Clinical and Epidemiologic Research

Prevalence of Myopia and its Association with Body Stature and Educational Level in 19-Year-Old Male Conscripts in Seoul, South Korea

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Purpose. To examine prevalence of refractive errors and its associated factors, such as body stature and educational level, among 19-year-old males in Seoul, Korea.

Methods. A population-based cross-sectional study was performed in male subjects ($n = 23{,}616$; age = 19 years) who were normally resident in Seoul for male compulsory conscripts during the study period (2010). Refractive examination was performed with cycloplegia. Height, weight, and educational level were examined. Myopia was defined as a spherical equivalent less than −0.5 diopters (D) and high myopia less than −6.0 D. The association of myopia with body stature and educational level was analyzed using logistic regression analysis.

Results. The prevalence of myopia in 19-year-old males in Seoul was 96.5%. The prevalence of high myopia was 21.61%. Body stature was not significantly associated with myopia. Four- to 6-year university students (odds ratio [OR] 1.69; $P < 0.001$) and 2 to 3-year college students (OR 1.68; $P < 0.001$) showed significantly higher risk for myopia than those with lower academic achievement (< high school graduation).

Conclusions. The 19-year-old male population in Seoul, Korea, demonstrated a very high myopic prevalence. Myopic refractive error was associated with academic achievement, not with body stature. (*Invest Ophthalmol Vis Sci.* 2012;53:5579–5583) DOI:10.1167/iovs.12-10106

Myopia is one of the most common causes of visual impairment worldwide. The onset of myopia occurs in childhood, and it usually causes significant discomfort in school-aged children, who need to use glasses or contact lenses for the rest of their lives. High cost associated with the correction of myopia contributes to public-health and economic concerns.[1,2]

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Supported by the Research Institute of Medical Science, Saint Vincent's Hospital (SVHR-2012-12).

Submitted for publication April 30, 2012; revised June 24 and July 16, 2012; accepted July 20, 2012.

Disclosure: **S.-K. Jung**, None; **J.H. Lee**, None; **H. Kakizaki**, None; **D. Jee**, None

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Prevalence of myopia is significantly different among racial groups, although its worldwide prevalence is approximately 30% (3%–84%).[3–9] The highest prevalence is found in East Asia, such as mainland China (78.4% in people aged 5–15 years)[4]; Hong Kong (70% in people aged 17 years)[3]; Taiwan (84.0% in peopled aged 16–18 years)[5]; and Japan (65.6% in people aged 17 years).[10] Mongolia has a markedly lower prevalence of myopia (17.2%), although this data was harvested from a group aged over 40 years.[6] However, there has been a lack of information about Korea.

Body stature contribution to myopia has been assessed in several population-based studies, especially in young adults. A recent study including the twin eyes of Chinese children showed a significant association between height and axial length.[11] Another study reported that height was inversely associated with refractive error among Chinese boys, although no such association was observed among girls.[12] In contrast, no relationship between body stature and myopia has been found in a study with 106,926 Israeli male military recruits (aged 17–19 years).[13] Although the inconsistency of these studies may be derived in part from ethnic and demographic differences, the relationship between body stature and myopia is still unclear.

Education level has been known to be associated with the prevalence of myopia.[7,9,14] The possible mechanism is that people with higher education spend more time doing near-work activities, which is a known risk factor for the development of myopia.[15,16] However, this association is unclear in the young Korean population.

We examined the prevalence of myopia and its associated risk factors, such as body stature and education attainment, using a survey of 19-year-old Korean males.

Subjects and Methods

Study Population

The study design followed the tenets of the Declaration of Helsinki for biomedical research and was approved by the Institutional Review Board of the Catholic University of Korea in Seoul, Korea.

A population-based cross-sectional study was performed in consecutive male conscripts who were aged 19 years and were normally resident in Seoul during the study period (2010). As all 19-year-old males in South Korea have a legal obligation to a physical examination for conscription, all 19-year-old males residing in Seoul were eligible for inclusion, yielding a total sample population of 23,616 individuals. Males exempted from military service were also included in this study because even these males were required to undergo a physical examination, the very process that determines who was to be exempted from military service. The exclusion criteria in this study include persons who had surgery for retinal detachment such as vitrectomy, encircling, or buckling, as the refractive error may change

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Table 1. Characteristics of Study Subjects

Variable	Number	Proportion (%)	Mean ± Standard Deviation
Age			
19 y	23,616	100.0	
Sex			
Male	23,616	100.0	
Educational level			
High school graduate or less	9,033	38.3	
Students in 2 to 3-y colleges	4,188	17.7	
Students in 4 to 6-y university	10,395	44.0	
Height (cm)	—	—	174.2 ± 5.7
Weight (kg)	—	—	69.0 ± 12.8
BMI (kg/m^2)			22.70 ± 3.92

after these surgeries. For subjects who had received refractive surgery, we obtained data concerning the preoperative cycloplegic refractive error from the hospitals in which they received surgery.

Data Collection

All 19-year-old males residing in Seoul underwent anthropometric measurement. Height was clinically measured using a wall-mounted measuring scale; and weight was measured in kilograms using calibrated electronic scales. Each individual was instructed to remove any footwear and heavy clothing before height and weight measurement. Height and weight data were then used to determine each participant's body mass index (BMI) using the universally recognized formula: Weight (kg) / Height (m)^2.

Cycloplegia was performed in all persons. Three drops of cyclopentolate 1% were administered 5 minutes apart to both eyes. Autorefraction was measured using an autorefractor (AR-500; Canon, Inc., Tokyo, Japan) by a professional optometrist (K.C.H.) hired by the Seoul Regional Military Manpower Administration as a full-time worker, while one of the authors (L.J.H.) supervised the procedures. A total of three readings were taken for each eye, and the average value was recorded. Results for each eye were converted to their spherical equivalent (sphere + 1/2 cylinder). Myopia was defined as < -0.50 diopters (D). Mild myopia was defined as > -3.0 D; moderate myopia was defined as < -3.0 D; and severe myopia was defined as < -6.0 D.

Information about educational level was obtained from administrative recruitment documents. The educational level of each individual was classified on a scale of 1 to 3, with 1 indicating those with a high school education or less, 2 indicating enrollment in a 2 to 3-year college, and 3 indicating enrollment in a 4- or 6-year university program.

Statistical Analyses

Analyses were performed using statistical analysis software (Statistical Package for the Social Sciences [SPSS] version 14.0; SPSS, Inc., Chicago, IL). Logistic regression models were used to assess the association of myopia (dependent variable) with body stature (independent variables: height, weight, and BMI). Each variable was divided into four quartiles, with the lowest serving as the reference point. The relationship of educational level to myopia was also assessed using a logistic regression model. The education variable was also divided into three levels, with the lowest serving as the reference point.

Results

A total of 23,616 19-year-old males residing in Seoul were enrolled in our study. The largest proportion in the educational level classification was the 4 to 6-year university students (44.0%; Table 1). Mean height, weight, and BMI are shown in Table 1.

Refractive error was expressed as the average value of both eyes' spherical equivalent, because the spherical equivalents in the right and left eyes did not differ significantly ($P > 0.05$). Myopia occupied 96.54% in the enrollment (Table 2). The prevalence of mild, moderate, and severe myopia was 31.00%, 43.92%, and 21.62%, respectively.

Myopia was not associated with height ($P = 0.159$); weight ($P = 0.571$); or BMI ($P = 0.323$; Table 3).

Four- to six-year university students (odds ratio [OR] 1.69, $P < 0.001$) and 2 to 3-year college students (OR 1.68; $P < 0.001$) showed significantly higher risk for myopia than those with lower academic achievement (high school diploma or less; Table 4).

Multivariate linear regression models revealed that the refractive error was associated with education level (regression coefficient –0.246, P value < 0.001) and was not associated with height, weight, or BMI (Table 5).

Discussion

The prevalence of myopia in this study was 96.54%, which is one of the highest prevalences of myopia in published reports to date. The prevalence of high myopia was 21.61%. The results in this study were extraordinarily high, although it is well known that myopia is more common among East Asians (38.1%–84%) than among Europeans (20%–30%); but the prevalence in North Korea is not known yet.[2,17] The prevalence of myopia is increasing at an "epidemic" rate, particularly in East Asia. This may be related to changing environmental factors, in particular the demands of near work.[18] Many 19-year-old males in Seoul spend large amounts of time studying for university entrance examinations. Higher educational attainment and excessive near-focus work are well-known risk factors for myopia development.[15,16,18] The prevalence of myopia is also known to be higher in urban

Table 2. Prevalence of Myopia

Classification	Number of Subjects	Prevalence (%, 95% CI)
Myopia (> −0.50 D)	22,800	96.54 (96.30, 96.78)
Mild myopia (−0.5 D to −2.99 D)	7,323	31.00 (29.94, 32.06)
Moderate myopia (−3.0 D to −5.99 D)	10,372	43.92 (42.96, 44.88)
High myopia (> −5.99 D)	5,105	21.62 (20.49, 22.75)
Moderately high myopia (−6.0 D to −7.99 D)	3,541	14.99 (13.81, 16.17)
Severe myopia (−8.0 D to −9.99 D)	1,228	5.20 (3.95, 6.44)
Severely high myopia (> −10.0 D)	336	1.43 (0.16, 2.70)

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Table 3. Myopic Prevalence in 19-Year-Old Males According to Body Stature

	Number of Myopic Patients	Prevalence (%)	Odds Ratio (95% CI)	*P* *
Weight (kg)				0.571
First quartile: <61	5815	96.39	1.00	
Second quartile: 61 to 67	5294	96.55	1.06 (0.65, 1.72)	
Third quartile: 67 to 75	5722	96.82	1.18 (0.80, 1.72)	
Fourth quartile: ≥75	5969	96.39	1.00 (0.76, 1.32)	
Height (m)^2				0.159
First quartile: <170	4448	96.70	1.00	
Second quartile: 170 to 174	5842	95.93	0.78 (0.60, 1.02)	
Third quartile: 174 to 178	6248	96.70	0.99 (0.78, 1.24)	
Fourth quartile: ≥178	6262	96.66	0.96 (0.38, 1.18)	
BMI				0.323
First quartile: <20.07	5696	96.53	1.00	
Second quartile: 20.07 to 22.02	5680	97.21	1.12 (0.70, 1.79)	
Third quartile: 22.02 to 24.50	5713	94.95	0.90 (0.62, 1.29)	
Fourth quartile: ≥24.50	5711	96.53	0.99 (0.76, 1.30)	

* A logistic regression model was used to assess the risk of having myopia with increasing quartiles of weight, height, and BMI. Each variable was divided into four quartiles, with the lowest serving as the reference point.

populations than in rural population[19] and our study population resided in a metropolitan area.

One particular concern is that over 20% of our population had a high prevalence of myopia (worse than –6.0 D). This figure is higher than that in reports from any other population worldwide. The prevalence of high myopes in the Baltimore Eye Study was approximately 1.4%,[20] and 8.2% in the Tajimi study in Japan.[21] High myopia may be complicated by potentially blinding conditions such as cataract, glaucoma, macular degeneration, and retinal detachment; whereas low to moderate degrees of myopia (ranged –0.5 D to –6.0 D) can be corrected with spectacles or contact lenses.[22] High myopia especially involves the macula, with several potential complications including myopic choroidal neovascularization, lacquer cracks, myopic chorioretinal atrophy, myopic macular retinoschisis, myopic macular holes, and posterior staphyloma.[23–26] Moreover, high myopia also may affect the optic nerve, causing myopic conus and myopic optic neuropathy.[26,27] Another problem is that the results of refractive surgery are less predictable in subjects with high myopia.[28] This result requires preventive action on the part of health policymakers.

Educational status has been among the most frequently noted socioeconomic associations of myopia.[7,9,14] These associations may be an indicator of near work and support the use-abuse theory for myopia. In the National Health and Nutrition Examination Survey, the prevalence of myopia increased with educational level.[7] Both the Baltimore and Beaver Dam studies showed a monotonic relationship between education and myopia.[8,20] Our study confirmed that high educational levels were associated with myopia. However, although the association with education level is statistically significant in our study, the effect is actually small in percentage terms, which suggests that even the people with low educational status may be substantially myopic in Korea.

There have been several studies on the balance between genes and environment as the etiology of myopia. A recent study has shown that ocular refraction is a complex phenotype that is influenced by both environmental factors and genetic predisposition, although environmental exposures play crucial roles in ocular growth and refractive development.[29] Another study suggested that environmental change appears to be a major factor in increasing the prevalence of myopia around the world, while there may be a small genetic contribution to school myopia.[30] Our results showing an association between myopia and academic achievements substantially support the above hypothesis.

No relationship between measurements of body stature (height, weight, and BMI) and myopia was demonstrated in our study. Our results are similar to the previous study that myopia was not associated with height or weight in 106,926 Israeli military recruits.[13] The age and sex of this study population were similar to those of our sample, although ethnicity differed. In contrast, some studies have found a correlation between myopic prevalence and height.[31,32] A recent study including the twin eyes of Chinese children showed a significant association between height and axial length.[11] Another study reported that height was inversely associated with refractive error among Chinese boys, although no such association was observed among girls.[12] A population-based Finnish study found that myopic males were 1.9 cm taller on average than nonmyopic males.[33] Among Danish recruits, myopes were 0.8 cm taller on average than emmetropes, and hypermetropes were 0.2 cm shorter than emmetropes.[34] Major studies examining the association between height and myopia are summarized in Table 6. The discrepancies in the results of these studies suggested that axial length is significantly correlated with height, whereas refractive error may not be. One possible reason is that emmetropization can adjust axial length by flat cornea to

Table 4. Prevalence of Myopia According to Education Level

Education Level	Prevalence (%)	Odds Ratio (95% CI)	*P* *
High school graduate or less	95.95	1.0	<0.001
Student in 2 to 3-y college	96.89	1.68 (1.44, 2.00)	
Student in 4 to 6-y university program	96.89	1.69 (1.41, 2.00)	

* A logistic regression model was used to assess the risk of having myopia with increasing educational level, with the lowest level serving as the reference point.

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Table 5. Linear Regression Analysis of Refraction (Spherical Equivalent) by Education and Body Status

Variable	Regression Coefficient (95% CI)	*P* *
Education level	−0.246 (−0.29, −0.20)	<0.001
Height	−0.010 (−0.04, 0.02)	0.524
Weight	0.002 (−0.04, 0.04)	0.916
BMI	−0.002 (−0.12, 0.12)	0.980

Data represent the regression coefficient and 95% CI.

* A linear regression model was used to assess the degree of refractive error (spherical equivalent) with increasing weight, height, and BMI.

produce emmetropic refraction. The results of our study measuring refractive error might be affected by emmetropization.

The major limitation is that only males were included in this study. Several studies have reported a higher prevalence of myopia in females compared with males.[35,36] This sex difference is often attributed to females having more near-work and less outdoor activities during a young age. Thus, our data have the possibility of underestimation in the prevalence of myopia compared with the general population.

Another limitation of this study is a lack of evaluation of axial length, which is essential to evaluate the cause of the myopia. Prevalence of myopia without axial length measurement might be affected by the process of emmetropization that may reduce the impact of bigger eyes with the flatter corneas and longer axial length on refractive status by matching the axial length of the eye to the corneal power to produce an approximately emmetropic refraction. However, many studies have reported the prevalence of myopia without axial length measurement.[3–5,8,14,35,36] It might be due to the technical and economical difficulty of these studies with regard to ocular epidemiology.

Recently, a new environmental factor having protective effects against the development of myopia has been discovered.[26,37] Increased amounts of time spent outdoors protects against the development of myopia, whereas near work or having myopic parents is less associated with the risk of developing myopia. Indoor sports and engagement in specific sports were found to have no association with the development of myopia.[38] The postulated mechanism is that the increased light intensity outdoors may have protective effects owing to the increased release of dopamine, which is known to reduce eye growth.[39] Unfortunately, in this study, we were not able to collect information about outdoor activities, detailed near work, and parental myopia, all of which are well-known factors associated with the prevalence of myopia.

In conclusion, our study provides population-based data on the prevalence of refractive errors in young adult males residing in a large metropolitan area in Korea. The prevalence of myopia was extremely high (96.5%) in this population: 20.61% of our population had high myopia, with potentially serious ophthalmic implications. Myopic refractive errors were associated with educational level, whereas measurements of body stature were not associated with the development of myopia in Korean young adults. Further studies on high myopia and its complications are needed to improve eye health in South Korea.

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Table 6. Association between Height and Myopia

Author (y)	Country	Number	Age	Measurement	Association with Height
Zhang (2011)	China	1,130	7 to 15	Axial length	Yes
Selovic (2005)	Croatia	1,600	8 to 14	Axial length	Yes
Rosner (1995)	Israel	106,926	17 to 19	Refractive error	No
Sharma (2010)	China	3,226	12 to 17	Refractive error	Only in males
Teikari (1987)	Finland	790	8 to 16	Refractive error	Only in males
Teasdale (1988)	Denmark	7,950	18	Refractive error	Yes
Ojami (2005)	Australia	1,765	5 to 8	Both	Axial length only
Wong (2001)	Singapore	951	40 to 81	Both	Axial length only
Eysteinsson (2005)	Iceland	846	55 to 75	Both	Yes
Saw (2002)	Singapore	1,449	7 to 9	Both	Yes

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