and gallium for selenium.

Statistics analysis

Perceived stress scores, cadmium and selenium concentrations were first examined for normal distributions using the D'Agostino & Pearson omnibus normality test. The association between perceived stress scores, cadmium and selenium concentrations with age was examined. Differences between perceived stress, cadmium and selenium concentrations for gender were compared with student t-test. Linear regression was performed to assess which factors predict perceived stress. All statistical analysis was performed with GraphPad V4, San Diego, CA, USA.

RESULTS

21 participants provided nails for trace element analysis (Table 1).

Table 1. Mean Trace Element Concentrations in Nail Samples (n=21)

	Cadmium	**Selenium**
Mean	0.046	1.207
Std. Dev.	0.054	1.302

All units are mg kg^{-1}

The only single variable to predict perceived stress was age (r^2=0.64, p=0.002). There were no differences between trace element concentrations in nail samples for age or gender.

Two multiple regression models were used to assess if nail trace element concentrations predicts perceived stress. Model 1, using nail cadmium and selenium concentrations as factors, was predictive of perceived stress (r^2=0.58, F=4.53, p=0.026). Higher concentrations of Selenium (p=0.009, coefficient=-3.28), and lower concentrations of Cadmium (p=0.013, coefficient=3.10) were associated with lower perceived stress.

Model 2, which included age in addition to the previous model was more predictive of perceived stress than age alone or model 1 (r^2=0.79, F=9.51, p<0.001). Higher selenium (p=0.007, coefficient=-3.31) and older age (p<0.001, coefficient=-0.57) were associated with lower perceived stress. Higher cadmium (p=0.006, coefficient=3.11) was associated with higher perceived stress.

DISCUSSION

The aim of this study was to explore nail selenium and cadmium concentrations as factors for perceived stress in a population living in New Zealand, an area with low levels of selenium and a growing concern with increasing exposure to cadmium. The perception of psychological stress is markedly higher in younger individuals compared with older individuals in the studied population. We found that individuals with higher concentrations of nail cadmium have higher perceived stress than individuals with lower nail concentrations. Conversely, higher concentrations of nail selenium are associated with lower perceived stress. Our findings support that selenium may offer protection from cadmium toxicity. Dietary micronutrients and in particular selenium intakes may be important considerations to reduce perceived stress.

The perception of psychological stress is higher in younger individuals compared with older individuals in the studied population. This is an important finding as time frames for increased risk of disease after stress are lengthy with psychological stress encountered when young linked [9] to chronic diseases of ageing. The younger participants in this study may be at higher risk for increased inflammation [7], accelerated cell ageing [5], and many physical diseases [2, 5, 6]. Strategies to reduce perceived stress in younger individuals should be a priority at the studied institution.

We found that individuals with higher concentrations of nail cadmium have higher perceived stress than individuals with lower nail concentrations. Cadmium is a pollutant with serious dose-dependent toxicity risks for humans [15]. To our knowledge, our current study is the first to report a specific association with perceived stress. Such an association is not unexpected as cadmium exposure is known to affect the central nervous system, and clinical symptoms may include neurological disturbances [17, 18]. Of specific concern considering the association between age and perceived stress is that cadmium does not readily penetrate the blood-brain barrier in adults. [17]. However, in comparison to adults, the blood-brain barrier in younger subjects may not be fully functional, which increases the vulnerability of young subjects to cadmium toxicity [25]. We believe our research supports lowering safety limits for food cadmium levels.

Higher concentrations of nail selenium are associated with lower perceived stress, which is similar to previous findings in blood [13]. Essential dietary metals play important roles in protecting against cadmium toxicity [17] and selenium is known (for review see [19]) to protect against cadmium neurotoxicity. Thus in the current study population, the stress-reducing association with selenium may be a selenium protective action against cadmium. Diet is the main route for selenium intake and areas of selenium deficiency are widespread in New Zealand [14] Thus the association with stress may be particularly relevant for other low selenium areas. New Zealand has successfully combated the re-emergence of iodine deficiency with 2009 legislation for the mandatory fortification of bread with iodised salt [26]. There may also be a similar case for selenium fortification.

A limitation of the current study is that trace element levels in nails may not be indicative of levels in the blood, which is the sample type most commonly employed to assess toxicity. However, nail analysis has been suggested to hold several advantages compared with blood, including a higher concentration of elements and reflecting a longer retrospective time frame [23]. Both the perceived stress scale and nail clippings offer a retrospective window for perceived stress and trace elements respectively. While we cannot draw firm conclusions in terms of toxicity or nutritional status, our results were very similar to nail concentrations reported recently [27] in adults for selenium. Additionally, our median nail selenium concentration (0.75 mg kg^{-1}) suggests no overt toxicity when compared with the nail selenium concentrations restored to baseline (0.81 mg kg^{-1}) following the most severe selenium toxicity outbreak in the US history [28]. In that outbreak, nail samples from individuals with selenosis symptoms recorded peak nail concentrations of 18.3 and 44.1 mg kg^{-1} in fingernails and toenails respectively before returning to baseline, which took many months.

In conclusion, New Zealand is an area with low levels of selenium and a growing concern with increasing exposure to cadmium. In our population individuals with higher concentrations of nail cadmium recorded higher perceived stress than individuals with lower nail concentrations. Conversely, higher concentrations of nail selenium are associated with lower perceived stress. The perception of psychological stress is markedly higher in younger individuals compared with older individuals. Our findings support that selenium may offer protection from cadmium for stress. Dietary micronutrients and in particular selenium intakes may be important considerations in areas with low selenium levels.

ETHICAL CONSIDERATION

This study was approved by the Eastern Institute of Technology Research Committee on 11/12/2018 Reference (REF 18/17).

Consent

Informed consent for this reseach and publication of results was obtained from all individual participants included in the study.

Conflicts of interest

None.

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