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Article

An Objective Comparison of Light Intensity and Near-Visual Tasks Between Rural and Urban School Children in China by a Wearable Device Clouclip

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Purpose: To compare light intensity and near-visual tasks objectively between rural and urban children.

Methods: Clouclip, a wearable device, was applied to assess metrics of these two factors in 78 fifth-grade students from an urban and from a rural school.

Results: The light intensity experienced by urban students was found significantly lower both in the school period (614.05 $\pm$ 178.77 vs. 918.41 $\pm$ 257.81 lux, $P < 0.001$) and on the weekend (444.53 $\pm$ 216.65 vs. 882.21 $\pm$ 536.67 lux, $P < 0.001$). The duration of exposure to bright light (>1000 lux) was also substantially shorter for urban students. Although no significant difference was found in near work–related behaviors during the school period and the weekend, for the after-school period the urban students had a shorter average viewing distance (30.94 $\pm$ 4.14 vs. 34.81 $\pm$ 3.93 cm, $P < 0.001$), a longer accumulated duration of near work (2.25 $\pm$ 0.53 vs. 1.95 $\pm$ 0.46 hours, $P = 0.010$), a greater time ratio of near work (56% $\pm$ 14% vs. 49% $\pm$ 14%, $P = 0.045$), and a greater time ratio of excessively close near work (49% $\pm$ 13% vs. 40% $\pm$ 12%, $P = 0.001$).

Conclusions: Our data indicate there were substantial differences in light exposure and near-work metrics between the two regions. The correlation between these differences and the discrepancy in regional myopia prevalence needs further investigation.

Translational Relevance: The objective quantification of these metrics might help explain the varied myopia prevalence among regions.

Introduction

Nearsightedness, or myopia, is an ocular disorder that occurs when the focal power of the optical components is less than the axial length. This means that the main symptom is blurred distant vision. When myopia progresses into high myopia (i.e., more myopic than –6.00 diopters [D]), there is a significantly increased risk of developing irreversible blindness caused by conditions, such as retinal detachment and glaucoma.[1] The prevalence of myopia has increased remarkably in the last few decades. According to a recent report, the number of people with myopia worldwide has increased from 1.41 billion in 2000 to 1.95 billion in 2010, and the number is expected to further rise to 4.76 billion by 2050.[2] Therefore, myopia has been one of five immediate priorities of the "Vision 2020" initiative of the World Health Organization.[3]

Although the prevalence of myopia demonstrates a general picture of increasing tendency worldwide, significantly different level of prevalence exists among regions, varying from approximately 10% in Africa to around 35% in Europe and North America, and to approximately 50% in East Asia.[2] This discrepancy of myopia prevalence might reflect the distinct genetic susceptibility to myopia between ethnicities,[4] but might also reflect some unknown independent factors that vary among these regions. Actually, a series of literature has shown difference in the myopia prevalence between populations even with a similar genetic background but different levels of urbanization. For instance, Saw et al.[5] reported that the myopia prevalence in second-year students in Xiamen City, China, was 19.3%, while the prevalence was only 6.6% in their counterparts from rural areas. He et al.[6] also found that 78.4% of 15-year-old students in Guangzhou City, China, suffered from myopia, whereas the prevalence was only 53.9% in the 17-year-old students in Yangxi County that is a rural area located just around 200 km away.[7] Similar difference in the prevalence of myopia between urban and rural areas has also been reported in studies conducted in India.[8,9]

Urbanization leads to remarkable changes of many aspects in human life, among which near-work activities and outdoor exposure have been linked by scholars into the field of myopia research. For example, the consideration that excessive near-work activities might be a potential cause to myopia development could be dated back to four centuries ago,[10] but the reported association is very controversial. In a recent systematic review and meta-analysis, Huang and colleagues[11] summarized that only 10 of 15 cross-sectional studies showed more near-work activities were associated with the increase of myopia prevalence. In addition, only two of six cohort studies reported excessive near-work activities increased the risk of myopia development, while others found no correlation. Also, only two of six longitudinal studies demonstrated the link between near-work activities and myopia progression. In contrast, the link between outdoor exposure and myopia development gained much more consistent results from literature. It was first observed that higher amounts of outdoor time were associated with a lower incidence of myopia in children, even after adjusting for near work, parental myopia, and ethnicity.[12] Two clinical trials further demonstrated that increased outdoor time could significantly decreased the rate of myopia onset.[13,14] However, the biological pathways mediating outdoor exposure and myopia is not completely clear yet. Although animal studies indicated that ambient illuminance might play an important role,[15] direct evidence in humans is limited.

The Aier Myopia Etiology Study with Clouclip (AMESC) is a multicontinental longitudinal project that aims to illustrate the environmental pathogenesis of myopia by comparing the rate of myopia development and the environmental data among regions with different levels of urbanization. The environmental data will be objectively collected by a wearable device called Clouclip that we developed recently (Wen L, et al. *IOVS* 2016;57:ARVO E-Abstract 2491; Wen L, et al. *IOVS* 2017;58:ARVO E-Abstract 2403). In the present study, we present cross-sectional data with regard to near-visual tasks and outdoor exposure collected using this device, from one school located in an urban area and one school located in a rural area in the project.

Methods

Participants

Participants for this study were recruited from among fifth-grade students of two primary schools, including Yunshan Primary School, located in an urban area, and Lao Liangcang Primary School, located in a rural area. Yunshan Primary School is located in the urban area of Guangzhou, which is one of the most developed cities in China with an annual GDP of 313.2 billion USD (2017). By contrast, Lao Liangcang Primary School is located in Ningxiang, a remote town in the subdeveloped areas of China's central region, with an annual GDP of 17.8 billion USD (2017).

The study was in compliance with the Helsinki Declaration and has been approved by the Aier Eye Hospital Group Ethics Committee (No. IRB2016004). The nature of the study and all possible consequences were explained in detail to the students and their parents before the commencement of the study. Assent from children and written parental permission to participate to the study were achieved and their signed informed consent for participation was obtained.

Quantification of Near-Visual Tasks and Ambient Illuminance

Clouclip (Glasson Technology Co. Ltd., Hangzhou, China) was worn on the right arm of the eyeglass frame for the quantification of near work and ambient illuminance (Fig. 1). Clouclip has a built-in infrared distance sensor (measurement range, 15–60 cm) and a light intensity sensor (measurement range, 1–655336 lux) for detecting the working distance and the ambient light intensity in real-time fashion. In brief, the infrared distance sensor emits a

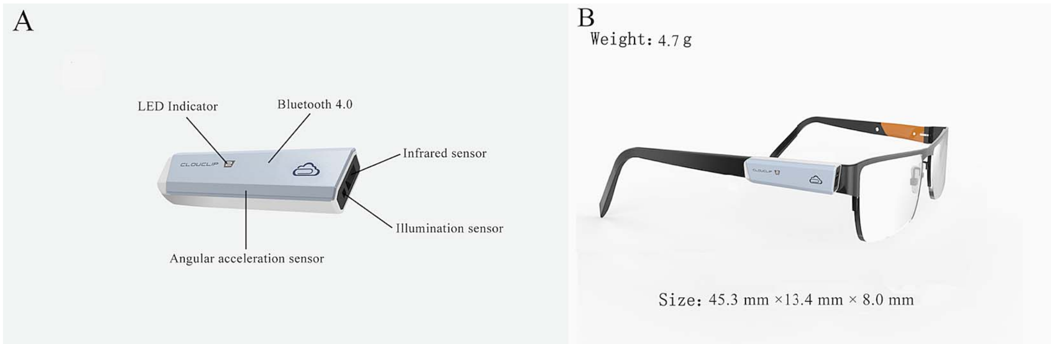

Figure 1. The Clouclip structure. (A) Location of the sensors in Clouclip. (B) Clouclip attached to the right arm of an eyeglass frame.

beam of infrared light, which forms a reflection process after irradiating the object. Then the sensor receives the reflected signal, and uses the charge-coupled device image to process the time difference between transmission and reception data and calculate the distance. The light intensity sensor converts light intensity value into voltage value. The stronger the light intensity, the higher the voltage. In addition, Clouclip is equipped with a three-axis accelerometer (X, Y, and Z axes) that indicates whether it is being used or not. If the triaxial accelerometer does not detect any change for more than 40 seconds, the Clouclip enters "sleep mode" and no valid data are recorded. Clouclip is programed to measure the working distance every 5 seconds and ambient illuminance every 2 minutes. The data collected by Clouclip are stored in the internal memory of the device and then sent to the cloud platform via a smartphone application. Our previous study has shown that Clouclip has high accuracy and good repeatability for measuring the working distance and ambient light intensity (Wen L, et al. *IOVS* 2016;57:ARVO E-Abstract 2491).

Procedures

All volunteers underwent a comprehensive ocular examination, including ocular health and cycloplegic autorefraction. Only participants with normal ocular health and a spherical equivalent refractive error (i.e., spherical power + 1/2 cylindrical power [SER]) between −6.00 and +1.00 D and anisometropia less than 1.00 D were included in the study. Clouclips were then attached to the participants' spectacles. For those who did not wear spectacles, frames without lenses were provided so that Clouclip could be worn. In order to avoid any possible influence of the wearing of Clouclip and/or a new frame, we arranged an adaptation period of 3 days within which the data collected by Clouclip were not included in the analysis.

The participants were required to wear Clouclip throughout the day, except during bathing or sleeping, continuously for 1 week (including 5 weekdays and 2 weekend days), and were encouraged to go about their activities as usual during the week. To improve compliance, teachers and parents were asked to keep a check on whether the participants were wearing the devices every day at school or at home. Parents were also requested to upload the data from the device to the cloud platform via their smartphones every day.

Data Retrieval and Preanalysis

Following the week of wearing the device, all raw data, including working distance, eye-level illuminance, and the corresponding collection time points, were downloaded from the cloud platform.

For each of the week days, data were categorized into the school period (7:30 AM to 3:30 PM, 8 hours) and after-school period (3:30 PM to 8:00 PM, 4.5 hours). For the weekend days, data collected from 7:30 AM to 8:00 PM (12.5 hours) were categorized as one period. Even though the students were required to wear Clouclip, and the teachers and parents supervised their wearing of the device, it was logical that not each student would wear it all day. Therefore, we defined a valid period as a period in which data could be achieved from not less than 80% of the total required wearing time. A valid subject sample was defined as one who had valid periods of at least 3 days during weekdays or at least 1 day during weekend.

To conduct a comprehensive evaluation of near-work behavior, data on viewing distance were calculated and compared based on five metrics. Please note that in the present study, "near work" referred to close work activity that occurred less than 60 cm

Table 1. Demographics of the Recruited Students From the Urban and Rural School

	Urban Students	Rural Students	*P*
N	39	39	
Female, *n* (%)	17 (43.59)	16 (41.03)	0.17
Male, *n* (%)	22 (56.41)	23 (58.97)	
Age, mean ± SD, y	11.29 ± 0.40	11.26 ± 0.41	0.87
Spherical equivalent, mean ± SD, D	−0.91 ± 1.40	−1.06 ± 1.23	0.50
Emmetrope, *n* (%)	17 (43.59)	17 (43.59)	>0.999
Myope, *n* (%)	22 (56.41)	22 (56.41)	

away, as a result of the maximum measurement limit of the device. The following parameters were calculated: (1) average daily near-work distance, which was the mean of the viewing distance for each day; (2) accumulated duration of near work (number of hours); (3) time ratio of near work, which is the ratio of the near-work activity duration to the total wearing duration; and (4) time ratio of excessively close near work, which is the ratio of near-work activity time that occurred less than 30 cm away and near-work activity time that occurred less than 60 cm away. In addition, the "average daily frequency of continuous near work" was used to evaluate the temporal pattern of shifts in the viewing distance between near (≤60 cm) and distant (>60 cm), because animal studies showed that the temporal pattern of focusing position plays an important role in ocular growth.[16] An episode of continuous near work was defined as near work that lasted continuously for more than 30 minutes with a less than 60-second interruption (i.e., the time spent in the distance after near work was <60 seconds). This definition was somewhat empirical and was estimated based on findings in animals that (1) the summation of the effect of the ocular go/stop signal is nonlinear,[17,18] and (2) although the shift frequency of the ocular go/stop signals is more important than the acting duration for each episode, the reverse is true if the episode is too brief.[17] With regard to ambient illuminance, data on illuminance were evaluated based on two metrics: the average daily level of light intensity and exposure duration at various levels of light intensity.

Statistical Analysis

Data with normal distribution are expressed as mean ± standard deviation (M ± SD). Data with abnormal distribution are expressed as median (25th percentile, 75th percentile). Statistical analyses were performed using SPSS 25.0 (SPSS Inc., Chicago, IL). The cut-off for statistical significance was set at $P <$ 0.05. Repeated-measures ANOVA was conducted to compare the differences of the metrics between rural and urban students for the three repeated periods observed, with age, sex, and refractive error as the covariates. For the subjects who did not meet the previous definition of the validity, a strategy of multiple imputation by fully conditional specification regression model was applied for the imputation of the missing values. As the interaction effect between the location and the time variables was found, covariance analysis was further used to determine the differences between the two locations for each period with Bonferroni post hoc correction. Therefore, the corresponding statistical significance was 0.05 divided by 3, which equals to 0.017.

Results

A total of 78 fifth-grade students, 39 from the urban school and 39 from the rural school, were recruited for the study. Students from these two schools were well matched for age, sex, and refractive error (Table 1).

The 7-day period for wearing Clouclip for urban students was from May 25 to May 31, 2018, and for the rural students, it was from June 7 to June 14, 2018. It was early summer in both areas, and the overall weather conditions in Guangzhou and Ningxiang during this period were similar. Specifically, in Guangzhou, there were 2 days of light rain and three cloudy days during the week and two cloudy days on the weekend. In Ningxiang, there were 2 days of light rain, two cloudy days and one cloudy and then sunny day during the week, and both the weekend days were cloudy. The sunrise and sunset times in the two areas were the same. In addition, the school timings were identical in both schools, that is, 7:30 AM to 3:30 PM. Table 2 shows the Clouclip-wearing compliance rate during different periods of the study. Overall, compliance during the school period was satisfactory

Table 2. Clouclip-Wearing Compliance Among the Students in the Urban School and in the Rural School

	N		Mean Valid Days, d[a]			Mean Daily Wearing Time, hr[a]		
	Urban Students	Rural Students	Urban Students	Rural Students	*P*	Urban Students	Rural Students	*P*
Weekday school period (7:30 AM to 3:30 PM)	39	39	4.49 ± 0.68	4.44 ± 0.75	0.86	7.48 ± 0.38	6.52 ± 0.35	<0.01
Weekday after-school period (3:30 PM to 8:00 PM)	30	29	3.45 ± 0.51	3.14 ± 0.44	0.02	4.13 ± 0.38	4.05 ± 0.42	0.42
Weekend (7:30 AM to 8:00 PM)	24	22	1.91 ± 0.29	1.77 ± 0.43	0.22	11.50 ± 1.34	10.77 ± 1.22	<0.01

[a] Data are expressed as mean ± SD.

for the students from both urban and rural schools. However, after school, especially during the weekend days, only 24 of 39 urban students and 22 of 39 rural students were found to wear Clouclip for more than 80% of either day of the weekend days. Specifically, with regard to the mean daily wearing time, students in the urban school wore the Clouclip significantly longer than those in the rural school during the school period on weekdays (7.48 ± 0.38 vs. 6.52 ± 0.35 hours, $P < 0.01$) and on the weekend days (11.50 ± 1.34 vs. 10.77 ± 1.22 hours, $P < 0.01$), while there was no significant difference in the after-school period on weekdays. It was also noted that Clouclip-wearing compliance was different between myopes and emmetropes. Specifically, according to our requirement of wearing time during weekdays, 81.82% (36/44) of myopes were valid, while only 64.71% (22/34) of emmetropes were valid. On the weekends, the valid subjects accounted for 68.18% (30/44) in myopes, while only 41.18% (14/34) in emmetropes. Nevertheless, there was no difference in the mean daily wearing time between the valid emmetropes and valid myopes, no matter during the weekdays or on the weekends.

Repeated-measures ANOVA showed that interaction effect was found existed between urban–rural group and three different analysis periods for all the metrics of near work and ambient illumination exposure (Table 3). Covariance analysis was further conducted to clarify the differences between the two locations for each period, with age, sex, and refractive error as the covariates.

Comparison of Ambient Light Exposure

Figure 2 illustrates the light exposure experienced by students in the rural and urban school. It was found that, during the school period, the light

Table 3. Outcomes of Repeated-Measures ANOVA With Adjustment of Age, Sex, Refractive Error

	Group[a]		Time[b]		Group × Time[c]	
	F	*P*	*F*	*P*	*F*	*P*
Average level of light intensity, lux	29.80	<0.001	4.85	0.012	14.06	<0.001
Average exposure duration with light intensity >1000, hr	18.74	<0.001	4.49	0.024	6.72	0.005
Average exposure duration with light intensity >2000, hr	15.49	<0.001	5.90	0.009	8.39	0.002
Average exposure duration with light intensity >3000, hr	14.76	<0.001	7.16	0.004	10.24	0.001
Average exposure duration with light intensity >5000, hr	10.20	0.002	7.64	0.004	11.25	0.001
Average distance of near work, cm	4.16	0.045	0.21	0.760	17.55	<0.001
Accumulated duration of near work, hr	0.16	0.688	1.93	0.162	11.88	<0.001
Time ratio of near work (≤60 cm)	1.16	0.285	0.05	0.947	14.71	<0.001
Time ratio of excessively close near work (<30 cm)	3.37	0.071	1.24	0.290	9.42	<0.001
Average frequency of continuous near work	1.16	0.284	1.34	0.262	6.25	0.005

[a] Urban–rural group.
[b] Three different analysis time periods.
[c] Interaction between urban–rural group and three different analysis time periods.

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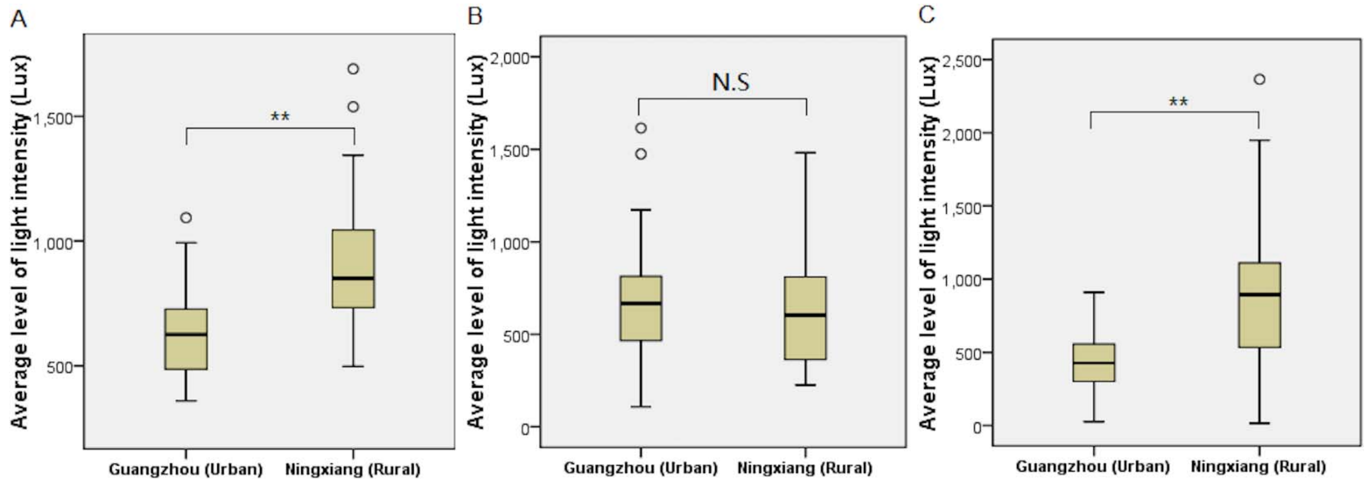

Figure 2. Boxplots of the average daily light intensity in different analysis periods. (A) School period, (B) after-school period, (C) weekend days. N.S: not significant, $^{**}P < 0.01$.

intensity that rural students (918.41 ± 257.81 lux) were exposed to was significantly higher than the light intensity that urban students were exposed to (614.05 ± 178.77 lux) ($P < 0.001$). By contrast, the light intensity exposure during the after-school period was similar between the two groups of students (urban: 689.83 ± 326.48 lux versus rural: 626.03 ± 307.36 lux, $P = 0.454$). On the weekend, again, students in the rural school experienced significantly higher levels of light intensity than those in the urban school (882.21 ± 536.67 vs. 444.53 ± 216.65 lux, $P < 0.001$).

Interestingly, students in the urban school experienced a significantly higher light intensity on weekdays than at the weekend (618.47 ± 124.35 vs. 397.12 ± 183.22 lux, $P < 0.001$), but this was not the case for the students in the rural school (889.47 ± 221.34 vs. 855.29 ± 591.48 lux, $P = 0.218$).

Because the inhibitory effect of light exposure on myopia is nonlinear,[19] light intensity was classified into more than 1000, 2000, 3000, and 5000 lux, and the corresponding exposure duration was summarized (Fig. 3). During the school period, the average exposure duration for light levels greater than 1000, 2000, and 3000 lux for rural students (1.09 ± 0.44, 0.59 ± 0.25, and 0.44 ± 0.19 hours, respectively) was 0.40, 0.15, and 0.11 hours longer than that for urban students (0.69 ± 0.27, 0.44 ± 0.20, and 0.33 ± 0.15 hours, respectively) ($P < 0.01$ for all). However, there was no significant difference between these two groups of subjects in the duration of exposure to light levels greater than 5000 lux (urban: 0.22 ± 0.09 hours, rural: 0.26 ± 0.12 hours, $P = 0.076$).

During the after-school period, there was no significant difference in the duration of exposure to light levels greater than 1000, 2000, 3000, and 5000 lux between the rural students (0.61 ± 0.33, 0.37 ± 0.21, 0.25 ± 0.16, 0.15 ± 0.10 hours, respectively) and the urban students (0.63 ± 0.28, 0.42 ± 0.21, 0.31 ± 0.18, 0.10 ± 0.08 hours, respectively) ($P > 0.017$ for all).

On the weekend, the rural students spent a significantly longer duration of time in light levels greater than 1000 (1.60 ± 0.97), 2000 (1.04 ± 0.65), 3000 (0.80 ± 0.55), and 5000 lux (0.48 ± 0.40 hours) than urban students (1.09 ± 0.51, 0.64 ± 0.32 , 0.45 ± 0.25 h, 0.25 ± 0.17 hours, respectively, $P < 0.01$ for all).

Comparison of Near Work

As shown in Table 4, in general, there were no significant differences between the two groups of students in the school period with regard to the average distance of near work, the time ratio of near work, and the time ratio of excessively close near work. Nevertheless, the after-school near-work behavior was found to be significantly different between the rural and urban students. Specifically, students in the urban school were found to have a significantly shorter near-work distance (30.94 ± 4.14 vs. 34.81 ± 3.93 cm, $P < 0.001$) and to spend a greater proportion of their time in near work (56% ± 14% vs. 49% ± 14%, $P = 0.010$). Further, a significantly greater proportion of excessively close near work occurred within a distance of less than 30 cm among the urban students (49% ± 13% vs. 40% ± 12%, $P = 0.001$).

On the weekend, the rural students were found to spend a greater proportion of time on near work than

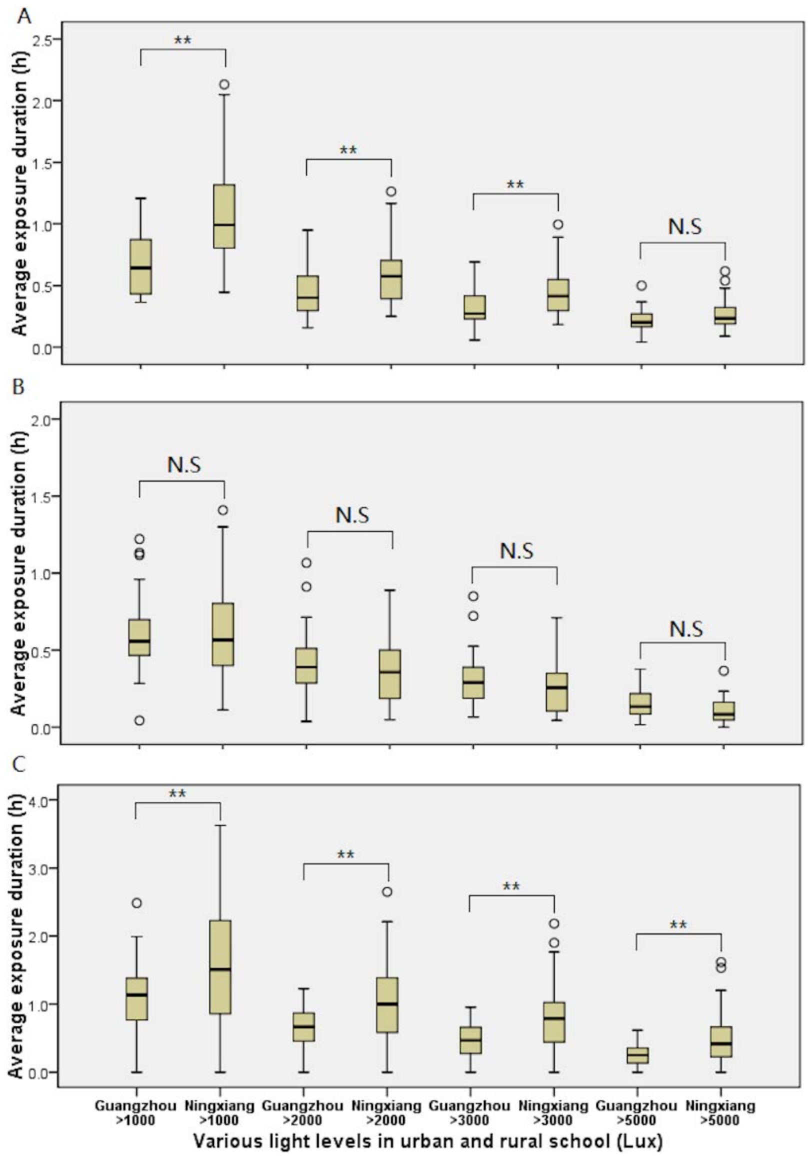

Figure 3. Boxplots showing the distribution of the time spent in various light levels, from >1000 to >5000 lux, in different analysis periods for rural students and urban students. (A) School period, (B) after-school period, (C) weekend days. N.S: not significant, $^{**}P < 0.01$.

the urban ones (49% ± 14% vs. 41% ± 10%, $P = 0.002$), while no significant difference was found in the average distance and in the time ratio of excessively close near work.

With regard to visual habits indicated by the average frequency of continuous near work, no difference was found between the students in the urban and in the rural school for all the analysis periods.

Discussion

Several wearable devices have been previously reported to apply for the measurement of ambient illuminance, such as HOBO,[20] Acit-Watch,[21] and Fitsight.[22] Clouclip; however, is the first device that can measure not only ambient illuminance but also the viewing distance of the wearers. Because Clouclip is clipped to the right arm of the spectacle frame, it is able to measure the illuminance approximately along the visual axis. This position also facilitates the measurement of both metrics simultaneously. Through the data obtained with the device, we found that the environmental risk factors that were measured, light exposure and near work, differed significantly between students from the urban and the rural school.

Table 4. Overview of Near Work Metrics for Urban Students and Rural Students in the Different Analysis Periods

	Weekday		
	School Period	After-School Period	Weekend
Average distance of near work, cm			
Urban students	31.07 (29.53, 33.08)[a]	30.94 ± 4.14[b]	32.69 ± 2.76[b]
Rural students	32.07 (30.15, 33.12)[a]	34.81 ± 3.93[b]	31.89 ± 4.49[b]
P	0.161	<0.001	0.406
Accumulated duration of near work, hr			
Urban students	4.39 (3.81, 4.81)[a]	2.25 ± 0.53[b]	4.59 ± 1.09[b]
Rural students	4.15 (3.76, 4.52)[a]	1.95 ± 0.46[b]	5.25 ± 1.64[b]
P	0.109	0.010	0.152
Time ratio of near work (≤60 cm)			
Urban students, %	59 ± 10[b]	56 ± 14[b]	41 ± 10[b]
Rural students, %	63 ± 10[b]	49 ± 14[b]	49 ± 0.14[b]
P	0.059	0.010	0.002
Time ratio of excessively close near work (<30 cm)			
Urban students	51 ± 11[b]	49 ± 13[b]	49 ± 11[b]
Rural students, %	49 ± 8[b]	40 ± 12[b]	51 ± 13[b]
P	0.193	0.001	0.678
Average frequency of continuous near work			
Urban students	1.55 ± 0.84[b]	0.95 (0.46, 1.27)[a]	2.50 ± 0.50[b]
Rural students	1.42 ± 0.59[b]	0.62 (0.39, 0.99)[a]	2.42 ± 0.37[b]
P	0.139	0.484	0.076

[a] Data are expressed as median (25th percentile, 75th percentile).
[b] Data are expressed as mean ± SD.

With regard to light intensity, the students from the urban school experienced significantly lower levels of light intensity than those in the rural school during both the school period and the weekend days. This indicates that the urban students spent much lesser time outdoors than the rural students. This was supported by the finding that the average daily exposure duration of urban students to high levels of illuminance during these two periods was shorter than that of rural students. In fact, the difference could be even greater, because the rural students spent almost 1 hour less time wearing Clouclip during the school period and the weekend days (Table 2). Even though the measuring technique used was different, these findings are consistent with those of previous studies. A series of studies that used a self-reported questionnaire reported that kids in rural or outskirt areas spent more time outdoors than their counterparts in cities, including Beijing,[23] Xiamen,[5] and Sydney.[24] Another study that used the objective light meters HOBO and Acit-Watch showed that kids in Sydney spent 105 ± 42 min/d, while kids in Singapore spent only 61 ± 40 min/d outdoors.[21]

During the after-school period, no difference was found between the two groups in the average light intensity and the duration of exposure to various light intensities. This might be because the outdoor light intensity had already begun to decrease after school.

Surprisingly, it was observed that students in the urban school experienced a significantly higher light intensity on weekdays than at the weekend, while this was not observed in the case of the students in the rural school. This is contrary to the general picture revealed by previous findings. For example, Dharani et al.[20] found that the average light intensity that students in Singapore were exposed to during the weekdays was 702.87 lux, but it increased to 950.85 lux during the weekends. Further, Read et al.[25] reported that for Australian children aged 10 to 15 years, the average light intensity was 1009 lux on weekdays and 1231 lux on the weekends. Similarly, Verkicharla et al.[20] also showed that in Singapore, the light intensity experienced by children on weekdays was significantly weaker than that on the weekends. The contrasting finding between the present and the previous studies might reflect the highly stressful education system in China. Students in China, especially those from urban areas, commonly attend various classes at private coaching institutes during the weekends and therefore spend lesser time outdoors than they do during the weekdays.

With regard to the near-work metrics, it was not surprising that there was no significant difference between the two groups of students during the school period. This is because the two schools selected, although from different socioeconomic regions, were both typical public primary schools that shared a standard in-school education system. Nevertheless, students in the urban school were found to spend more time in near work during the after-school period, and the time ratio of near work was significantly greater in the urban students. This finding is in alignment with the fact that education pressure and competition in developed areas are usually stronger than that in less-developed areas. That is, students in cities tend to spend more time after school in completing their homework and even attending additional coaching classes.

It was interesting to find that students in the rural school spent a greater ratio of time in near work than the urban ones on the weekend. We assumed that this was because most of the children attending the rural school lived with their grandparents, as their parents were liking to be working in cities. This is a special social phenomenon that is being witnessed in the current economic scenario of unbalanced development in China, and the children of such families have been given the term "stay-at-home children" or "left-behind children." One of the problems associated with this phenomenon is that the supervision of students in rural areas by their grandparents is less effective. As a result, rural children are more likely to be addicted to electronic games on smartphones and tablets on the weekends than urban children who are supervised by their parents. Combined with our previous finding that urban students spent less outdoor time than rural ones, these findings suggest that although Chinese parents are aware that near work may induce myopia, they are still not very well informed about the relatively new concept that lack of outdoor exposure also induces myopia. Thus, it is necessary to raise awareness about the causes of and ways to manage childhood myopia.

Due to the lack of quantification techniques to measure the average distance for near work previously, results from the current study could be compared with those obtained through self-reported data from literature. Lu et al.[26] reported that the habitual distance of near work for adolescents of 15 years was around 32 cm in another rural Chinese area, and Zhang et al.[27] showed that the average distance of near work for adolescents between 12 and 16 years was 29 cm. In the present study, it was also observed a similar level of habitual distance for near work, regardless of whether the students were from urban or rural areas. Although accommodative demand (which is inversely related to the viewing distance) has been suggested to be one of the influential factors that affect myopia development,[28] it seems that there is very little scope in terms of modifying this factor to prevent and inhibit myopia. By contrast, it might be more feasible to modify other near work-related factors, such as the duration and the temporal pattern of near work, or even the contrast polarity of the reading materials.[29]

There are several limitations of the study, which are worth attention and further investigation. First, the study only covered a period of 7 days and a longer observation period might give a picture of the environmental factors occurred in the subjects with more confidence. Nevertheless, students' life style, no matter during or after school, is relatively regular. Therefore, a period of 7 days, including weekdays and weekend days and the encouragement of a maximum wearing duration for each day, is believed to provide enough representative data of interest. Second, given the measurement limit of the imbedded sensor of the device, all the aforementioned analysis of the near work activities was only based on the distance which was less than 60 cm. However, considering the types of near-work activities during the ages when myopia usually develops, this measurement range actually represent the most scenario of relevant activities. Third, given the cross-sectional nature of the study, our findings are unable to illustrate the association between myopia development and environmental factors, neither able to explain the cause of different myopia prevalence among regions. These questions await the AMESC to answer in the future. Last, we found that the ratio of valid subjects in emmetropes was lower than that in myopes, reminding us to modify or optimize the wearable manner of the device (e.g., like as a form of earphone), so that it is more feasible to be applied in the future study.

In summary, based on data obtained from the wearable device Clouclip, we found that in our samples, urban students were exposed to significantly lower light intensity than rural students and also spent less time outdoors on the weekend days than on the week days, probably due to their enrollment in various coaching classes. In addition, urban students were found to spend more time in near work and a higher proportion of this time after school. Based on these findings, different strategies can be considered for the management of childhood myopia in urban and rural areas in China.

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