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The relationship between serum zinc levels and myopia

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Clinical significance: Myopia is inherently associated with eye growth and thereby possibly amenable to nutritional influence. However, little attention has been given to possible dietary influences. This study demonstrates that serum zinc does not play a role in myopia development.

Background: Myopia is inherently associated with eye growth and thereby possibly amenable to nutritional influence. A number of Asian studies have reported lower levels of serum zinc in myopic children. This study was designed to assess the relationship between serum zinc and myopia in the Korean population – using a subsample of participants from nationally representative data.

Methods: Data from the fifth Korean National Health and Examination Survey (KNHANES) 2010 were used to explore zinc status in relation to refraction. A total of 304 participants were analysed, ranging in age from 12 to 19 years. Serum zinc levels were measured using inductively coupled plasma mass spectrometry, while refractive error was determined by non-cycloplegic autorefraction. Multivariate analysis was used to examine the association.

Results: A significant majority of participants (n = 255; 84 per cent) were myopic. There was no significant difference in serum zinc levels between myopic and non-myopic children (p = 0.81). In multivariate logistic regression, serum zinc was not significantly associated with myopia after adjustment for age, gender, residence, body mass index, family income and recreational activity. Similarly, no relationship was observed between spherical equivalent refraction and serum zinc within the myopic group (p = 0.46).

Conclusion: In a subset of 12–19-year-old participants from the population-representative KNHANES study, no association was found between serum zinc and myopia. However, the lack of a sensitive biomarker for zinc status remains a major limitation in this, and all current studies.

Key words: KNHANES, myopia, refractive error, serum zinc

The prevalence of myopia has risen dramatically over recent decades, with no evidence of slowing.[1] Myopia levels of 80–90 per cent have been reported in school leavers in countries like Singapore, South Korea, China, and other high-income areas of East and South East Asia.[1] In fact, a study carried out in Seoul, South Korea, in 2010, found the prevalence of myopia to be 96.5 per cent in 19-year-old males.[2] These rising levels have serious public health implications, creating a range of detrimental health and socio-economic impacts. Health impacts arise where optical correction to alleviate the symptoms of myopia is unavailable and because of the range of ocular comorbidities associated with myopia.[3] Socio-economic impacts include lost productivity associated with vision loss, the direct and indirect costs of treating myopia and its ocular comorbidities, costs associated with vision impairment and blindness along with any resultant quality of life effects. The global productivity lost due to uncorrected myopia, for example, is estimated to be a massive $244 billion annually, with an additional $6 billion loss due to just one of the complications associated with myopia, myopic macular degeneration.[4] In Singapore alone, the annual direct cost of optical correction of myopia for adults has been estimated at US$755 million.[4]

Genetic factors are thought to play a role in myopia development or susceptibility to myopia, but it is clear that genetic change is too slow to account for these accelerated rates.[5] It is therefore now widely accepted that environmental influences play a large role. Environmental factors have influenced and changed many aspects of our modern lifestyle – increasing urbanisation, for example, is a generally accepted risk factor for myopia, which may relate, at least in part, to behavioural aspects of urban living.[6,7] Currently, there is a need for exploration and investigation into other potential environmental or lifestyle-based driving forces in this myopia pandemic.

Little attention has been given to possible dietary influences, which is somewhat surprising as myopia is inherently associated with ocular growth and diet has been identified as a factor in many other ocular diseases such as age-related macular degeneration, cataract and diabetic retinopathy.[8,9] The Singapore Cohort Study of Risk Factors for Myopia (SCORM) performed a dietary analysis on 851 Chinese children through a food frequency questionnaire, and found that saturated fat and cholesterol intake may be associated with axial elongation in otherwise healthy Singapore Chinese schoolchildren,[10] but no association was found between any specific nutrient and myopia development. Older studies, which examined the diet of myopes, have yielded inconsistent findings, perhaps reflecting study limitations including inadequate dietary data collection methods and small samples sizes.[11,12]

More recently, a small number of Asian studies have reported lower levels of micronutrients such as zinc and copper in myopic children/adolescents, when compared to controls. A study which examined trace elements in hair samples of 100 college students aged 20–24 found zinc levels were inversely associated with degree of myopia.[13] Similar findings were noted in three other Chinese observational studies, suggesting that lower zinc levels merit consideration as a possible factor in the development and/or progression of myopia.[14–16]

The use of a large nationally representative population-based source of zinc status and refraction data to investigate the possible relationship between zinc and myopia would provide an important advance on existing studies. The Korean National Health and Nutrition Examination Survey (KNHANES) represents an ideal source of such data. The Korean diet, which is predominantly comprised of rice, vegetables, fish and fermented vegetables, is very different from the Western diet, where high sugar, high fat and overly processed foods make-up a substantially larger proportion of the diet.[17] While the Korean diet carries many health benefits, and Korea is known to have some of the lowest rates of childhood obesity,[18] bioavailability of some micronutrients can be low, zinc in particular, due to high intakes of phytates (a known inhibitor to zinc absorption) from rice and vegetables.[19,20]

Zinc is particularly highly concentrated in retinal and choroidal tissue and is involved in various pathways which could be relevant to myopia development and progression including vitamin A metabolism,[21] transcriptional processes and gene expression.[22,23] Many genes identified for their role in myopia development contain an all-important zinc finger (ZMAT4, ZIC2, ZBTB38),[24] while novel mutations found in ZN644, which encodes zinc finger transcription factors, and gene *SCL39A5* (zinc transporter) have been associated with early-onset non-syndromic high myopia.[25] The aim of this study, therefore, was to assess the association between serum zinc and myopia in the Korean population – using a subsample of adolescents from the KNHANES 2010 study.

Methods

Study population

This study is based on data obtained from the first round of the fifth KNHANES 2010 survey (KNHANES V-1). The KNHANES is a nationwide population-based cross-sectional survey; it was conducted on a triennial basis from 1998 to 2005, and in 2007 became an annual survey program. The survey is performed by the Division of Chronic Disease Surveillance, Korea Centres for Disease Control and Prevention. It is carried out to determine public health status and to provide baseline data for the evaluation and improvement of public health policies in the Korean population. Data collected from the KNHANES V-1 conducted from January to December 2010 were used in this study, as this was the last cycle to concurrently assess zinc levels in serum and refractive status.

Participants included non-institutionalised individuals, aged one year and over, living in Korea, and were selected using a stratified, multi-stage cluster probability sampling design to guarantee an independent and comparable sampling each year, as well as nationally representative sampling. Data were collected by a variety of means. Health interviews and examinations were performed in mobile examination centres.[26] Vision examination was carried out in those aged five or more years. Blood samples were collected from participants 11+ years; however, heavy metals were only measure in 1/3 of those participants. The Institutional Review Board of the Korean Centres for Disease Control approved all the protocols and the participants provided written informed consent at baseline. KNHANES V study design followed the tenets of the Declaration of Helsinki. Additional details regarding the study design and methods is provided elsewhere.[27]

Participant data and measurement

Demographic variables, including age, gender, area of residence and parental income were collected at household interviews. Area of residence was categorised as urban or rural. Among the 16 districts of South Korea, eight major cities (Seoul, Gyeonggi, Busan, Daegu, Incheon, Gwangju, Daejeoun, and Ulsan) were grouped as urban areas, and the other provinces (Gangwon, Chungbuk, Chungnam, Jeonbuk, Jeonnam, Gyeongbuk, Gyeongnam, and Jeju) were grouped as rural areas. Parental income was divided into quartiles and participants were placed in the low-income group if their parental income fell in the lowest quartile.

A trained examiner completed all anthropometric assessments. Height was measured to the nearest 0.1 cm using a portable stadiometer (SECA 225; SECA Deutschland, Hamburg, Germany) while the participants were standing barefoot. Weight was measured to the nearest 0.1 kg using an electronic scale (GL–6000–20; CAS KOREA, Seoul, Korea) while the participants wore a lightweight gown. Body mass index (BMI) was determined by dividing weight in kilograms by height in metres squared (kg/m^2). Waist circumference was measured after normal expiration to the nearest 0.1 cm using a measuring tape (SECA 200; SECA Deutschland).[28]

Recreational activity was established by self-reporting using the International Physical Activity Questionnaire.[29] Moderate physical activity was categorised as 'yes' when participants engaged in moderate-intensity physical activity for more than 20 minutes at a time and more than three times per week. Moderate-intensity physical activity was defined as the physical activity that causes a slight increase in breathing or heart rate for at least 10 minutes, such as when carrying light loads, cycling at a regular pace, or playing tennis.[29]

Ophthalmic examinations were conducted in mobile examination centres. Non-cycloplegic auto refraction was performed three times in both eyes on all participants, using a picture target with the standard background illumination of the Topcon KR8800 auto refractor (Topcon, Tokyo, Japan). The average refraction measurements were separately recorded for each eye. In line with standards, tests were performed by epidemiological survey members of the Korean Ophthalmologic Society, spherical equivalent (SE) refractive error was calculated as sphere and half of the cylinder value. Myopia was defined by a SE of −0.50 dioptres (D) or more. Refractive error was defined based on the right eye.

Laboratory measurements

Participants were asked to provide overnight fasting blood samples. To measure serum zinc concentrations, a trace element tube was used and serum zinc concentration was determined by inductively coupled plasma – mass spectrometry (ICP-MS) using a PerkinElmer mass spectrometer (PerkinElmer, Waltham, MA, USA). Serum samples were diluted with two per cent nitric acid, and serum zinc concentration was obtained from a linear relationship (r = 0.999) between concentrations of zinc stock standard (1,000 mg/ml, SPEX CertiPrep, Metuchen, NJ, USA) and absorbance. The accuracy of the analytical procedures was verified with standard reference material (ClinChek Serum Controls, lyophilised for trace elements, RECIPE, Munich, Germany). The standard deviation index was 0.50, and coefficients of variation for inter- and intra-assay were two per cent, and four per cent, respectively.[30]

Statistical analysis

Statistical analysis was performed using SAS survey procedure (version 9.2; SAS Institute Inc., Cary, NC, USA) to reflect the complex sampling design and sampling weights of KNHANES and to provide nationally representative prevalence estimates. The procedures included unequal probabilities of selection, oversampling, and nonresponse so that conclusions could be made about the Korean adolescent participants. Participants' characteristics were described using mean and standard error for continuous variables and number and percentages for categorical variables. T-tests and Chi-square tests were used for analysis of continuous and categorical variables, respectively. Serum zinc was categorised based on quartiles (quartile 1: < 25th percentile, quartile 2: ≥ 25 to 50th percentile, quartile 3: ≥ 50 to 75th percentile, quartile 4: > 75th percentile). Simple and multiple logistic regression were performed to test the association between serum zinc and myopia, with quartile 1 as the reference category. Model 1 was adjusted for age and gender, while model 2 was adjusted for age, gender, residence, BMI, family income and recreational activity. To further explore the relationship between total zinc intake and myopia, multivariate linear regression was performed on the association between serum zinc level and SE, in the myopic population. All reported probabilities were two-sided, with $p < 0.05$ considered statistically significant.

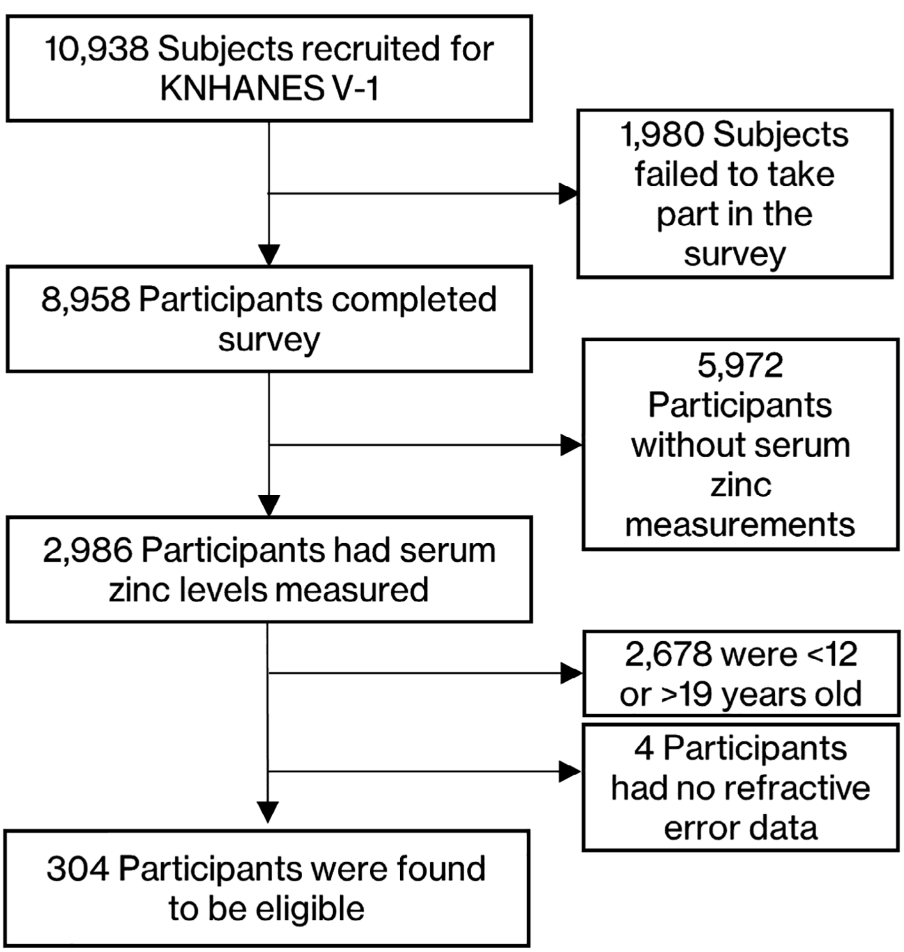

Figure 1. Flow diagram of selection process.

Results

In the KNHANES V-1, 10,938 participants were recruited, 8,958 completed the survey (participation rate: 81.9 per cent). Among those, 2,986 had serum zinc levels measured. To specifically target those most at risk of myopia development and progression, only participants aged 12–19 years were selected for the study (n = 308). Of these, four were missing refractive error data, so were excluded from the study. Finally, 304 participants were found to be eligible (see Figure 1).

Baseline and clinical characteristics of participants, according to refractive status are reported in Table 1. Among the 304 eligible participants, 255 (84 per cent) were classified as myopic.

The characteristics of the myopic and non-myopic subjects are shown in Table 1. Apart from refraction, the only significant difference between the two groups was in BMI. Myopes were found to have a higher BMI (21.5 $\pm$ 0.2 versus 19.8 $\pm$ 0.6, $p = 0.02$), but still within the normal range (18.5–24.9). There were no significant differences in age, gender, residence, parental income, height, and weight or waist circumference between myopes and non-myopes ($p > 0.05$ for all). Similarly, there was no significant difference between groups on self-reported level of recreational activity.

Mean serum zinc was slightly lower in the myopic group (138.1 $\pm$ 2.3 versus 139.3 $\pm$ 5.3, $p = 0.809$), but not statistically significantly so. Figure 2 shows the distribution and probability density of zinc level by myopia status as a violin plot. Each dot represents a participant. Table 2 presents the distribution of serum zinc by percentile, according to myopic status.

The association between serum zinc and myopia, in simple and multiple logistic regression models is presented in Table 3. The simple odds ratio (OR) with 95% confidence intervals (CI) indicated that serum zinc is not associated with risk of myopia.

	Non-myopes SE > −0.50 D	Myopes SE < = −0.50 D	p-value
Number of subjects (%)	49 (16%)	255 (84%)	
Gender (%)			
Male	28 (57.1%)	125 (49.1%)	
Female	21 (42.9%)	130 (50.9%)	0.32
Age (years)	15.4 ± 0.4	15.7 ± 0.2	0.56
Region (%)			
Urban	38 (77.5%)	213 (83.5%)	
Rural	11 (22.5%)	42 (16.5%)	0.88
Ocular exam			
Spherical equivalent	+0.37 ± 0.2	−3.30 ± 0.2	**< 0.001**
Systemic evaluation			
Height (cm)	1.65 ± 1.6	1.65 ± 0.7	0.94
Weight (kg)	54.6 ± 2.3	58.8 ± 0.9	0.10
Body mass index (weight/height^2)	19.8 ± 0.6	21.5 ± 0.2	**0.02**
Waist (cm)	68.6 ± 1.6	71.4 ± 0.7	0.12
Recreational activity			
Yes	7 (14.3%)	60 (23.5%)	
No	42 (85.7%)	195 (76.5%)	0.44
Low income (%)			
No	38 (77.5%)	218 (85.4%)	
Yes	11 (22.5%)	37 (14.5%)	0.42
Serum zinc (μg/dl)	139.3 ± 5.3	138.1 ± 2.3	0.81

Data are presented as mean ± standard error or number and percentage. Nominal/categorical data analysed by Chi-square, continuous data analysed by t-test.

Table 1. Baseline and clinical characteristics of study participants

After adjustment for age and gender, the results were similar. Additional adjustments were made for BMI, residence, family income and recreational activity, in multivariate analysis. The multivariate adjusted ORs (95% CI) of myopia were 0.75 (0.27–2.03, p-trend = 0.66) in the highest versus lowest quartile of serum zinc; no significant regression equation was found (F = 0.54, p = 0.66).

The results of multiple linear regression for association between serum zinc and SE in the myopic group are shown in Table 4. The SE was not associated with serum zinc, in the simple model, or after adjustment for age and gender in model 1 (p = 0.52), and subsequent adjustment for BMI, residence, family income, recreational activity in model 2 (p = 0.46) (F = 0.56, p = 0.46, with an R^2 = 0.057).

Sensitivity analyses were conducted to confirm the robustness of the results. Initially, all analyses were repeated using an alternative cut-off for myopia (≤ −1.00 D), to account for lack of a cycloplegic agent during autorefraction. There was no significant difference between mean serum zinc in the myopic group (n = 217) compared to non-myopes (n = 87) (140.2 ± 3.4 versus 137.4 ± 2.7, p = 0.47). Similar to the above findings, no association was found between serum zinc and myopia after multiple logistic regression analysis (p = 0.61).

The analysis was also replicated for an older age group (20–39 years), to investigate the relationship further. Of the sample (n = 745), 185 were found to be non-myopic, while 560 were myopic. Again, there was no significant difference in mean serum zinc level (p = 0.89). The multiple logistic adjusted ORs (95% CI) of myopia were 1.43 (0.818–2.526, p-trend = 0.86) in the highest versus lowest quartile of serum zinc. The SE was not significantly associated with serum zinc after adjustment for confounders (p = 0.98).

Discussion

In this present study, we found no significant association between serum zinc and myopia in Korean adolescents aged 12–19, after adjustment for potential confounders. There were very few significant differences between the myopic and non-myopic subjects other than BMI which was marginally higher in the myopic adolescents – perhaps a reflection of a more sedentary lifestyle, or different dietary patterns. This study, which is perhaps one of the first to explore the association between serum zinc and myopia in adolescents using a subset of nationally representative data, revealed no association between serum zinc and refractive status.

These findings replicate the lack of association observed between myopia and dietary zinc status in a representative Western adolescent population,[23] but are generally inconsistent with previous studies which have explored the relationship between serum zinc and myopia status. In a study of 121 children/adolescents, including 83 myopes and 38 controls, mean serum zinc was lower in myopes (0.865 ± 0.221 mg/l) compared to controls (1.054 ± 0.174 mg/l; p < 0.001).[31] Similar results were found in a study involving Chinese schoolchildren, where lower levels of serum zinc were found in myopic subjects (0.98 ± 0.21 versus 1.5 ± 0.23 mg/l; p < 0.05).[15] Another study involving 220 primary school children in Dongguan district in China, again found significantly lower measures of serum zinc in myopes (n = 120), when compared to emmetropes (n = 100).[14] This finding was backed-up by Huo et al. (males: 1.55 ± 2.4 versus 1.22 ± 3.1 mg/l; females: 1.48 ± 2.4 versus 1.21 ± 2.7 mg/l; p < 0.01), and a negative correlation between serum zinc and degree of myopia was also reported.[16]

One possible explanation for the difference in findings may relate to methodological variation in serum zinc measurement and to reliability issues associated with the respective techniques. Previously published observational studies have all used an atomic absorption spectrometry technique, whereas, in our study, serum zinc was determined by ICP-MS. Both tools have their advantages, but it has been well documented that ICP-MS is a more sensitive technique, thus has better detection limits.[32] Therefore, direct comparison between studies is difficult, and this may contribute to conflicting results. Retest reliability can also be poor in serum zinc testing. In a recent study, two different laboratories performed two subsequent serum zinc measurements in blinded duplicate of serum samples. The

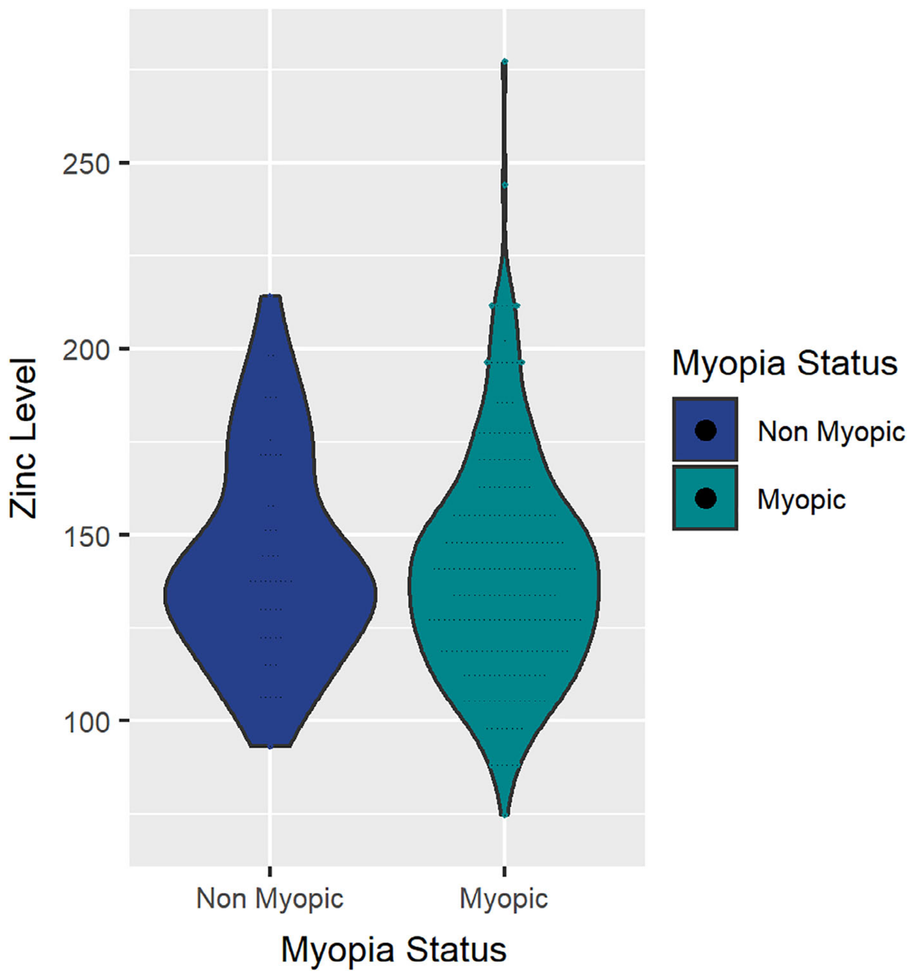

Figure 2. Violin plot of serum zinc concentration by myopic status.

commercial laboratory showed no significant correlation between both measured serum zinc concentrations (r = 0.21; p = 0.44), while the laboratory specialising in trace element research demonstrated a significant correlation of results from two subsequent measurements (r = 0.69; p < 0.01). This only emphasises the difficulties in establishing zinc status, and the unreliability of measures.[33]

Plasma zinc concentration is the most widely used biomarker to determine zinc status; however, measurements are extremely sensitive to both internal and external factors, thus, according to recently published guidelines by the International Zinc Nutrition Consultative Group, the collection method for specimens should adhere to strict protocols and quality control procedures. Collection time and fasting status of donors should be recorded and controlled for, as fasting leads to higher zinc levels and there can be up to 20 per cent variation in diurnal zinc concentrations.[34] Accordingly, all participants in this study had blood samples collected at a similar time in the morning, after 12 hours fasting. Information regarding these specific processes are lacking in other published studies,[15,31] leading to uncertainty around collection procedures. In addition to this, sample sizes are relatively small in current observational studies, therefore, data is unlikely to come from a diverse group – most studies include a sample of participants from the same school, most likely all from a similar geographical area, and socio-economic group.[14,16] The interpretation of findings in relation to other studies is problematic, due to limitations such as homogenous data, certain confounders not adequately controlled and most importantly, differences in serum collection procedures and the overall difficulties in zinc measurement.

Micronutrient status is influenced by a plethora of factors. Differences in trace element concentration could result from soil, geographical location, food preparation, ethnic differences in body composition, genetics, cultural practices and even seasonal variation.[35] In this study, all serum zinc measurements were found to be within the normal range, and mean serum zinc levels of participants was higher than in other study populations, as measured by the same or different methods.[36,37] Previous studies have suggested that Koreans have a poorer zinc status when compared to Western countries. A study which looked at dietary zinc intake and serum zinc status of Koreans living in rural, urban and metropolitan areas of South Korea, reported zinc intakes lower than the Korean recommended daily allowance; it was also suggested that marginal zinc deficiency may be prevalent.[38] However, interestingly, within each region plasma serum zinc measurements were within normal ranges (70–150 mg/l).[38] Another observational study examined the bioavailable zinc intake in 841 Korean adults; similar results were described, with below normative zinc intake in 62 per cent of males and 50 per cent of females.[20] These data demonstrate a discrepancy between dietary and serum zinc measures.

	n	Mean	Q1 (25th percentile)	Median (50th percentile)	Q3 (75th percentile)	p-value
Non-myope	49	139.3	116.5 (100.7–132.3)	136.2 (127.3–145.1)	154.6 (135.6–173.6)	0.81
Myope	255	138.1	117.8 (112.5–123.1)	133.6 (128.8–138.5)	152.5 (147.2–157.7)	

Table 2. Distribution of serum zinc by percentile in myopic and non-myopic Korean adolescents

	Serum zinc quartiles				p-trend
	1	2	3	4	
Simple	1.0	1.48 (0.43–5.14)	0.98 (0.33–2.91)	1.01 (0.37–2.76)	0.88
Model 1	1.0	1.61 (0.46–5.33)	1.04 (0.36–2.98)	1.06 (0.39–2.86)	0.84
Model 2	1.0	1.31 (0.41–4.21)	0.78 (0.28–2.17)	0.75 (0.27–2.03)	0.66

Model 1 adjusted for age and gender.

Model 2 adjusted for age, gender, body mass index, residence (urban versus rural), family income, and recreational activity.

Table 3. Weighted odds ratio (95% confidence interval) for myopia across serum zinc level quartile

A potential dietary factor promoting marginal zinc deficiency in Koreans is high phytate and calcium intake, which decreases zinc absorption. In an analysis of Korean dietary patterns, cereals and grains were found to contribute most dietary zinc to the diet (48.9 per cent). Animal products, which contain the best sources of zinc, supplied 30 per cent of total zinc. The majority of phytate was supplied by cereals such as rice, barley and legumes such as soy products. Rice alone contributed 54.1 per cent of total dietary phytate, making rice the major source of both zinc and phytate in the Korean diet.[20] Phytate can bind zinc in the intestinal lumen and form an insoluble complex that cannot be digested or absorbed because humans lack the intestinal phytase enzyme. The negative effect of phytate on zinc absorption is dose-dependent.[39] For this reason, plant-based diets are sometimes low in micronutrients, especially zinc. A systematic review of 34 studies compared males and females consuming vegetarian diets versus non-vegetarian diets; 26 studies were included in a meta-analysis, and dietary intake and serum zinc concentration were found to be significantly lower in populations that consistently followed vegetarian compared to a non-vegetarian diets.[40] Interestingly, a study carried out on young adults in India, found a higher prevalence of myopia among vegetarians than non-vegetarians;[41] a separate UK study showed myopic children, treated with a high animal protein diet displayed slower progression of myopia, when compared to controls.[11]

The present study does have some limitations. All participants in this study were of Korean descent, it may be possible that serum zinc differs across different ethnic groups. The mean serum zinc level of myopic participants in this study was much higher when compared to other studies. Admittedly, the extent to which genetic factors influence an individual's serum zinc is unknown, but genetic polymorphisms that affect gene expression may alter zinc metabolism and homeostasis[42] and therefore, findings in this study cannot be extrapolated to other populations.

The high prevalence of myopia among participants may have influenced results. The ratio of controls to cases is 0.2:1.0, far from the ideal in an epidemiology case/control study which is likely to be a consideration in all studies conducted in regions where myopia prevalence is high. Also, only one-third of the total examined group in KNHANES V was chosen at random to give heavy metals blood samples, thus limiting sample size, and perhaps impacting the demographic diversity of the data sources. No cycloplegic was used during measurement of refractive status, therefore there may have been an overestimation of myopes, due to involuntary accommodation. However, a sensitivity analysis at more myopic thresholds did not change the results. Recreational activity was included in this study as a proxy for time spent outdoors; however, it is uncertain how true this measure is of UV light exposure, thus potential for residual confounding remains. In addition, axial length or corneal thickness were not measured and variables such as family history of myopia were not taken into consideration, and therefore again results may be confounded.

Conclusion

No significant association was found between serum zinc and myopia in a representative subsample of the Korean population in this age group. However, further well-designed prospective studies should be performed in a large cohort involving diverse ethnic groups, perhaps in less developed countries of South East Asia where zinc deficiency has been well documented.[43] Furthermore, considering the vast limitations of serum zinc as a marker of zinc status, further resources should be devoted to

	Simple model			Model 1			Model 2		
	Beta	95% CI	p-value	Beta	95% CI	p-value	Beta	95% CI	p-value
Serum zinc	−0.00	−0.01, 0.01	0.54	−0.00	−0.02, 0.00	0.522	−0.00	−0.02, 0.00	0.46
Age				−0.08	−0.24, 0.06	0.265	−0.13	−0.29, 0.02	0.10
Gender				−0.29	−1.02, 0.43	0.419	−0.44	−1.19, 0.31	0.25
Residence							0.63	−0.29, 1.56	0.18
Body mass index							0.03	−0.06, 0.13	0.49
Family Income							0.47	−0.54, 1.47	0.36
Recreational activity							−0.97	−1.98, −0.05	0.06

Model 1 adjusted for age and gender.

Model 2 adjusted for age, gender, body mass index, residence (urban versus rural), family income, and recreational activity.

Table 4. Multiple linear regression analysis for the association between serum zinc and spherical equivalent in the myopic group (n = 255)

the development of a better, more sensitive biomarkers of zinc status.

Q4

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