**Thirty-Five Years Trend in the Prevalence of Refractive Error in Austrian Conscripts based on 1.5 million participants**

**Authors**:

Lin Yang, PhD,1,2,3 Clemens Vass, MD,4 Lee Smith, PhD,5 Alfred Juan, MA,6 Thomas Waldhoer, PhD1

1 Department of Epidemiology, Center for Public Health, Medical University of Vienna, Vienna, Austria

2 Department of Cancer Epidemiology and Prevention Research, Alberta Health Services. Holy Cross Centre. 2210-2nd Street SW. Box ACB. Calgary. AB. T2S 3C3. Canada

3 Preventive Oncology & Community Health Sciences. Cumming School of Medicine. University of Calgary. Hospital Drive NW. Calgary. Alberta. Canada

4 Department of Ophthalmology and Optometry, Medical University of Vienna, Vienna, Austria

5 The Cambridge Centre for Sports & Exercise Sciences, Anglia Ruskin University, Cambridge, UK

6 Personnel Marketing Division, Ministry of Defence, Vienna, Austria

**Correspondence:**

Thomas Waldhoer, Univ.-Prof., PhD

Department of Epidemiology, Center for Public Health, Medical University of Vienna

Kinderspitalgasse 15, Vienna, Austria

Tel.: +43 (0)1 40160 – 34702

ORCID ID: 0000-0003-2043-8299
E-Mail: thomas.waldhoer@meduniwien.ac.at

**Synopsis**

In Austrian conscripts prevalence of myopia nearly doubled from 1983 to 2017. It was constantly lower, yet increased more rapidly among those with low education levels

Contributors: Dr Smith, Dr Vass and Juan, MA reviewed the manuscript. Dr Yang analysed the data, drafted and revised the manuscript for important intellectual content.
Dr Waldhoer designed the study, acquired and analysed the data, drafted the initial manuscript and reviewed the manuscript. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

**ABSTRACT**

**Background**: To quantify the current burden of myopia and hyperopia in Austrian young men, and the time trend of myopia in the past 35 years by individual and social correlates.

**Method**: We included data on all Austrian military conscripts from 1983 to 2017 (n=1,507,063) from six medical investigation stations. Young men provided data on education, weight and height for calculating body mass index, blood pressure, and resting heart rate. Non-cycloplegic refractions were measured by an autorefractometer. Spherical equivalent (SE) was calculated by standard formula (sphere + cylinder/2, unit diopters (D)). Myopic refractive error was defined as <-0.5 D). Hyperopic refractive error was defined as >0.5 D.

**Results**: The largest burden of refractive error in Austria is myopia, which rose from 13.8% to 24.4% over 35 years, with less than 5% hyperopic population. Over time, the prevalence of myopia was constantly lower, yet increased more rapidly among those with low education levels (11.4% to 21.7%) compared to those with higher education (24.5% to 29.6%) in all medical investigation stations. We found consistent associations of some unfavourable health indicators (underweight: ORs 1.1 to 1.4, higher resting heart rate: all P-trend <.001) with higher myopia prevalence, which point toward lifestyle factors playing an important role in the development of myopia.

**Conclusion**: Primary preventive measures are needed to curb the observed trend in myopia among Austrian young men. Future research should investigate the impact of modifiable factors on myopia development and progression, particularly lifestyle factors that are dramatically shifting.

**Key words**: Refractive error, urbanization, education, population based, conscripts

**INTRODUCTION**

Refractive errors occur when a mismatch of the axial length and the refractive power of the eye prevents light from focusing directly on the retina, resulting in a blurred image. Myopia, hyperopia, and astigmatism are common forms of refractive errors ([1](#_ENREF_1)). Despite a number of correction approaches which are available, i.e., spectacles, contact lenses or refractive surgery, uncorrected refractive error appears prevalent in both developing and developed countries ([1](#_ENREF_1)) and may induce productivity loss ([2](#_ENREF_2), [3](#_ENREF_3)). More importantly, refractive error is associated with higher risks of developing later life visual impairments in spite of correction, such as glaucoma, age-related macular degeneration, and myopic macular degeneration ([4](#_ENREF_4)). Although the strongest risk of such impairment is carried with high myopia, low and medium myopia can progress to high myopia and exhibit significant risk in developing later life glaucoma ([5](#_ENREF_5), [6](#_ENREF_6)).

Globally, the majority of research has focused on the high prevalence of myopia and its urban/rural disparity in East Asian countries (up to 80-90%) ([7-10](#_ENREF_7)), with some controversies regarding hyperopia ([11](#_ENREF_11)). A recent investigation has reported considerable high (23.5%), more importantly, increasing prevalence of myopia in Europe (the European Eye Epidemiology Consortium, the E3 Consortium) ([1](#_ENREF_1)).

The correction of refractive error, potential productivity loss due to uncorrected refractive error, and treatment for later life visual impairment can cause considerable economics and health care burden ([4](#_ENREF_4), [12](#_ENREF_12)). Therefore, myopia prevention has become an international public health priority ([13](#_ENREF_13)). To the best of our knowledge, no study has reported epidemiology of refractive error using routinely collected national data over a long period.

To fill this knowledge gap, we aim to quantify the time trend in the prevalence of refractive error in young men over three and half decades using the health examination data from Austrian conscripts. Secondary aim was to explore if the time trend in refractive error differ by individual and social factors to inform medical practice and public health policy.

METHODS

Study population

In the year of reaching age 18, all Austrian men are obligated to serve military or alternative service with compulsory medical investigations, of which data was obtained and used for this study. The medical investigation procedure of Austria military conscription has been previously detailed elsewhere ([14-17](#_ENREF_14)). In brief, the dataset contains anonymized data on all young men in Austria in the year they complete 18th year of life at each year’s compulsory medical investigation. Therefore, this data set represents the total population. Due to the potential influence of age on myopia, conscripts who were 19 or older at the time of medical investigation were excluded for the present analyses. We included young men who have complete data on education, weight and height, blood pressure, resting heart rate, provinces of residence and valid data to calculate spherical equivalent from 1983 conscript cohort to 2017 conscript cohort (9.6% missing). The study design and conduct of the research obtained approval from the Medical University of Vienna Ethics Review Board (ECS 1393/2018).

Refractive error

Non-cycloplegic refractions were routinely measured by an acuity tester (Maico, Germany; most recent model: Maico Titmus V4) during the medical investigation at conscription during the last most recent years. Unfortunately, there is no specific information available how refraction was measured the years before and the model of the device as well as way of measuring non-cycloplegic refractions may have differed over time. A total number of six stations in Austria facilitate conscription medical investigation covering 9 provinces: Burgenland + Vienna, Carinthia + Salzburg, Tyrol + Vorarlberg, Styria, Upper Austria, and Lower Austria. These routinely collected data were stored in the electronic system over the medical investigation stations, and were centralized at the Ministry of Defence, Austria. Data on sphere and cylinder of left eyes were used to calculate the spherical equivalent (SE) following the standard formula (SE=sphere + cylinder/2, unit diopters (D)). Refractive error was defined as myopia (< -0.5 D) or hyperopia (> 0.5 D) ([11](#_ENREF_11)).

Individual and social factors

For exploratory analyses, we retrieved data on a range of individual characteristics including height, weight, blood pressure, resting heart rate, and education.

Height and weight were measured following standard procedures and were carried out by trained technicians using standardized equipment, with Austrian conscripts wearing underwear and no shoes. Height was measured using a standard anthropometer, and body weight was determined to the nearest 100g on calibrated scales ([14](#_ENREF_14), [17](#_ENREF_17), [18](#_ENREF_18)). Body mass index (BMI) was calculated as weight in kg/(height in meters)2. The age range of the Austrian conscripts is round the upper limit of the US Centers for Disease Control and Prevention growth chart which provides each BMI with a corresponding BMI-for-age percentile (2-19 years) ([19](#_ENREF_19)). This approach uses the 5th, 85th and 95th percentiles to define weight category: below 5th percentile (underweight); 5th-<85th percentiles (normal weight); 85th-<95th percentile (overweight) and ≥95th (obese). In our study sample, the corresponding BMI for these percentiles were 18.3, 26.0, and 30.0 kg/m2, which approximate the standard BMI categories cut-off in adults (≥20 years). Therefore, we categorized study participants into standard BMI categories: underweight (<18.5kg/m2), normal weight (18.5-<25 kg/m2), overweight (25-<30 kg/m2), and obese (≥30.0-60 kg/m2).

Resting heart rate was recorded using electrocardiogram (ECG, Schiller, Switzerland) with the young men in a lying position to undergo resting electrocardiography assessment. All men were rested for at least 3 minutes before the assessment was taken, required resting heart rate to be lower than 110 beats per minutes (1.49% over 110 bpm excluded). Resting heart rate was classified into three groups using the 10th and 90th percentiles: 40-59; 60-94; and 95-110 beats per minute.

Blood pressure was taken with young men in a sitting position using standard devices (Riester minimus® II and/or III, Germany; Riester precisa /N, Germany; Boso clinicus 2, Germany; Boso clinicus K1, Germany). Based on the 2017 American College of Cardiology and American Heart Association high blood pressure guideline, blood pressure were defined as normal: Less than 120/80 mm Hg; elevated: Systolic between 120-129 and diastolic less than 80; stage 1 hypertension: Systolic between 130-139 or diastolic between 80-89; and stage 2 hypertension: Systolic at least 140 or diastolic at least 90 mm Hg ([20](#_ENREF_20)).

Education was classified into four categories: low (lower than 9 years of compulsory school); medium (completed compulsory school); high (graduated from professional training or served an apprenticeship); and very high (qualified for university entrance), then collapsed to two groups: low to medium, and high to very high.

In total, there are 121 districts in Austria. Among the six stations in Austria which facilitate conscription medical investigation covering 9 provinces, Vienna is the “most urban” area with 3,738 persons per km2 with 1.8 million inhabitants, while population densities in other provinces (Burgenland, Carinthia, Lower Austria, Upper Austria, Salzburg, Styria, Tyrol, and Vorarlberg) are less than 2,500 persons per km2) ([16](#_ENREF_16)).

**STATISTICAL ANALYSES**

We grouped years of conscription by five years interval in one wave (seven waves over 35 years) to provide stable figures for refractive error subtypes with small counts. Descriptive statistics were analyzed in the most recent wave of conscript cohort (2013-2017) to present the contemporary status of individual and social factors and prevalence of myopia and hyperopia in each stratum of included factors. Because of the extremely low prevalence of hyperopia (<5%), further analyses were presented for myopia only. Multivariable logistic regression estimated odds ratios (OR) and 95% confidence intervals (CI) to identify contemporary correlates of myopia.

To explore time trends in myopia from conscript cohort 1983-1987 to 2013-2017, we calculated the crude prevalence of myopia in each conscript cohort and presented differences in prevalence of the most recent (2013-2017) comparing with the earliest (1983-1987) cohort overall and by medical investigation station. Further, crude and multivariable adjusted logistic regressions were used to evaluate time trend in myopia using conscript cohort as a predictor in each medical investigation station. We tested for interaction effects between conscript cohort and BMI, resting heart rate, hypertension and education level, respectively. Significant interaction was found between conscript cohort and education, therefore the multivariable logistic regressions were further grouped by level of education. To exhibit comparisons of the rate of change in myopia prevalence over education levels, ORs for time trends were compared between conscripts with lower and higher education levels using Kruskal-Wallis test.

The trends of myopia were illustrated using predictive margins of myopia prevalence by low to medium, and high to very high education levels, respectively. All predicted margins were estimated standardizing to the joint sample distribution of age, BMI, resting heart rate, and hypertension.

Sensitivity analyses were conducted using SE calculated by the sphere and cylinder of right eyes, as well as the average of both left and right eyes. Statistical significance for testing interaction and trends of OR was set at P < 0.05. P-values were not adjusted for multiple tests and should be interpreted explanatorily only. All analyses were performed using SAS version 9.4 (SAS Institute Inc., Cary, NC, USA).

**RESULTS**

Data on 1,507,063 young men were used for analyses. Over 1.5 million young men were grouped by five-year interval in seven conscript cohorts, with the minimal size of 192,726 young men in each cohort. Among conscript cohort 2013-2017, myopia was highly prevalent (24.4%, 95% CI: 24.2 to 24.6%), in contrast to the low prevalence of hyperopia (3.2%, 95% CI: 3.1 to 3.3%) (Table 1). Majority of the conscript cohort 2013-2017 had normal weight (66.2%), resting heart rate 60-94 beats per minute (78.8%), and low to medium education (63.31%) (Table 1).

[Insert table 1]

In the multivariable logistic regression, higher prevalence of myopia was observed in the underweight young men (ORs = 1.2 to 1.4, all p value <.001), and those with high to very high education (ORs = 1.3 to 1.7, all p value <.001) in conscript cohort 2013-2017 across all six medical investigation stations. In addition, prevalence of myopia appeared strikingly high with increased resting heart rate (all p for trend < 0.001).

[Insert table 2]

The overall prevalence of myopia increased from 13.8% (95% CI: 13.6% to 13.9%) to 24.4% (95% CI: 24.2 to 24.6%) over 35 years (Table 3). This increasing trend was steady across all medical investigation stations (all p for trend < 0.001), with the smallest increase in Carinthia+Salzburg (difference: 7.8%, 95% CI: 7.1 to 8.4) and the largest increase in Upper Austria (difference: 12.2%, 95% CI: 11.6 to 12.7).

[Insert table 3]

Table 4 summarizes time trends in myopia prevalence in multivariable adjusted models. We observed consistent association between BMI, resting heart rate and blood pressure status with myopia prevalence across conscript cohort similar to Table 2. Owing to the significant interaction between conscript cohort and education, we presented the estimated ORs and 95% CI of conscript cohort by education for each medical investigation station, adjusting for BMI, resting heart rate and hypertension. Across all stations, we observed increased prevalence of myopia in both education groups (all p for trend < 0.001). However a more rapid as well as significant increase was seen in the low to medium education group (ORs = 1.8 to 2.7, 2013-2017 vs. 1983-1987) compared to young men in the high to very high education group (ORs = 1.2 to 1.7, 2013-2017 vs. 1983-1987) using the Kruskal-Wallis test (p=0.009). (Table 4)

[Insert Table 4]

The marginal prevalence of myopia differed by medical investigation station, yet consistently higher in Burgenland + Vienna in low to medium education groups (1983-1987: 15.3%. 95% CI: 14.9 to 15.87%; 2013-2017:25.7%, 95% CI: 25.0 to 26.4%) compared to other stations (figure 1 and table 1).

Sensitivity analyses using SE calculated by the sphere and cylinder of right eyes (Spearman Rho=0.93 with SE of left eyes), as well as the average of both left and right eyes retrieved similar results to that from all conducted analyses (Data not shown).

**DISCUSSION**

In a population-based sample of young men, the prevalence of myopia has been steadily increasing over the last three and half decades in Austria, suggesting an urgent need of preventive measures to curb this trend. By 2017, only 72.4% young men in Austria were free of refractive error. The greatest burden of refractive errors in this population is attributable to myopia (24.4%). The associations of BMI and resting heart rate with myopia prevalence were consistent over time, suggesting a protective effect of being physically healthy. Importantly, we found that myopia prevalence increased more rapidly among the low to medium education group than the high to very high education group. Hence, the magnitude of myopia prevalence gap across education levels has been narrowing over time. This novel finding suggested potentially unique risk factors of myopia in young men of the low to medium education group. We speculate the increasing prevalence myopia might be partially attributable to increased amount of personal screen devices. Nevertheless, our data do not allow a detailed investigation due to the lack of data on personal device use at the individual level.

To the best of our knowledge, we are among one of the largest studies to report time trend in prevalence of myopia using population based data. Our findings are consistent with a previously myopia trends investigation using the Israeli conscripts cohort during the years 1990 through 2002. Although the prevalence of myopia in that study was lower, the upward trends existed independently from levels of education ([21](#_ENREF_21)).

We observed a rapid increase in the overall prevalence of myopia in Austrian young men, which agrees with “The Myopia Boom” phenomenon that has raised public health attention in recent years ([13](#_ENREF_13)). It was estimated that half of the world population would be myopic by 2050 ([22](#_ENREF_22)). Population myopia prevalence varies with age and peaks among the age group of 20-29 years old ([22](#_ENREF_22)). Hence, our data likely reflects the myopia prevalence in Austria close to its peak value in the male population. In fact, epidemic of myopia has been clustered in East and Southeast Asia in the past, and a prevalence as high as 80-90% were seen in some countries’ urban population at their completion of high school (17-18 years old) ([23](#_ENREF_23), [24](#_ENREF_24)). The prevalence of myopia also increased in America (estimated 22.5% in 1971-1972 increased to 29.7% by 1999-2004 among 18-24 years old male) ([25](#_ENREF_25), [26](#_ENREF_26)).

Less data has been available in Europe, particularly among the younger age group ([23](#_ENREF_23)). Recently, Williams and colleagues reported increasing prevalence of myopia in Europe using data from the E3 Consortium,([1](#_ENREF_1)) which supports our findings. In addition, E3 Consortium found an impact of high education level on myopia prevalence in their study population of 60,125 individuals, however this association was unclear in their young age group (20-24 years old) due to a very small sample size (n=216) ([1](#_ENREF_1)). Our data have demonstrated the impact of education on myopia around this age group, although we were not able to trace the age of onset, nor the progression thereafter.

Education and its associated near work (e.g. reading) is the most commonly discussed risk factor for myopia development. A recent study has shown a causal effect such that genetic variants associated with more years of education lead to more myopia using a Mendelian randomization design ([27](#_ENREF_27)). Indeed this association has been reported repeatedly in observational studies;([13](#_ENREF_13)) however we should not neglect the impact of other environmental and social factors. Our data have shown that not only the prevalence of myopia, but also the growth of prevalence over time differ between education levels, where the most rapid growth (ORs = 1.8 to 2.7 across six stations) was seen among those with low to medium education (up to completed 9 years of compulsory school). Clearly, factors contributing to the myopia development in the low to medium education group need to be further explored. A plausible explanation might be of the urbanization and industrialization over the past 35 years, with decreased time spent outdoor and increased population access to screens such as personal computer, and mobile devices like handheld game consoles, cellular phones and smart phones. Recent research has shown an increased risk of incident myopia in children with increasing near visual activities ([28](#_ENREF_28)). One might speculate that the difference in near work between educational groups was reduced by the spread of the above devices. However, our data did not contain information on screen time or other near work and time spent outdoors, precluding further explorations.

Besides education, we explored a few individual factors that were not studied previously. We found that young men who were underweight or with high resting heart rate were presenting with the highest prevalence of myopia. Although our data is not able to establish causal inference, we speculate these factors may point to lowered fitness level. This is in line with the idea of suggesting students to spend more outdoor time to prevent myopia or manage its progression ([29](#_ENREF_29), [30](#_ENREF_30)). This mechanism is yet to be elucidated in details, since both light exposure and physical activity were proposed pathways. Prior studies have been limited with lack of objective measures of outdoor time ([31](#_ENREF_31)) and light exposure ([32](#_ENREF_32)). Similarly, measurement issue exists with physical activity thus findings on its association with myopia development and progression have been inconsistent ([33-35](#_ENREF_33)).

This study is not without limitation. The measurement of refractive error was carried out as part of the medical investigation of Austria military conscription. Routinely collected data are prone to potential errors that might lead to reduced statistical significances. For instance, although the device used in the medical investigation were from the same manufacture, the model of the device may differ over time as well as way of measuring non-cycloplegic refractions the years before the introduction of electronic devices. Moreover, the testing protocol and degree of control of accommodation during the medical investigation are unknown. This type of measurement errors are unlikely introduced a bias on our analyses on trends. This is also supported by the upwards trends in myopia in the multivariable model after adjusting for medical investigation station, as well as the consistent findings cross different medical investigation stations. However changing equipment is not avoidable for a study spanning over 30 years and this potentially might be a source of bias. Yet, given the fact that one of our main findings was different time trends depending on the educational level were consistently observed in all six stations, any potential bias introduced by the equipment or by the change of equipment appear to be an implausible explanation for our findings. It is worth noting that the present study did not take astigmatisms into account but focus only on the spherical equivalent. In addition, due to the nature of the data source, we were not able to include information on family history of myopia, time spent on near work or outdoors to elucidate the mechanisms of the observed increasing trends in myopia prevalence. This should be investigated in future studies. Finally, although ethnicity is a strong factor that influences the myopia prevalence, the demographic in Austria is highly homogeneous with 95% of the conscripts being Austrian born. In addition, the largest non-Caucasian immigrant group in Austria is ethnic Turks, who make up 2-3% of the overall population, as of today. Therefore the impact of ethnic or immigrants background in Austria data is minimal, particularly the known ethnicity group to influence myopia, South Asian.

In conclusion, the prevalence of myopia has been steadily increasing in Austrian young men, suggesting an urgent need of preventive measures to curb this trend. Although education has been recognized as a strong causal factor, our data showed a distinct role of lifestyle in myopia epidemic. Future research with robust measurement tool should investigate aim to elucidate the impact of outdoor light exposure, screen time and physical activity on myopia development and progression. Nevertheless, medical practice and public health policy should join forces in promoting the awareness of myopia in the youth, and design population based intervention and policy targeting at modifiable factors, particularly those have been shifted dramatically over the past decades.

Funding:

There is no funding source.

Conflict of interest

The authors declare that there are no conflicts of interest.

**References:**

1. Williams KM, Verhoeven VJ, Cumberland P, Bertelsen G, Wolfram C, Buitendijk GH, et al. Prevalence of refractive error in Europe: the European Eye Epidemiology (E(3)) Consortium. European journal of epidemiology. 2015;30(4):305-15.

2. Frick KD, Joy SM, Wilson DA, Naidoo KS, Holden BA. The Global Burden of Potential Productivity Loss from Uncorrected Presbyopia. Ophthalmology. 2015;122(8):1706-10.

3. Smith TS, Frick KD, Holden BA, Fricke TR, Naidoo KS. Potential lost productivity resulting from the global burden of uncorrected refractive error. Bulletin of the World Health Organization. 2009;87(6):431-7.

4. Verhoeven VJ, Wong KT, Buitendijk GH, Hofman A, Vingerling JR, Klaver CC. Visual consequences of refractive errors in the general population. Ophthalmology. 2015;122(1):101-9.

5. Qiu M, Wang SY, Singh K, Lin SC. Association between myopia and glaucoma in the United States population. Investigative ophthalmology & visual science. 2013;54(1):830-5.

6. Shen L, Melles RB, Metlapally R, Barcellos L, Schaefer C, Risch N, et al. The Association of Refractive Error with Glaucoma in a Multiethnic Population. Ophthalmology. 2016;123(1):92-101.

7. Guo YH, Lin HY, Lin LL, Cheng CY. Self-reported myopia in Taiwan: 2005 Taiwan National Health Interview Survey. Eye (London, England). 2012;26(5):684-9.

8. Shih YF, Chiang TH, Hsiao CK, Chen CJ, Hung PT, Lin LL. Comparing myopic progression of urban and rural Taiwanese schoolchildren. Japanese journal of ophthalmology. 2010;54(5):446-51.

9. Lin LL, Shih YF, Hsiao CK, Chen CJ. Prevalence of myopia in Taiwanese schoolchildren: 1983 to 2000. Annals of the Academy of Medicine, Singapore. 2004;33(1):27-33.

10. Wang TJ, Chiang TH, Wang TH, Lin LL, Shih YF. Changes of the ocular refraction among freshmen in National Taiwan University between 1988 and 2005. Eye (London, England). 2009;23(5):1168-9.

11. Hashemi H, Fotouhi A, Yekta A, Pakzad R, Ostadimoghaddam H, Khabazkhoob M. Global and regional estimates of prevalence of refractive errors: Systematic review and meta-analysis. Journal of current ophthalmology. 2018;30(1):3-22.

12. Fricke TR, Holden BA, Wilson DA, Schlenther G, Naidoo KS, Resnikoff S, et al. Global cost of correcting vision impairment from uncorrected refractive error. Bulletin of the World Health Organization. 2012;90(10):728-38.

13. Morgan IG, French AN, Ashby RS, Guo X, Ding X, He M, et al. The epidemics of myopia: Aetiology and prevention. Progress in retinal and eye research. 2018;62:134-49.

14. Hermanussen M, Danker-Hopfe H, Weber GW. Body weight and the shape of the natural distribution of weight, in very large samples of German, Austrian and Norwegian conscripts. International journal of obesity and related metabolic disorders : journal of the International Association for the Study of Obesity. 2001;25(10):1550-3.

15. Kapusta ND, Pietschnig J, Plener PL, Bluml V, Lesch OM, Walter H. Does breath carbon monoxide measure nicotine dependence? Journal of addictive diseases. 2010;29(4):493-9.

16. Kapusta ND, Zorman A, Etzersdorfer E, Ponocny-Seliger E, Jandl-Jager E, Sonneck G. Rural-urban differences in Austrian suicides. Social psychiatry and psychiatric epidemiology. 2008;43(4):311-8.

17. Wallner A, Hirz A, Schober E, Harbich H, Waldhoer T. Evolution of cardiovascular risk factors among 18-year-old males in Austria between 1986 and 2005. Wiener klinische Wochenschrift. 2010;122(5-6):152-8.

18. Kirchengast S, Schober E, Waldhor T, Sefranek R. Regional and social differences in body mass index, and the prevalence of overweight and obesity among 18 year old men in Austria between the years 1985 and 2000. Collegium antropologicum. 2004;28(2):541-52.

19. WHO Multicentre Growth Reference Study Group. WHO Child Growth Standards: Length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age: Methods and development. Geneva: World Health Organization. 2006.

20. Muntner P, Carey RM, Gidding S, Jones DW, Taler SJ, Wright JT, Jr., et al. Potential U.S. Population Impact of the 2017 ACC/AHA High Blood Pressure Guideline. Journal of the American College of Cardiology. 2018;71(2):109-18.

21. Bar Dayan Y, Levin A, Morad Y, Grotto I, Ben-David R, Goldberg A, et al. The changing prevalence of myopia in young adults: a 13-year series of population-based prevalence surveys. Investigative ophthalmology & visual science. 2005;46(8):2760-5.

22. Holden BA, Fricke TR, Wilson DA, Jong M, Naidoo KS, Sankaridurg P, et al. Global Prevalence of Myopia and High Myopia and Temporal Trends from 2000 through 2050. Ophthalmology. 2016;123(5):1036-42.

23. Morgan IG, Ohno-Matsui K, Saw SM. Myopia. Lancet (London, England). 2012;379(9827):1739-48.

24. Saw SM, Wu HM, Seet B, Wong TY, Yap E, Chia KS, et al. Academic achievement, close up work parameters, and myopia in Singapore military conscripts. Br J Ophthalmol. 2001;85(7):855-60.

25. Vitale S, Cotch MF, Sperduto RD. Prevalence of visual impairment in the United States. Jama. 2006;295(18):2158-63.

26. Vitale S, Sperduto RD, Ferris FL, 3rd. Increased prevalence of myopia in the United States between 1971-1972 and 1999-2004. Archives of ophthalmology (Chicago, Ill : 1960). 2009;127(12):1632-9.

27. Mountjoy E, Davies NM, Plotnikov D, Smith GD, Rodriguez S, Williams CE, et al. Education and myopia: assessing the direction of causality by mendelian randomisation. BMJ (Clinical research ed). 2018;361:k2022.

28. Ku PW, Steptoe A, Lai YJ, Hu HY, Chu D, Yen YF, et al. The Associations between Near Visual Activity and Incident Myopia in Children: A Nationwide 4-Year Follow-up Study. Ophthalmology. 2019;126(2):214-20.

29. He M, Xiang F, Zeng Y, Mai J, Chen Q, Zhang J, et al. Effect of Time Spent Outdoors at School on the Development of Myopia Among Children in China: A Randomized Clinical Trial. Jama. 2015;314(11):1142-8.

30. Wu PC, Tsai CL, Wu HL, Yang YH, Kuo HK. Outdoor activity during class recess reduces myopia onset and progression in school children. Ophthalmology. 2013;120(5):1080-5.

31. Alvarez AA, Wildsoet CF. Quantifying light exposure patterns in young adult students. Journal of modern optics. 2013;60(14):1200-8.

32. Dharani R, Lee CF, Theng ZX, Drury VB, Ngo C, Sandar M, et al. Comparison of measurements of time outdoors and light levels as risk factors for myopia in young Singapore children. Eye (London, England). 2012;26(7):911-8.

33. Jacobsen N, Jensen H, Goldschmidt E. Does the level of physical activity in university students influence development and progression of myopia?--a 2-year prospective cohort study. Investigative ophthalmology & visual science. 2008;49(4):1322-7.

34. Lundberg K, Suhr Thykjaer A, Sogaard Hansen R, Vestergaard AH, Jacobsen N, Goldschmidt E, et al. Physical activity and myopia in Danish children-The CHAMPS Eye Study. Acta ophthalmologica. 2018;96(2):134-41.

35. Muhamedagic L, Alajbegovic-Halimic J, Muhamedagic B, Muracevic B. Relation between physical activity and myopia progression in student population. Medicinski glasnik : official publication of the Medical Association of Zenica-Doboj Canton, Bosnia and Herzegovina. 2013;10(2):385-90.

|  |
| --- |
| **Table 1. Characteristics of Austrian conscripts cohorts between 2013-2017 (age < 19 years old)** |
|  |  |  |  | **Myopia**  |  |  **Hyperopia** |
|  | **Sample size** | %a |  | n; prevalence (%) |  | n; prevalence (%) |
| **Age** |  |  |  |  |  |  |  |  |  |  |
| 15-<18 | 26,075 | 13.5 |  | 6,463 |  | 24.8 |  | 863 |  | 3.3 |
| 18 | 143,490 | 74.5 |  | 35,051 |  | 24.4 |  | 4,650 |  | 3.2 |
| 18-<19 | 23,161 | 12.0 |  | 5,552 |  | 24.0 |  | 685 |  | 3.0 |
| **Body mass index (kg/m^2)** |  |  |  |  |  |  |  |  |  |  |
| <18.5  | 13,044 | 6.8 |  | 3,812 |  | 29.2 |  | 414 |  | 3.2 |
| 18.5 - <25  | 127,602 | 66.2 |  | 30,438 |  | 23.9 |  | 3,983 |  | 3.1 |
| 25 - <30  | 36,266 | 18.8 |  | 8,753 |  | 24.1 |  | 1,210 |  | 3.3 |
| 30-60  | 15,757 | 8.2 |  | 4,052 |  | 25.7 |  | 589 |  | 3.7 |
| **Resting heart rate (beats per min)** |  |  |  |  |  |  |  |  |  |
| 40-59 | 22,689 | 12.0 |  | 4,594 |  | 20.3 |  | 705 |  | 3.1 |
| 60-94 | 149,301 | 78.8 |  | 36,215 |  | 24.3 |  | 4,747 |  | 3.2 |
| 95-110 | 17,432 | 9.2 |  | 5,239 |  | 30.1 |  | 606 |  | 3.5 |
| **Blood pressureb** |  |  |  |  |  |  |  |  |  |  |
| Normal  | 34,991 | 18.2 |  | 8,509 |  | 24.3 |  | 1,193 |  | 3.4 |
| Elevated  | 40,508 | 21.0 |  | 9,676 |  | 23.9 |  | 1,339 |  | 3.3 |
| Stage 1 hypertension | 87,357 | 45.3 |  | 21,110 |  | 24.2 |  | 2,706 |  | 3.1 |
| Stage 2 hypertension | 29,870 | 15.5 |  | 7,771 |  | 26.0 |  | 960 |  | 3.2 |
| **Educationc** |  |  |  |  |  |  |  |  |  |  |
| Low  | 3,509 | 1.9 |  | 718 |  | 20.5 |  | 139 |  | 4.0 |
| Medium | 121,982 | 63.3 |  | 26,487 |  | 21.7 |  | 4,007 |  | 3.3 |
| High | 64,454 | 33.4 |  | 18,978 |  | 29.4 |  | 1,985 |  | 3.1 |
| Very high | 2,713 | 1.4 |  | 873 |  | 32.2 |  | 61 |  | 2.3 |
| **Medical investigation station** |  |  |  |  |  |  |  |  |  |  |
| Burgenland+Vienna | 35,027 | 18.2 |  | 9,739 |  | 27.8 |  | 1,039 |  | 3.0 |
| Carinthia+Salzburg | 25,468 | 13.2 |  | 5,307 |  | 20.8 |  | 744 |  | 2.9 |
| Tyrol+Vorarlberg | 28,186 | 14.3 |  | 6,321 |  | 22.4 |  | 815 |  | 2.9 |
| Styria | 27,482 | 14.3 |  | 6,337 |  | 23.1 |  | 769 |  | 2.8 |
| Upper Austria | 35,804 | 18.6 |  | 8,970 |  | 25.1 |  | 1,413 |  | 4.0 |
| Lower Austria | 40,759 | 21.2 |  | 10,392 |  | 25.4 |  | 1,418 |  | 3.5 |
| a Percentages do not add up 100 due to missing valuesb Normal: Less than 120/80 mm Hg; Elevated: Systolic between 120-129 and diastolic less than 80; Stage 1 hypertension: Systolic between 130-139 or diastolic between 80-89; Stage 2 hypertension: Systolic at least 140 or diastolic at least 90 mm Hgc Low: lower than 9 years of compulsory school; Medium: completed 9 years of compulsory school; High: graduated from vocational training or served an apprenticeship; Very high: had a general qualification for university entrance |

|  |
| --- |
| **Table 2. Correlates of myopic refractive error (<-0.5 Da) among Austrian conscript cohorts 2013-2017 (age <19 years old)** |
|   | **Burgenland+Vienna** |  | **Carinthia+Salzburg** |  | **Tyrol+Vorarlberg** |  | **Styria** |  | **Upper Austria** |  | **Lower Austria** |
| **BMI (kg/m^2)** |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
|  <18.5  | 1.1 | (1.0 to | 1.3) |   | 1.4 | (1.1 to | 1.6) |   | 1.4 | (1.3 to | 1.6) |   | 1.4 | (1.2 to | 1.6) |   | 1.3 | (1.2 to | 1.4) |   | 1.2 | (1.1 to | 1.4) |
|  18.5 - <25  | reference |   | reference |   | reference |   | reference |   | reference |   | reference |
|  25 - <30  | 1.1 | (1.0 to | 1.2) |   | 1.0 | (0.9 to | 1.1) |   | 1.0 | (0.9 to | 1.1) |   | 1.1 | (1.0 to | 1.2) |   | 1.0 | (0.9 to | 1.1) |   | 1.0 | (0.9 to | 1.1) |
|  30-60  | 1.1 | (1.0 to | 1.3) |   | 1.0 | (0.8 to | 1.1) |   | 1.1 | (0.9 to | 1.2) |   | 1.1 | (1.0 to | 1.3) |   | 1.0 | (0.9 to | 1.1) |   | 1.2 | (1.1 to | 1.3) |
| **Resting heart rate** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  40-59 | reference |   | reference |   | reference |   | reference |   | reference |   | reference |
|  60-94 | 1.4 | (1.3 to | 1.5) |   | 1.1 | (0.9 to | 1.2) |   | 1.2 | (1.1 to | 1.3) |   | 1.2 | (1.0 to | 1.3) |   | 1.3 | (1.2 to | 1.4) |   | 1.2 | (1.1 to | 1.3) |
|  95-110 | 1.9 | (1.6 to | 2.1) |   | 1.5 | (1.2 to | 1.9) |   | 1.6 | (1.4 to | 1.8) |   | 1.5 | (1.2 to | 1.7) |   | 1.7 | (1.5 to | 2.0) |   | 1.4 | (1.3 to | 1.6) |
|  *P*-for trend | <.001 |   | <.001 |   | <.001 |   | <.001 |   | <.001 |   | <.001 |
| **Blood pressurec** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  Normal  | reference |   | reference |   | reference |   | reference |   | reference |   | reference |
|  Elevated | 0.9 | (0.9 to | 1.0) |   | 0.9 | (0.8 to | 1.0) |   | 1.0 | (0.9 to | 1.1) |   | 0.9 | (0.9 to | 1.0) |   | 1.0 | (0.9 to | 1.1) |   | 1.0 | (0.9 to | 1.0) |
|  Stage 1 Hypertension | 1.0 | (0.9 to | 1.1) |   | 1.1 | (0.9 to | 1.2) |   | 1.1 | (1.0 to | 1.2) |   | 1.0 | (0.9 to | 1.2) |   | 1.1 | (1.0 to | 1.2) |   | 1.0 | (0.9 to | 1.1) |
|  Stage 2 Hypertension | 1.0 | (0.9 to | 1.1) |   | 1.0 | (0.9 to | 1.2) |   | 1.1 | (1.0 to | 1.2) |   | 1.2 | (1.1 to | 1.4) |   | 1.0 | (0.9 to | 1.1) |   | 1.0 | (0.9 to | 1.1) |
|   *P*-for trend | 0.766 |   | 0.261 |   | 0.041 |   | 0.013 |   | 0.415 |   | 0.562 |
| **Education** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  Low to medium | reference |   | reference |   | reference |   | reference |   | reference |   | reference |
|  High to very high | 1.3 | (1.3 to | 1.4) |   | 1.6 | (1.4 to | 1.7) |   | 1.7 | (1.6 to | 1.8) |   | 1.5 | (1.4 to | 1.6) |   | 1.5 | (1.4 to | 1.6) |   | 1.4 | (1.3 to | 1.5) |
| a Spherical equivalent (SE) = sphere + cylinder/2, unit diopters (D), 95%CIb Multivariable regression models were adjusted for age, BMI, resting heart rate, blood pressure and education level.c Normal: Less than 120/80 mm Hg; Elevated: Systolic between 120-129 and diastolic less than 80; Stage 1 hypertension: Systolic between 130-139 or diastolic between 80-89; Stage 2 hypertension: Systolic at least 140 or diastolic at least 90 mm Hg |  |   |
|  |

**Table 3. Time trend in the prevalence (%) of myopic refractive error (<-0.5 Da) among Austrian conscript cohorts between 1983-1987 and 2013-2017 (age < 19 years old)**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Years of conscription | 1983-1987 | 1988-1992 | 1993-1997 | 1998-2002 | 2003-2007 | 2008-2012 | 2013-2017 | *P* for trend |  2013-2017 vs. 1983-1987d |
|   |   | n=260,244 | n=222,358 | n=193,136 | n=207,065 | n=212,525 | n=219,009 | n=192,726 | Unadjusted b | Multivariable-adjustedc |
| **Austria overall** | 13.8 | 15.8 | 16.7 | 19.7 | 22.2 | 23.0 | 24.4 |  < .001 |  < .001 | 10.7 |
|  |  | (13.6, 13.9) | (15.7, 16.0) | (16.5, 16.8) | (19.6,19.9 ) | (22.1, 22.4) | (22.8, 23.2) | (24.2, 24.6) |  |  | (10.4, 10.9) |
|  |  |  |  |  |  |  |  |  |  |  |
| Burgenland+Vienna | 19.3 | 21.9 | 22.0 | 23.2 | 25.3 | 26.3 | 27.8 |  < .001 |  < .001 | 8.5 |
|   |   | (19.0, 19.6) | (21.5, 22.2) | (21.6, 22.5) | (22.8, 23.6) | (24.8, 25.7) | (25.9, 26.7) | (27.3, 28.3) |  |  | (7.9, 9.1) |
|  |  |  |  |  |  |  |  |  |  |  |
| Carinthia+Salzburg | 13.1 | 14.2 | 14.5 | 18.5 | 21.0 | 20.7 | 20.8 |  < .001 |  < .001 | 7.8 |
|   |   | (12.8, 13.4) | (13.8, 14.6) | (14.1, 14.9) | (18.1, 18.9) | (20.6, 21.5) | (20.2, 21.1) | (20.3, 21.3) |  |  | (7.1, 8.4) |
|  |  |  |  |  |  |  |  |  |  |  |
| Tyrol+Vorarlberg | 10.4 | 13.0 | 14.0 | 19.6 | 20.6 | 20.0 | 22.4 |  < .001 |  < .001 | 12.0 |
|   |   | (10.1, 10.8) | (12.6, 13.4) | (13.6, 14.4) | (19.1, 20.0) | (20.1, 21.1) | (19.5, 20.4) | (21.9, 22.9) |  |  | (11.4, 12.6) |
|  |  |  |  |  |  |  |  |  |  |  |
| Styria | 11.5 | 14.2 | 16.3 | 18.7 | 20.3 | 21.3 | 23.1 |  < .001 |  < .001 | 11.6 |
|   |   | (11.2, 11.8) | (13.8, 14.5) | (15.9, 16.7) | (18.3, 19.2) | (19.8, 20.7) | (20.9, 21.7) | (22.6, 23.6) |  |  | (11.0, 12.1) |
|  |  |  |  |  |  |  |  |  |  |  |
| Upper Austria | 12.9 | 13.9 | 15.1 | 16.9 | 20.7 | 22.5 | 25.1 |  < .001 |  < .001 | 12.2 |
|   |   | (12.6, 13.2) | (13.5, 14.2) | (14.8, 15.5) | (16.5, 17.3) | (20.4, 21.2) | (22.1, 22.9) | (24.6, 25.5) |  |  | (11.6, 12.7) |
|  |  |  |  |  |  |  |  |  |  |  |
| Lower Austria | 13.6 | 15.9 | 16.7 | 21.0 | 24.3 | 25.5 | 25.5 |  < .001 |  < .001 | 11.9 |
|   |   | (13.3, 13.9) | (15.5, 16.2) | (16.4, 17.1) | (20.6, 21.4) | (23.9, 24.7) | (25.1, 25.9) | (25.1, 25.9) |  |  | (11.4, 12.4) |

a Spherical equivalent (SE) = sphere + cylinder/2, unit diopters (D), 95%CI

b *P* for trend were estimated using unadjusted logistic regression using years of conscription as a predictor.

c *P* for trend were estimated using logistic regression using years of conscription as a predictor, and adjusted for age, BMI, resting heart rate, blood pressure, education level, and medical investigation station (for Austria overall only).

d Change in prevalence were calculated by subtracting estimated myopia prevalence in 1983-1987 from that in 2013-2017.

|  |
| --- |
| **Table 4. Time trend in prevalence of myopic refractive error (<-0.5 Da) among Austrian conscript cohorts 1983-1987 to 2013-2017 by levels of education and medical investigation station (age <19 years old) b**  |
|   | **Burgenland+Vienna** |  | **Carinthia+Salzburg** |  | **Tyrol+Vorarlberg** |  | **Styria** |  | **Upper Austria** |  | **Lower Austria** |
| **Low to medium education**  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 1983-1987 | reference |   | reference |   | reference |   | reference |   | reference |   | reference |
| 1988-1992 | 1.1 | (1.0 to | 1.1) |   | 1.0 | (0.9 to | 1.0) |   | 1.1 | (1.0 to | 1.2) |   | 1.2 | (1.2 to | 1.3) |   | 1.0 | (1.0 to | 1.1) |   | 1.1 | (1.1 to | 1.2) |
| 1993-1997 | 1.1 | (1.0 to | 1.1) |   | 1.0 | (0.9 to | 1.1) |   | 1.3 | (1.2 to | 1.3) |   | 1.4 | (1.4 to | 1.5) |   | 1.1 | (1.0 to | 1.2) |   | 1.2 | (1.1 to | 1.2) |
| 1998-2002 | 1.3 | (1.2 to | 1.4) |   | 1.4 | (1.3 to | 1.5) |   | 2.0 | (1.9 to | 2.2) |   | 2.1 | (2.0 to | 2.2) |   | 1.5 | (1.4 to | 1.5) |   | 1.7 | (1.6 to | 1.8) |
| 2003-2007 | 1.4 | (1.3 to | 1.5) |   | 1.8 | (1.6 to | 1.9) |   | 2.2 | (2.1 to | 2.3) |   | 2.2 | (2.1 to | 2.3) |   | 1.7 | (1.6 to | 1.8) |   | 2.0 | (1.9 to | 2.1) |
| 2008-2012 | 1.6 | (1.5 to | 1.7) |   | 1.7 | (1.6 to | 1.8) |   | 2.2 | (2.0 to | 2.3) |   | 2.2 | (2.1 to | 2.3) |   | 1.9 | (1.8 to | 2.0) |   | 2.2 | (2.1 to | 2.3) |
| 2013-2017 | 1.9 | (1.8 to | 2.0) |   | 1.8 | (1.6 to | 1.9) |   | 2.6 | (2.4 to | 2.7) |   | 2.7 | (2.5 to | 2.8) |   | 2.3 | (2.2 to | 2.5) |   | 2.3 | (2.2 to | 2.4) |
|  P-for trenda | <0.001 |   | <0.001 |   | <0.001 |   | <0.001 |   | <0.001 |   | <0.001 |
|  |
| **High or very high education** |
| 1983-1987 | reference |   | reference |   | reference |   | reference |   | reference |   | reference |
| 1988-1992 | 1.1 | (1.0 to | 1.2) |   | 1.0 | (1.0 to | 1.1) |   | 1.2 | (1.1 to | 1.3) |   | 1.1 | (1.0 to | 1.2) |   | 0.9 | (0.9 to | 1.0) |   | 1.2 | (1.1 to | 1.3) |
| 1993-1997 | 1.1 | (1.0 to | 1.1) |   | 0.9 | (0.8 to | 1.0) |   | 1.1 | (1.0 to | 1.3) |   | 1.2 | (1.1 to | 1.3) |   | 0.9 | (0.8 to | 1.0) |   | 1.1 | (1.0 to | 1.1) |
| 1998-2002 | 1.2 | (1.1 to | 1.3) |   | 1.2 | (1.1 to | 1.3) |   | 1.6 | (1.5 to | 1.8) |   | 1.4 | (1.2 to | 1.5) |   | 1.0 | (0.9 to | 1.1) |   | 1.4 | (1.3 to | 1.5) |
| 2003-2007 | 1.3 | (1.2 to | 1.4) |   | 1.4 | (1.2 to | 1.5) |   | 1.6 | (1.4 to | 1.8) |   | 1.4 | (1.3 to | 1.5) |   | 1.3 | (1.2 to | 1.5) |   | 1.6 | (1.5 to | 1.8) |
| 2008-2012 | 1.3 | (1.2 to | 1.4) |   | 1.3 | (1.2 to | 1.5) |   | 1.6 | (1.4 to | 1.7) |   | 1.4 | (1.3 to | 1.5) |   | 1.4 | (1.3 to | 1.5) |   | 1.6 | (1.5 to | 1.7) |
| 2013-2017 | 1.2 | (1.1 to | 1.2) |   | 1.3 | (1.1 to | 1.4) |   | 1.7 | (1.5 to | 1.9) |   | 1.3 | (1.2 to | 1.4) |   | 1.4 | (1.3 to | 1.6) |   | 1.4 | (1.3 to | 1.5) |
| P-for trenda | <0.001 |  | <0.001 |  | <0.001 |  | <0.001 |  | <0.001 |  | <0.001 |

a Spherical equivalent (SE) = sphere + cylinder/2, unit diopters (D), 95%CI

b Multivariable logistic regression adjusted for age, BMI, resting heart rate, hypertension (OR, 95%CI)

c *P* for trend were estimated using multivariable logistic regression using years of conscription as a predictor.

**Figure 1a-1f. Predicted prevalence of myopic refractive error (<-0.5 Da) among Austrian conscript cohorts 1983-1987 to 2013-2017 by levels of education (low-medium vs. high-very high) and by medical investigation station.**

a Spherical equivalent (SE) = sphere + cylinder/2, unit diopters (D)