

Environmental and Behavioral Factors with Refractive Error in Israeli Boys

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SIGNIFICANCE: Evidence supporting the contributions of near work in myopia is equivocal. Findings from this pilot study suggest that a high prevalence of myopia in ultra-Orthodox boys may be attributed to intense near work at school and learning to read in preschool at an early age.

PURPOSE: This study aimed to assess factors that may influence myopia in three groups of Jewish boys with different educational demands.

METHODS: Healthy ultra-Orthodox, religious, and secular Jewish boys (n = 36) aged 8 to 12 years participated. Refractive status, education, time spent reading and writing, and electronic device use were assessed using a questionnaire, and time outdoors and physical activity were assessed objectively using an Actiwatch. Data were analyzed with χ^2 and Kruskal-Wallis tests with Bonferroni post hoc comparisons.

RESULTS: Ultra-Orthodox (n = 14) and religious (n = 13) children had greater myopia prevalence compared with secular children (n = 9; $P = .01$), despite no differences in parental myopia. Actigraph data showed that there were no differences in activity ($P = .52$) or time spent outdoors ($P = .48$) between groups. Ultra-Orthodox children learned to read at a younger age and spent more hours at school ($P < .001$ for both). All groups engaged in a similar amount of near work while not in school ($P = .52$). However, ultra-Orthodox boys had less electronic device use than did religious ($P = .007$) and secular children ($P < .001$).

CONCLUSIONS: This pilot study demonstrates that ultra-Orthodox, religious, and secular children have distinct educational demands but similar time outdoors, physical activity, and near work while not in school. The findings suggest that near work at school and/or learning to read in preschool at an early age may contribute to previously reported differences in refractive error between groups. However, conclusions should be confirmed in a larger sample size.

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Myopia is an epidemic, with a growing prevalence in Israel,¹ urban Eastern Asian countries,^{2–4} the United States,⁵ and other non-Asian countries.⁶ The prevalence of high myopia (>5 D) is also growing, with a reported eightfold increase from the 1970s to the 2000s.⁷ Estimates predict that, by 2050, approximately 50% of the global population will be myopic.⁸ Refractive development is regulated by a complex interaction between genetic, environmental, and behavioral factors.^{9,10} Parental myopia is a strong risk factor for the development of myopia.¹¹ However, despite recent success in identifying genetic variants associated with myopia, the rapid increase in prevalence is beyond what genetics alone can account for, which suggests that other factors, such as environment and behavior, may also contribute to the increasing prevalence. Accumulating evidence suggests that outdoor time is protective against myopia onset and progression, although studies have reported conflicting findings.^{12–15} Other potential myopiagenic factors include near work, physical activity,^{16,17} and use of screen devices.^{16,18,19} However, evidence regarding the roles of these factors is equivocal.^{11,20,21}

The Israeli Jewish male population provides a unique opportunity to study the contributions of genetic, environmental, and behavioral

factors in the etiology of myopia owing to known differences in myopia prevalence among different groups and diverse behaviors,^{22,23} combined with the genetic homogeneity of Israeli Jews. The Jewish people share genetic homogeneity because of their unique history. Since their emergence as a national and religious group in the Middle East more than 2000 years ago, Jews have maintained continuous cultural and religious traditions amid a series of diasporas including the traditions of intracommunity and consanguineous marriage.²⁴ This continued in Israel, albeit to a smaller extent, in recent years.²⁵ By taking advantage of this naturally occurring homogenous population, the impact of genetics is minimized, and focus can be placed on behavioral differences in various subgroups. A large population-based survey of 17-year-old Israeli Jewish boys demonstrated that ultra-Orthodox and religious boys have a higher prevalence of myopia (82.2 and 50.3%, respectively) compared with secular boys, with a prevalence (29.7%) similar to the global average.¹ This divergent rate of myopia in different populations of Israeli boys has been reported in several studies^{1,23,26} and is thought to be a result of the study habits of Jewish boys rather than genetic factors.

The educational systems and lifestyles are very different among ultra-Orthodox, religious, and secular populations in Israel. Ultra-Orthodox Jews have an educational system for boys that is known to involve intensive sustained near-work activity beginning at a young age. In addition, ultra-Orthodox, religious, and secular Jewish leaders have differing attitudes toward the use of electronic devices, which may also impact myopiagenic exposures.

Although evidence is increasing that environmental and behavioral factors influence myopia, the contributions of each factor and associations between them remain elusive. Investigating the study habits, traditions, and variable use of electronic devices of different Jewish populations in Israel allows us to elucidate key environmental and behavioral influences in myopia. These distinct groups of Israeli Jews have been studied previously using questionnaires²⁷; however, objective measurements of light exposure and physical activity, along with assessment of electronic device use with respect to refractive error, have not been performed. This pilot study aimed to objectively quantify outdoor light exposure and physical activity, as well as subjectively quantify near-work behaviors while not at school, in three populations of Israeli Jewish boys, ultra-Orthodox, religious, and secular. Objective measurements using the Actiwatch (Philips Respironics, Bend, OR)^{13,28–30} were used to assess time outdoors and physical activity, and an adaptation of the University of Houston Near Work, Environment, Activity, and Refraction Survey³¹ was used to assess ocular history, parental myopia, education, and behaviors while not at school, such as near work and use of electronic devices.

METHODS

Male children aged 8 to 12 years were recruited from urban areas in central Israel via word of mouth and advertisements posted at the Hadassah Academic College clinic and on social media. All parents provided written permission, and children provided assent. The study was approved by the ethics committee of Hadassah College and followed the tenets of the Declaration of Helsinki.

Healthy children with best-corrected visual acuity of 6/9 or better were included. Children were classified as ultra-Orthodox, religious, or secular based on the educational system at which they studied. Exclusion criteria included any anterior or posterior segment disease or pathology, such as strabismus and amblyopia; a history of ocular trauma or surgery causing abnormal vision; systemic diseases known to affect refractive error; contraindications to the use of dilation drops, such as a narrow anterior chamber angle; and a history or current use of any myopia control treatment.

The recruitment strategy used was to bring in one child of similar age (± 6 months) from each group (ultra-Orthodox, religious, and secular) each week to match for age, daylight hours, and weather. However, sometimes scheduling constraints on the part of parents resulted in rescheduling or canceling participation in the study. Furthermore, the data from six children were excluded for not meeting the inclusion criteria. Thus, matching for age was by frequency,³² which was possible with such a small sample size owing to the narrow age range.

Objective Measurements

An Actiwatch Spectrum (Philips Respironics, Bend, OR) was dispensed for subjects to wear continuously for 5 to 13 days. The Actiwatch Spectrum is a noninvasive wrist-worn device that measures ambient light exposure and physical activity continuously at 32 Hz. The device has been described in detail previously and is

actively used in both children and adults in various applications, including sleep-related studies³³ and, more recently, myopia-related studies.^{13,28–30,34} The light sensor in the Actiwatch Spectrum consists of light-sensitive photodiodes to measure illuminance of white light in units of lux (range, 0.1 to 200,000 lux). Physical activity is measured via a solid-state piezoelectric accelerometer and is expressed in counts per minute. The device displays the time and date, and a sensor detects “off-wrist” time to monitor subject compliance.

In this study, the Actiwatch was configured to average data over 1-minute epochs. Children were instructed not to remove the device for the entire measurement period and to take care not to cover the device with shirt sleeves or coats. Light exposure and activity counts were included in the analysis only when the subject wore the device for the entire day. Therefore, partial first and last days were excluded. Days were also excluded if the subject removed the device for more than 30 minutes, or if the light exposure dropped to zero for 30 minutes or more during daylight hours, indicating that the sensors on the device were obstructed by clothing. Mean daily activity was calculated by averaging counts per minute for the hours the subject was awake. Activity and light parameters were adapted from previous validation studies using a similar wrist-worn Actiwatch accelerometer in children. Minutes exposed to >1000 lux was used as an approximation for time spent outdoors during daylight hours.^{28,35} Children were dispensed watches only while school was in session, and holiday breaks were avoided. Only data from children who wore the Actiwatch for at least three weekdays were included in the analysis.

Daily duration of Jerusalem daylight was determined from timeanddate.com,³⁶ and daily temperature and rainfall were obtained from the Israel Government Portal for National Meteorological Service.³⁷ Mean daylight duration, temperature, and rainfall were assessed for potential differences between the three groups for the specific period each child wore the device.

Questionnaire

Parents completed a modified University of Houston Near Work, Environment, Activity, and Refraction Survey. This survey includes questions regarding demographics, ocular history, education, and behavioral factors that cannot be determined from the objective methods used in this study. Refractive status (myopic or nonmyopic) of the parents and children was determined from the questionnaire; this method has been shown to have reasonable sensitivity and specificity for determining whether subjects aged 14 to 85 years are myopic.³⁸ The refractive status was validated for 29 of 36 children for whom refraction was performed (cycloplegic where possible). Thirteen children's parents reported that they had glasses for distance. Of these, 11 were examined and confirmed to have myopia. Refraction was not possible for the remaining two children. Twenty-three children's parents reported that they did not wear glasses. Of these, 18 were examined. Emmetropia was confirmed in 14 children, and 4 children were found to be myopic (cycloplegic refraction, -0.75 to -4.3 D) and thus classified as myopic. Refraction was not available for seven children: four ultra-Orthodox, two religious, and one secular. To determine the number of parents with myopia, parents were asked whether the biological mother and father wore glasses and, if so, whether the glasses were for near, distance, or both.

Survey items related to education and near work included age at which the child learned to read, number of hours spent in school per day, grades in school, and daily time spent while not in school

engaged in near work and using electronic devices. The survey was adapted to reflect the Israeli culture (Appendix 1, available at <http://links.lww.com/OPX/A503>) and translated into Hebrew. For behavioral measures, parents were asked to estimate time spent in various activities for weekdays (while not at school) and for Shabbat. In Israel, the week is divided into weekdays (Sunday through Friday afternoon) and Shabbat (Friday evening through Saturday), reflecting school days and nonschool days, respectively. Shabbat was assessed independently because ultra-Orthodox and religious Jews have traditions on the Shabbat that are significantly different from the secular group and may impact myopiagenic exposures. The Jewish Shabbat begins at sundown on Friday and concludes an hour after sunset on Saturday night. Shabbat observance includes special prayer services in the synagogue, family time, and religious studies.³⁹ Shabbat-observant Jews refrain from specific actions such as writing, going to work, riding in a car, and using electric appliances and devices.⁴⁰ Secular Jews typically do not refrain from these activities but are on break from school and work.

Data Analysis

Mean daily behavior from both the questionnaire and Actiwatch data was analyzed separately for weekday (Sunday to Friday) and Shabbat. Mean daily behavior for the entire week was calculated using Equation 1.

Mean daily behavior for the week

$$= ((6 \times \text{mean of weekdays}) + (\text{mean of Shabbat}))/7 \quad [1]$$

Objective data derived from the Actiwatch were analyzed using the device software (Actiware 6.0.9; Philips Respironics), which uses algorithms to determine daily light exposure and active and rest times. Mean daily light exposure (in lux), hours spent outdoors (>1000 lux), and mean daily activity (in counts per minute) were calculated for each subject for weekdays, for Shabbat, and for the whole week (Equation 1). Mean hourly activity (in activity per minute) and the mean hourly light exposure (in lux) were calculated across 24 hours a day for weekdays, for Shabbat, and for the entire week for the three groups of children.

Subjective data derived from the University of Houston Near Work, Environment, Activity, and Refraction Survey were analyzed for demographics, parental myopia, ocular history, education, and time spent engaged in different distances of near work and use of electronic devices while not in school. The questionnaire included three types of outcomes: (1) continuous variables such as the child's age, age the child started to learn to read, and hours per day spent in school; (2) categorical variables such as sex, type of school, grades, and type of optical correction; and (3) categorical variables with fixed intervals on a linear scale to estimate time spent in various activities, which were indicated in 1 hour bins. A calculation was done to convert the categorical bins into continuous variables by taking the midpoint of each bin. For example, 0 to 1 hour was considered to be 0.5 hours, 1 to 2 hours was considered to be 1.5 hours, and so on.

Near work included activities known to generally be performed at distances less than 40 cm,³¹ including reading printed text (prayer books, regular books, homework, newspaper, and magazines), writing, drawing, and using handheld electronic devices (smartphone, tablet, kindle, and handheld video games). Intermediate work included activities performed at 40 to 100 cm, including card

games, board games, and computer use.³¹ Far work included activities performed at distances greater than 100 cm, including watching television and playing console video games.³¹ In addition, time that was not spent in school, in performing near or intermediate work outside of school, or in sleep was categorized as far viewing to sum up to 24 hours.

Statistics

Statistical analysis was performed using SPSS version 25 (IBM Corp., Armonk, NY). The χ^2 test was used to evaluate differences between the three groups of children for the refractive error group and parental myopia. Kruskal-Wallis test was used to evaluate the differences between the three groups of children for weather parameters during the observation period (day length, rainfall, and temperature), age, education, objectively measured physical activity, light exposure, and time outdoors, as well as subjectively reported time per day of different types of near work and use of electronic devices. The normality assumption of repeated-measures ANOVA was evaluated using the Shapiro-Wilk test and was not met. Thus, the Kruskal-Wallis test was used to assess objectively measured activity and outdoor light exposure at each hour of the day for weekdays, Shabbat, and the total for the week across the three groups of children.

The correction for multiple comparisons is a topic of controversy and has been covered in many reviews.^{41–43} According to Armstrong⁴¹ in an invited review, whether to use a correction for multiple comparisons in optometry research depends on the circumstances of the study. Using the criteria in that review,⁴¹ the circumstances of the current study do not dictate the need for correction for multiple comparisons. The aim of this pilot study was to compare environmental and behavioral factors between groups of children so as to use the results to plan future investigation. Thus, it is imperative not to make a “type II” error (real differences not detected) by the application of a correction of multiple comparisons such as the Bonferroni correction. Furthermore, the results of individual comparisons are of interest in this study. Therefore, only post hoc Bonferroni-corrected pairwise comparisons were applied to identify statistical differences for the Kruskal-Wallis tests. $P \leq .05$ was considered statistically significant.

RESULTS

Data from 36 boys (mean \pm standard deviation age, 9.9 \pm 0.8 years) who successfully wore the watches between June 2019 and March 2020 were included in this study. Data from six boys were excluded: four ultra-Orthodox children who had several days with >30 minutes of time in which the Actiwatch was off-wrist, and thus, less than three weekdays were recorded; one religious child because of a malfunction in the Actiwatch; and one secular child who was sick at home during the entire week he had the watch.

Meteorological data, including average hours of daylight, temperature, and rainfall, for the days that the children in each group wore the Actigraph showed that there were no statistical differences observed between any of the groups (Table 1). Thus, no significant differences were observed between the groups for hours of daylight and weather.

Age, refractive error group, parental myopia, and education metrics, as derived from the questionnaire, are shown in Table 2. Mean age was similar across the three groups ($P = .09$). There

TABLE 1. Meteorological data

	Ultra-Orthodox (n = 14)	Religious (n = 13)	Secular (n = 9)	P
Day length (h)	13.13 ± 1.40	12.47 ± 1.67	12.08 ± 1.02	.41
Range	10.15–14.22	10.25–14.22	10.15–14.20	
Maximum daily temperature (°C)	26.25 ± 8.18	21.76 ± 9.53	24.69 ± 7.91	.14
Range	6.70–36.10	4.8–35.40	4.90–35.40	
Rainfall (mm/d)	1.35 ± 5.03	2.68 ± 6.34	1.64 ± 5.44	.63
Range	0.00–34.30	0.00–26.50	0.00–26.50	

P values are shown for the Kruskal-Wallis test between groups. Mean ± standard deviation day length (in hours), temperature (in degree Celsius), and rainfall (in millimeters per day) during the observation period are shown for ultra-Orthodox (n = 14), religious (n = 13), and secular (n = 9) groups.

was a significant difference in the percentage of myopic children in each group, with the ultra-Orthodox and religious groups having more myopic children than the secular group ($P = .02$). A similar number of children in each group had zero, one, or two myopic parents ($P = .48$).

There was a significant difference in the age that the groups learned to read ($P < .001$). Post hoc pairwise comparisons showed that ultra-Orthodox children learned to read significantly earlier than did religious children ($P = .002$) and secular children ($P < .001$). The ages that religious and secular children learned to read were not significantly different from each other ($P = .38$). There was a significant difference in mean daily hours spent in school ($P < .001$). Post hoc pairwise comparisons showed that ultra-Orthodox children spent significantly more hours at school than secular children ($P < .001$) but not different from religious children ($P = .08$). Religious and secular children spent similar hours at school ($P = .34$). School performance (parent-reported grades) in school was similar across groups ($P = .47$). The questionnaire showed that children lived in different neighborhoods, suggesting that they went to different schools.

All objectively measured and parent-reported times spent in various activities are shown in Table 3. Physical activity, time outdoors, and mean daily light exposure were derived from the Actiwatch. All children were compliant in wearing the Actiwatch; however, four ultra-Orthodox children removed the Actiwatch on Shabbat (approximately 1 hour before sunset on Friday until 1 hour after sunset on Saturday) for religious reasons. On average, children wore the Actiwatch for 8.8 ± 1.9 days (range, 5 to 13 days). For all children, mean daily physical activity for the entire week was 574 ± 125 counts per minute (range, 382 to 807 counts per minute). Mean daily time spent outdoors for the entire week was 2.3 ± 1.3 hours (0.3 to 5.5 hours), and mean daily light exposure was 2319 ± 2365 lux (103 to 10,902 lux). There were no statistically significant differences between groups for mean daily physical activity (Fig. 1A), time spent outdoors (Fig. 1B), or daily light exposure on weekdays, Shabbat, or total for the week ($P > .05$ for all).

Activity and light exposure across 24 hours for weekdays, Shabbat, and total for the week between the three groups of children are shown in Fig. 2. No significant differences were observed

TABLE 2. Age, refractive characteristics, and educational milestones of subjects

	Ultra-Orthodox (n = 14)	Religious (n = 13)	Secular (n = 9)	P
Age (y)	9.8 ± 0.8	10.2 ± 0.8	9.6 ± 0.5	.09
Range	8.5–12.0	9.0–11.0	9.0–10.0	
Nonmyopes/myopes	4:10	7:6	8:1	.02
Parental myopia (0, 1, or 2 myopic parents)				
0	7%	23%	33%	.48
1	36%	31%	11%	
2	57%	46%	56%	
Father myopia	86%	62%	67%	.34
Mother myopia	64%	62%	56%	.92
Age learned to read (y)	4.3 ± 0.8	5.6 ± 0.5	6.2 ± 0.4	<.001
Range	3.0–6.0	5.0–6.0	6.0–7.0	
Mean daily time at school (h)	7.6 ± 0.8	6.9 ± 1.7	5.9 ± 0.9	.001
Range	6.0–9.0	5.0–12.0	5.0–8.0	
Grades at school	92.1 ± 6.1	88.9 ± 9.6	88.3 ± 10.0	.47
Range	75–95	65–95	65–95	

P values are shown for the Kruskal-Wallis or χ^2 test between groups. Mean ± standard deviation age, refractive error group, parental myopia, and education are shown for ultra-Orthodox (n = 14), religious (n = 13), and secular (n = 9) children.

TABLE 3. Objectively measured and parent-reported behaviors

	Ultra-Orthodox (n = 14)	Religious (n = 13)	Secular (n = 9)	P
Physical activity (mean daily counts per minute)				
Weekday	572 ± 124	559 ± 116	548 ± 128	.85
Range	406–796	378–731	400–775	
Saturday	583 ± 145	679 ± 223	514 ± 220	.21
Range	396–875	350–1108	255–809	
Weekly total	600 ± 122	576 ± 122	544 ± 138	.52
Range*	460–807	382–751	383–777	
Daily light exposure (lux)				
Weekday	2292 ± 1874	2513 ± 2984	1431 ± 1384	.52
Range	220–6736	177–9066	116–3874	
Saturday	1325 ± 919	3465 ± 6158	2354 ± 3137	.89
Range	271–3208	83–22,771	33–9178	
Weekly total	2579 ± 1570	2619 ± 3228	1596 ± 1569	.37
Range*	311–5899	166–10,902	103–4100	
Time outdoors (h/d)				
Weekday	2.29 ± 1.14	2.38 ± 1.58	1.77 ± 1.05	.47
Range	0.78–3.66	0.42–5.19	0.36–3.26	
Saturday	1.82 ± 0.64	3.29 ± 2.46	2.25 ± 2.23	.34
Range	0.88–2.61	0.13–8.00	0.03–5.48	
Weekly total	2.44 ± 0.94	2.52 ± 1.57	1.85 ± 1.18	.48
Range*	0.88–3.41	0.40–5.53	0.32–3.53	
Near work <40 cm (h/d)				
Weekdays	2.71 ± 2.28	2.69 ± 1.89	2.72 ± 1.39	.79
Range	0.50–9.00	0.50–5.50	1.00–5.50	
Shabbat	2.36 ± 1.29	1.81 ± 1.11	2.44 ± 1.42	.42
Range	0.50–3.50	0.50–3.50	0.50–5.50	
Weekly total	2.66 ± 2.04	2.57 ± 1.68	2.68 ± 1.35	.76
Range*	0.50–5.21	0.64–5.21	0.93–5.50	
Intermediate near work 40–100 cm (h/d)				
Weekdays	1.04 ± 1.26	2.35 ± 2.02	1.83 ± 1.44	<.03
Range	0.00–5.00	0.50–7.50	0.50–5.00	
Shabbat	0.96 ± 1.42	1.65 ± 0.92	2.33 ± 1.60	<.01
Range	0.00–5.50	0.50–3.50	0.00–5.00	
Weekly total	1.03 ± 1.17	2.25 ± 1.74	1.90 ± 1.42	<.02
Range*	0.07–4.50	0.64–6.50	0.43–5.00	
Far viewing (television) >100 cm (h/d)				
Weekdays	0.04 ± 0.13	0.81 ± 0.99	1.83 ± 1.0	<.001
Range	0.00–0.50	0.00–3.50	0.50–3.50	
Shabbat	0.00 ± 0.00	0.04 ± 0.14	2.28 ± 1.20	<.001
Range	0.00–0.00	0.00–0.50	0.50–3.50	
Weekly total	0.03 ± 0.11	0.70 ± 0.85	1.90 ± 0.90	<.001
Range*	0.00–0.43	0.00–3.00	0.64–3.50	
Electronic device use including handheld devices, computers, and television (h/d)				
Weekdays	0.6 ± 0.7	3.2 ± 3.2	4.8 ± 2.4	<.001
Range	0.0–2.0	0.5–10.5	2.5–10.5	
Shabbat	0.1 ± 0.3	0.2 ± 0.4	5.4 ± 3.2	<.001
Range	0.0–1.0	0.0–1.5	1.5–10.5	
Weekly total	0.6 ± 0.6	2.9 ± 2.7	4.7 ± 2.1	<.001
Range*	0.0–1.7	0.6–9.0	2.4–9.3	

P values are shown for the Kruskal-Wallis test across groups. *Because the weekly total is based on Equation 1, the range is different from the range in weekday/Saturday. Objectively measured mean ± standard deviation daily physical activity (in counts per minute), mean daily light exposure (in lux), and time outdoors (hours) and parent-reported children's mean daily near work time (in hours) for near, intermediate, and far viewing, as well as electronic device use (in hours) for ultra-Orthodox (n = 14), religious (n = 13), and secular (n = 9) groups during weekdays, on Shabbat, and for the week.

for most hours of the day. In general, ultra-Orthodox children tended to be more active at night compared with religious and secular children; these differences were greatest on Shabbat (Kruskal-Wallis test). Although ultra-Orthodox boys also had more light exposure a night, it was less than 1000 lux and thus not likely to influence myopia development.

Percentages of time spent in school; near, intermediate, and far viewing while outside of school; and sleep, as derived from the questionnaire, are shown for the three groups of children in Fig. 3. Mean daily near work while not in school is shown in Fig. 1C. Mean daily hours spent engaged in near work as estimated by parents was similar across the groups for weekdays ($P = .79$), Shabbat ($P = .42$), and the whole week ($P = .76$). However, the type of near work differed significantly. The secular boys spent significantly more time using handheld electronic devices, whereas the ultra-Orthodox kids spent significantly more time reading printed material and writing (Appendix Table A1, available at <http://links.lww.com/OPX/A504>).

Mean daily hours spent engaged in intermediate distances (Fig. 1D) showed significant differences between the groups of children for weekdays ($P = .03$), Shabbat ($P = .01$), and the whole week ($P = .01$). Post hoc analysis showed that on Shabbat the secular boys spent significantly more time than ultra-Orthodox engaged in intermediate viewing ($P = .02$), and for the whole week, the religious boys spent more time than ultra-Orthodox in intermediate viewing ($P = .03$). All other comparisons did not reach significance.

Mean daily hours spent engaged watching television at a far distance (Fig. 1E) showed significant differences between the groups of children for weekdays ($P < .001$), Shabbat ($P < .001$), and the whole week ($P < .001$). Post hoc analysis showed that, for weekdays, the ultra-Orthodox boys spent significantly less time watching TV than did the secular and religious boys ($P < .001$ and $P = .04$, respectively). As expected, on Shabbat, the secular boys watched significantly more TV than did the religious and ultra-Orthodox boys ($P < .001$, for both). For the whole week, the same pattern was observed as for Shabbat ($P < .001$ and $P = .04$ for ultra-Orthodox and religious boys, respectively).

The use of all electronics, including handheld devices, computers, and television, was also analyzed as a separate category despite different viewing distances because it has been considered as a distinct category in the etiology of myopia (Fig. 1F). Electronic device use, as estimated by parents, was significantly different across groups for weekdays, Shabbat, and mean daily use for the week ($P < .001$ for all). During weekdays, ultra-Orthodox children had significantly less time using electronics than did religious boys ($P = .01$) and secular boys ($P < .001$), whereas time was similar between religious and secular children ($P = .29$). However, on the Shabbat, ultra-Orthodox and religious children had similar electronic device use ($P > .99$), which was significantly less than secular children ($P < .001$ for both). Considering mean daily electronic device use for the entire week, ultra-Orthodox children had significantly less time than did religious ($P = .01$) and secular ($P < .001$) children, whereas time was similar between religious and secular children ($P = .28$).

DISCUSSION

This pilot study conducted in Israel examined daily behaviors of ultra-Orthodox, religious, and secular boys. Ultra-Orthodox Jewish

boys learn to read at a younger age than religious and secular Jewish boys and spend more hours at school than secular boys; however, their near work outside of school, at less than 40 cm, is not significantly different from the other groups. All groups of boys demonstrated similar amounts of physical activity, light exposure, and time outdoors and a similar amount of sleep. The major behavioral difference between the boys while not in school, as reported by their parents, was in far work in front of television monitors and overall use of electronic devices. The secular boys watched significantly more television and spent significantly more time using electronic-viewing devices (TV, computer, and handheld devices) than did the other groups.

There was a higher percentage of myopic children in the ultra-Orthodox and religious groups compared with the secular group. However, all three groups had similar numbers of parents with myopia. These findings implicate the different educational systems and the age the children started reading as main contributors to observed differences in myopia prevalence among these three groups. Previous studies have shown that ultra-Orthodox males in Israel are significantly more myopic than religious or secular males.^{1,23,26} The authors hypothesized that the diverse educational systems contributed to the different rates of myopia, most likely because of near-work demands of the various systems. However, this has not yet been tested in a systematic manner. The current study provides the first assessment of both education and objective data characterizing physical activity, light exposure, and time outdoors in these groups of children and supports the hypothesis of the previous studies.

Research investigating the role of near work and myopia was spurred, in part, by early studies reporting an increased prevalence of myopia in Orthodox males.²² Associations between near work and myopia persisted even after adjustment for sociodemographic factors.¹ Although these studies provide evidence of independent associations between educational systems and myopia, further research is needed to understand the contributions of various environmental and behavioral factors. In the current study, given the diverse educational patterns between groups and lack of significant differences for near work while not at school, physical activity, and time outdoors, findings implicate the educational system as a main contributing factor to the increased prevalence of myopia found in ultra-Orthodox boys.^{1,23,26} However, a larger sample size is needed to unequivocally confirm this hypothesis.

The methodology used in the current study did not aim to characterize near-work behavior while the children were in school. However, there are many indications that the near-work demands vary between the school systems of the different groups of children. The curriculum and study habits for ultra-Orthodox boys are distinctly different from other groups in Israel, including ultra-Orthodox girls and religious and secular girls and boys. Ultra-Orthodox boys begin school at age 3 years and are immediately taught to read. From this point and on, their curriculum primarily focuses on Jewish religious texts such as the Hebrew Bible, Talmud, and religious codes. Most of this time is spent in reading and discussing the texts. The texts are characterized by different sizes of print side by side. Whereas the print of the main text is of normal size, the commentaries are often in smaller and different font; letters in the commentaries may be as small as 1 mm in height.⁴⁴ Secular and religious children in Israel, as well as ultra-Orthodox girls, learn to read in first grade (age of 6 years) and have a more traditional curriculum that includes math and science.⁴⁵ Religious girls and boys, as well as ultra-Orthodox girls, study longer hours than do secular girls and boys, spending several

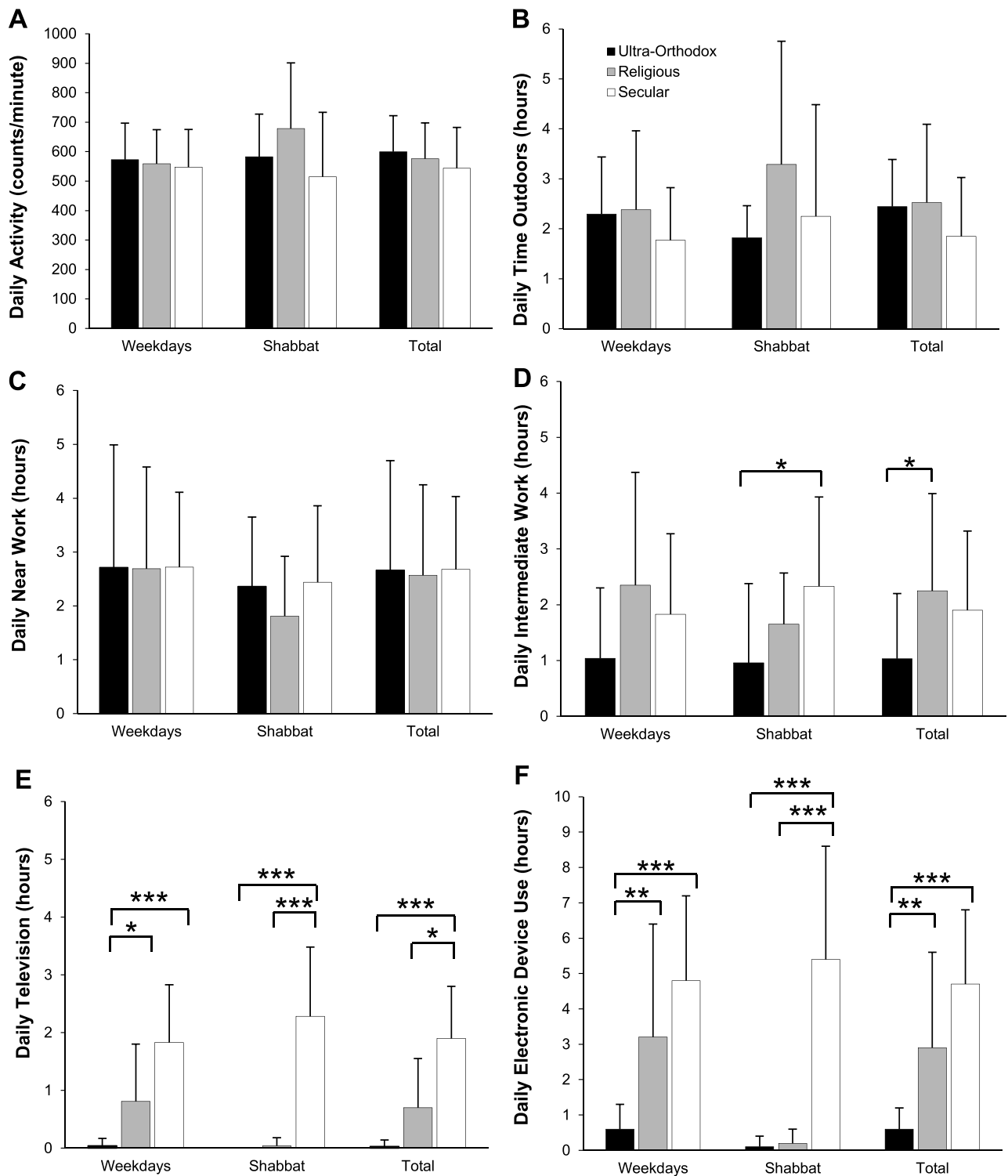


FIGURE 1. Environmental and behavioral measures. Mean \pm standard deviation daily (in hours) physical activity (A), time outdoors (B), near work (approximately <40 cm; C), and intermediate work (approximately 40 to 100 cm; D), television (far work; E), and all electronic device use (F) are shown for weekdays, Shabbat, and the whole week for ultra-Orthodox (filled bars), religious (gray bars), and secular (open bars) children; * $P < .05$, ** $P < .01$, *** $P < .001$ for Bonferroni-corrected post hoc pairwise comparisons.

additional hours a week studying the Jewish religious texts mentioned previously.⁴⁴ The results of the questionnaire used in this study reflect these divergent study habits, with parents reporting

that ultra-Orthodox boys learned to read at a significantly younger age than did religious and secular boys and spend significantly longer days at school than do the secular boys. These characteristics

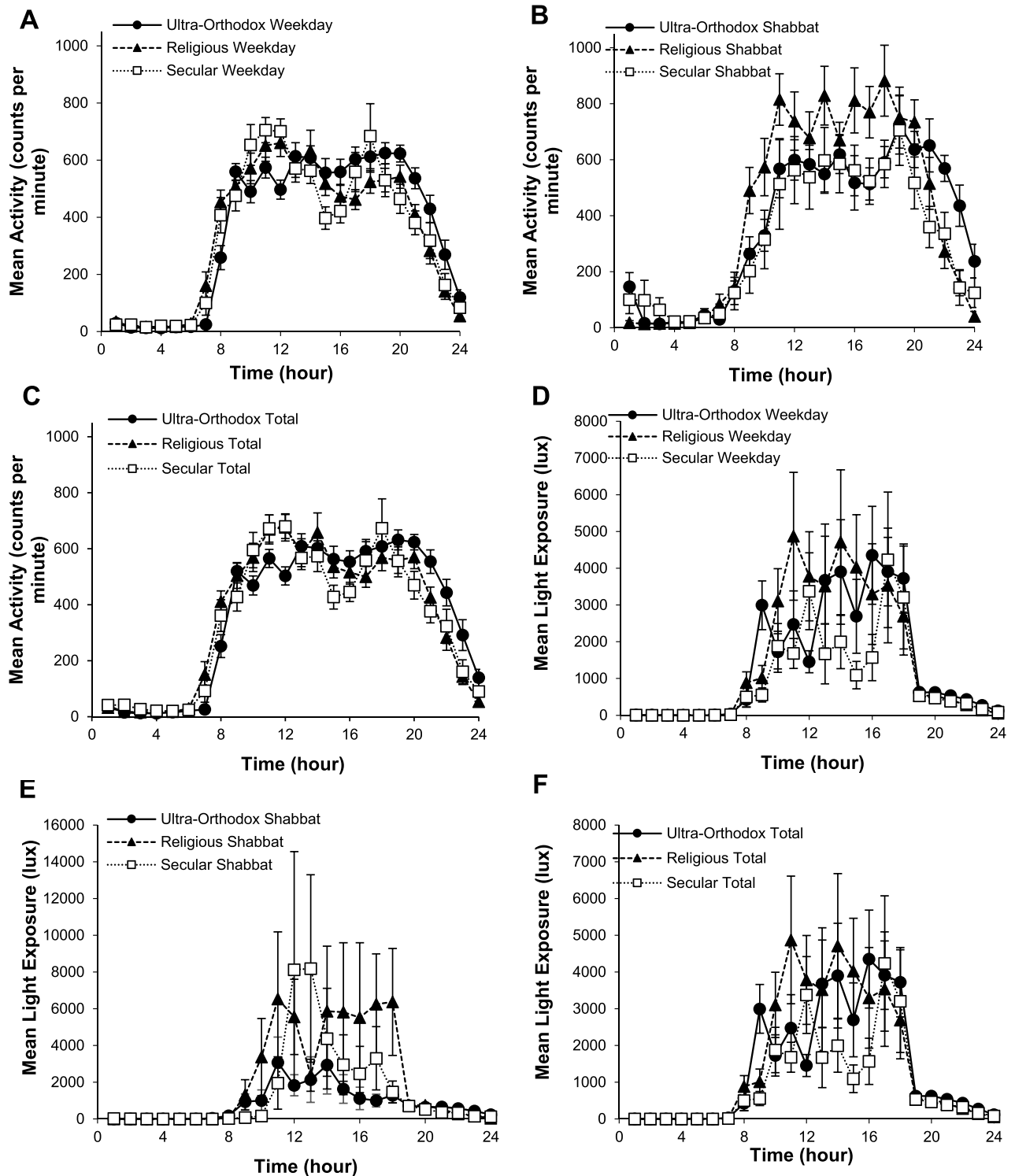


FIGURE 2. Objectively measured activity and light exposure across 24 hours. Mean \pm standard error activity (in counts per minute) across 24 hours for weekdays (A), Shabbat (B), and total for the week (C), and mean light exposure (in lux) across 24 hours for weekdays (D), Shabbat (E), and total for the week (F) for ultra-Orthodox (filled circles), religious (filled triangles), and secular (open squares) children; *Significant difference between ultra-Orthodox and religious children. †Significant difference between ultra-Orthodox and secular children. ‡Significant difference between religious and secular children.

of the educational systems, taken together with the results from the current study regarding behavior at home, suggest that the near work performed by ultra-Orthodox boys at school from a young

age (preschool) may lead to the high prevalence of myopia found in this group at the end of high school.¹ However, this study did not address time outdoors during preschool years. Thus, it may be

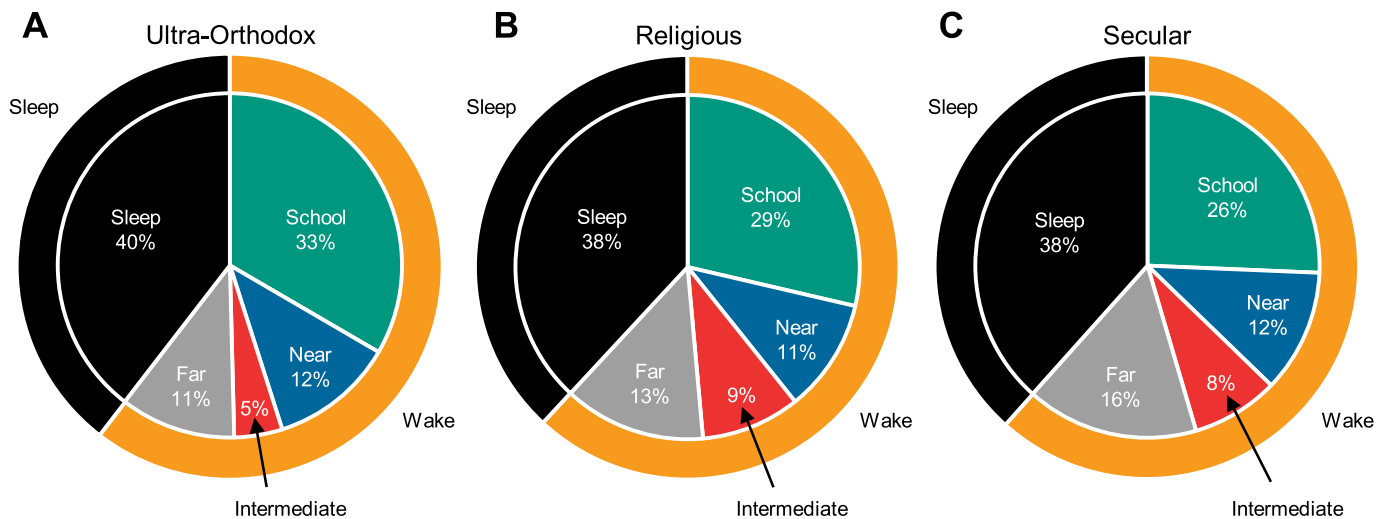


FIGURE 3. Parent-reported daily behaviors across 24 hours. Wake period is shown in gold and sleep period in black. Wake is further divided into the percentage of the day spent in school (seafoam) and outside of school performing near work (blue), intermediate work (red), and far viewing (gray) for ultra-Orthodox (A), religious (B), and secular children (C).

the lack of time outdoors, early reading, or a combination of both factors that lead to the high prevalence of myopia in ultra-Orthodox adolescent boys. A future study with a larger sample size may be able to evaluate the contribution of these factors.

The focus on near work performed at distances less than 40 cm was based on recent research that suggests that the absolute viewing distance of near work is important for myopia onset and progression. The Myopia Investigation Study in Taipei,⁴⁶ a population-based cohort study of 9- to 11-year-olds, found that children with near-work distance <30 cm had significantly more myopic progression. Similar results were found by Yao et al.,⁴⁷ in aviation cadets. In Polish schoolchildren aged 6 to 18 years, reading and writing led to a higher prevalence of myopia.⁴⁸ Guo et al.⁴⁹ found that longer time at near work at shorter distances was associated with an increasing risk of myopia in children. Some of these studies also found that the duration of the near work without viewing breaks is also a risk factor for myopia onset and progression.^{46,47,49} However, the current study did not assess absolute working distance or viewing breaks.

Accumulating evidence shows that increased time in outdoor light is protective for myopia onset and, in some studies, progression.^{15,50} Contrary to our original hypothesis, all three groups of children in this study demonstrated similar daily time outdoors, as measured objectively and continuously for 1 week. However, we found that ultra-Orthodox children started school and learned to read at a younger age than did secular and religious kids. It can be hypothesized that the ultra-Orthodox children were indoors more often and performing near work in their early years, thus leading to myopia. In contrast, the secular children prevented myopia onset by spending more time outdoors at an early age.

The children in this study spent 111 to 151 min/d outdoors, which is greater than previous reports in children from other countries using similar objective methodology. For example, a previous study showed that children in Australia spent a mean daily time of 105 minutes outdoors, and children in Singapore spent 61 minutes outdoors.³⁰ The authors concluded that the decreased time outdoors in Singaporean children contributed to a potentially increased risk

of more rapid eye growth and myopia, as supported by the higher prevalence of myopia noted in large-scale epidemiological studies in Singaporean children.⁵¹ Compared with children in Australia and Singapore and previous reports from the United States (approximately 92 minutes outdoors per day),²⁹ all three groups of Israeli children spend more time outdoors, with a mean of 139 min/d across groups. In accordance with the time spent outdoors, mean daily light exposure in Israeli children (2319 lux) was greater than that reported in Australian children in Queensland (1072 lux)¹³ and American children in Texas (1627 lux).²⁹ Given the relatively high amount of time spent outdoors by all groups of children in Israel, it is possible that the protective effects of time outdoors reached a ceiling effect; that is, after more than so many minutes outdoors, additional time does not offer additional benefit, and other factors, such as near work, override the protective effects of outdoor time. Indeed, the authors of a meta-analysis of outdoor light exposure at school recommended that ≥ 120 min/d may be the most effective intervention.⁵² Furthermore, a meta-analysis of time spent in outdoor activities in relation to myopia prevention and control found a dose-response relationship for the risk of myopia approaching an asymptote at approximately 90 min/d.⁵³ Here, the majority of Israeli children in all groups spent greater than 120 minutes outdoors per day. It is also possible that this pilot study was not sufficiently powered to detect significant differences in light exposure between groups.

Although early studies suggested that physical activity, such as time in sports, may influence myopia, more recent studies have found that physical activity is not associated with myopia.^{14,30} We found that physical activity, measured objectively, was similar across groups, with a daily mean of 574 counts per minute. All children in this study live in urban areas, attend neighborhood schools, and often walk to school. In Israel, it is common for children to play outdoors without supervision from a young age. They often informally meet their friends after school. Australian children aged 10 to 15 years demonstrated a mean daily physical activity level of 460 counts per minute,¹³ and children aged 5 to 10 years in the United States demonstrated a mean daily level of approximately 560 counts per minute.²⁹ Both of these studies also concluded

that physical activity was similar between myopic and nonmyopic children and not a contributing factor to myopia development.

Activity across the day for the three groups of the children showed that ultra-Orthodox children are less active during the morning and more active in the evening into the night. It is possible that ultra-Orthodox children do not play as much during morning recess. Increased evening activity, particularly on Shabbat, may represent the Shabbat traditions in that ultra-Orthodox boys play later and go to evening prayer service at the synagogue. In addition, ultra-Orthodox children do not use electronic devices, the use of which may tend to decrease activity.

Interestingly, electronic device use was not associated with myopia in these groups of children. Ultra-Orthodox boys demonstrated significantly lower electronic device use compared with religious and secular boys. Speculation exists that increased use of electronic devices contributes to the increased prevalence of myopia. A recent study showed that computer use was associated with myopia at age 9 years, as well as reading time and reading distance⁵⁴; however, findings showed that traditional near work had a stronger association with myopia, whereas computer use was only moderately associated with myopia. Mutti and colleagues⁵⁵ found no associations between myopia and video games/computer use, and no studies have been able to show an effect of electronic device use on incident myopia or myopia progression. Differing views regarding the use of electronic devices in Israel provide an opportunity to uniquely control for this factor. Ultra-Orthodox rabbis believe that mass media in any form (TV, Internet, radio) provokes gossip and steals time from religious studies; use of electronic media is discouraged in this population. On the other hand, religious rabbis favor limited access to media,²⁷ and secular leaders have a Western attitude toward this issue. These differing attitudes may impact the amount of time children in the three groups are exposed to electronic devices and offer an opportunity to investigate the impact of electronic devices on myopia. In the current study, parents of ultra-Orthodox boys reported significantly less electronic device use than religious or secular boys, despite having more myopia. Therefore, at least in this population, electronic devices are not a significant contributor to myopia.

The genetics of myopia in Ashkenazi Jewish families has been studied using exome genotyping⁵⁶ and genome-wide scanning.⁵⁷ Results reveal complex genetic heterogeneity of myopia, even in a genetically isolated population such as Ashkenazi Jews with highly aggregated families, most likely involving many low-penetrance genes combined with environmental factors. All the boys in the current study were Jewish and had similar numbers of myopic parents, despite ultra-Orthodox and religious boys having higher myopia prevalence. However, given the small sample size in this pilot study, we cannot rule

out genetic differences between the groups of children being the cause of the different proportions of myopia in each group. In contrast, Bez et al.¹ studied 22,823 Israeli Jewish adolescent male army candidates. Because army conscription is mandatory for all male Jews in Israel, it is likely that each group (ultra-Orthodox, religious, and secular) had an equal representation of the different Jewish ethnicities. Thus, the difference between the groups is not likely due to genetic factors.

A limitation of the current study is the small sample size, and therefore, some of the results may reflect a low power rather than differences that are not statistically significant. The purpose of this pilot study was to collect preliminary data to plan future large-scale experiments. Because of the small sample size, the different proportions of myopia may be due to genetic diversity between the groups rather than behavioral factors. Another limitation in this study includes a lack of cycloplegic refraction for all subjects. Specifically, we were unable to perform a refraction for 7 of the 36 children and had to rely on the survey to classify these subjects as myopic or nonmyopic. Whereas the questions in the survey asked to determine refractive error have been previously validated in adults, they have not been validated in children. Therefore, it is possible that some of the children were misclassified. Indeed, 4 of 18 children (22%) classified by the questionnaire as emmetropic were myopic. Refraction was not obtained for seven children classified as emmetropic by the survey. It is possible that they were hyperopic or had undiagnosed myopia. In future studies, we aim to recruit larger numbers of children, including ultra-Orthodox girls; provide a thorough optometric evaluation, including cycloplegic refraction; and use objective measures for not only time outdoors and activity but also near work. In addition, we will follow behaviors longitudinally to investigate associations between visual activity and axial elongation over time and across groups. Lastly, the questionnaire did not use a true linear scale to estimate time spent in various activities. Rather, it converted categorical variables with fixed intervals to a linear scale. However, in this context with few subjects, it is unlikely to bias the results.

In summary, this pilot study shows that ultra-Orthodox, religious, and secular Jewish male children demonstrate similar amounts of time outdoors and physical activity and near work at ≤ 40 cm while not in school, but significantly different amounts of electronic device use. Ultra-Orthodox males, who have been shown to have a higher prevalence of myopia in previous studies, reported an earlier age for learning to read, more hours at school, and less electronic device use. These findings suggest that the myopiagenic effects of near work at school and/or early (preschool) reading may override protective effects of time outdoors. However, one cannot discount the possibility that starting school early may have been associated with less time outdoors.

ARTICLE INFORMATION

Supplemental Digital Content: Appendix 1. Questionnaire (available at <http://links.lww.com/OPX/A503>). The University of Houston Near Work, Environment, Activity, and Refraction Survey was filled out by the parents. This survey includes questions regarding demographics, ocular history, education, and behavioral factors. The survey was adapted to reflect the Israeli culture and translated into Hebrew. For behavioral measures, parents were asked to estimate time spent outdoors and in various activities for weekdays (Sunday through Friday afternoon) and for Shabbat (Friday evening through Saturday), reflecting

school days and nonschool days, respectively. Shabbat was assessed independently because ultra-Orthodox and religious Jews have traditions on the Shabbat that are significantly different from the secular group and may impact myopiagenic exposures.

Appendix Table A1. Parent-reported behaviors (available at <http://links.lww.com/OPX/A504>). Parent-reported children's mean daily time \pm standard deviation (in hours) for different activities and sleep duration for ultra-Orthodox ($n = 14$), religious ($n = 13$), and secular ($n = 9$) groups during weekdays, on Shabbat, and for the whole week. *P* values are shown for the Kruskal-Wallis test across groups.

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