WULFENIA JOURNAL KLAGENFURT, AUSTRIA ISSN:1561-882X
Vol 23, No. 6;Jun 2016

The impaction of horizontal acceleration and irregular vibration on mobile vehicles on decreased vision during short time and induce myopic progression in school children after one year in Taiwan

Li-Yu Wu[1], John Ching-Jen Hsiao[2,3], Kuang-Jen Chien[4,5], Chi-Ting Horng[5,6,*]

[1] Department of Nursing, Kaohsiung Armed Forces General Hospital, Kaohsiung City, Taiwan.

[2] Department of Optometry, Chung Shan Medical University, Taichung 40201, Taiwan.

[3] Department of Ophthalmology, Chung Shan Medical University Hospital, Taichung 40201, Taiwan.

[4] Department of Pediatrics, Kaohsiung Veterans General Hospital, Kaohsiung City, Taiwan.

[5] Department of Pharmacy, Tajen University, Pingtung City, Taiwan.

[6] Medical Education Center, Kaohsiung Armed Forces General Hospital, Kaohsiung City, Taiwan.

h56041@gmail.com

* Corresponding author: Chi-Ting Horng. MD, MS.

Address: Medical Educational Center, Kaohsiung Armed Forces General Hospital. No.2., Jhong-Jheng 1st Rd. District of Lingya, Kaohsiung City, Taiwan.

Abstract

Objects: To investigate the effects of horizontal acceleration and irregular vibration on the human visual acuity during short time and the refractive changes after one year.

Methods: In two studies, only all the right eyes of the subjects were enrolled. In experiment 1, we tried to discover the influence of horizontal acceleration. All the 20 subjects' vision who aged 18.6 ± 2.5 years revealed 20/20 on the ground.(static vision) Then, we created forces from two different types (> or < 0.1G) and two directions (X- or Y- axis) by special machine. When the volunteer stood on accelerating platform, the dynamic vision was checked again. In experiment 2, total 60 students were enrolled (mean age 11.3 ± 0.8 years). The mean refraction was - 0.50 D (dipoter). The retrospective charts were reviewed from Jan 2012 to Jan 2013. According to the ways to school, subjects were divided into 3 groups including group 1 (walking), group 2 (by buses or cars) and group 3 (by Rapid Transit System). In experiment 1, the differences between static and dynamic vision was analyzed. We compared the myopia changes between three groups after one year.

Results: In experiment 1, bare vision of all subjects all revealed 20/20 on the floor. Acceleration < 0.1 G in the X- or Y- axis, did not affect static and dynamic vision. The mean vision decreased from 0.02 log MAR to 0.25 log MAR. When Gx > 0.1G Visual acuity worsened (mean from 0.02 log MAR to 0.19 log MAR when Gy > 0.1G In experiment 2, Besides, the children reading books on the moving vehicles in group 2 and 3 may be found myopic shift, even to - 2.00 diopter in group 3 after one year. most of the subjects complained about discomfort in reading.

Conclusion: The results indicated horizontal acceleration may result in the unstable body and the vision should become worse during acceleration. Besides, the children reading books on moving vehicles in group 2 and 3 may be found the myopic change after one year. The unstable position from horizontal accelerating vehicles indeed plays an important role in myopic changes and mild blurred vision. Hence, proper eye-sight protection during various moving vehicles may relieve ocular fatigue and retard the myopic progression.

Key words: Horizontal acceleration, vibration, visual acuity, myopic progression. .

Introduction

Myopia is the commonest ocular abnormality but as a research topic remains at the margins of main-steam ophthalmology. During the past two decades, myopia has risen to epidemic levels of the world now〔1〕. The similar results (the prevalence is 80 % or higher) have been reported in some Asian area among adult (ex. Japan, Singapore, Hong-Kong and China)〔2,3,4,5〕. To date, myopia becomes a significant public health problem in many Asian countries. For example, over 90% myopic students of university were found in South Korea〔6〕. In Taiwan, the strong association between prevalence of myopia and schooling were estimated〔7〕. Yen et al. had reported that the incidence of myopia from 5 % to 10 % to 35% to 45% from first grade to six grade of elementary school which was a serious issue in Taiwan〔8〕. The mean progression rate was 1.14D (Diopter) in 2 years. The longitudinal study in Taiwan also showed higher rate of myopic change. Several methods had made to stop the progression with optic correction, topical cycloplegia, bifocal spectacles, orthokeratology and even traditional Chinese methods (auricular acupoint), but all of they showed ineffective〔9〕.

As to the possible causes, the progression of some case of myopia may be due to gene mutations or polymorphisms (ex.PAX6, ZNF644, GRM6, CTNND2, MYOC, ACAN, HGF or MET genes et al.)〔10,11〕. Besides, the race should be taken into consideration. Some literature also showed that the prevalence of myopia is higher in Asian population than in Caucasian or African-American ones. For example, in USA, 25% of the adult population is myopic, while higher prevalence rates of 90% have been reported in some Asian population especially in Ease Asian〔12〕. In additional, environmental influence have an important role in the development of myopia. The underlying contributing factors yet remain poorly understood. Many children living in an urban environment, immersed in a culture that embraces educational achievement, and possessing computers, smartphones, and video games have the tendency to the progression of myopia. Now several statistical studies have addressed the subject of close work as a cause of myopia〔13〕.

Horizontal acceleration and vibration which induced the visual change during unstable body and impacted on the myopic progression had rare been discussed, however, the similar condition, indeed, may be continuous at time in some daily activities. Various acceleration mechanisms are seen in daily activities, such as walking, running, driving, travelling, and working in some vehicles (cars, high-speed rails, rapid transit systems, boats, railways, and airplanes, particularly helicopters) [14]. Humans such as sailors, aircrews, and passengers may acquire problems, including motion sickness and spatial disorientation, when they are inside moving equipment. Many ground workers also experience vibration and acceleration in their environments and machines, such as construction machineries (bulldozers, forklifts, and cranes), heavy equipment (grinders and jack hammer), and power hand tools [15].

We wanted to realize if horizontal acceleration and vibration resulting in human activities may interfere with their vision and even the changes of refractive errors or not. In the past, only few researchers roughly mentioned that the effects of vision depend on many factors including the vibration level, vibration frequency, viewing distance and objective size and illumination. Griffen et al. reported that the human vision affected by whole body vibration (WBV) was due to the degrees of vibration (e.g. amplitude, frequency and direction) and visual variables (such as illumination, size and viewing distance) 〔16〕. Besides, Krauskoff also demonstrated that the lower frequency (1-5 Hz) motion of retinal image will decrease in the contrast thresholds, however, higher frequency (10 to 50 Hz) motion will cause an increase of thresholds〔17〕. Nevertheless, they all focused on the relationship of contrast threshold and frequency of vibration. Currently, the exact impact of horizontal accelerating force and irregular vibration on human vision and refraction remained ambiguous. To our best knowledge; this is the first research to explorer the concrete data about the changes of visual acuity during unstable moving position and the myopic shift after a long time exposure in the world.

Materials and Methods

The experiment protocols were conducted in accordance with the Declaration of Helsinkin with ethical approval for this study obtained from the Institution Review Board (IRB) of Kaohsiung Armed Force General Hospital in all experiments. In experiment 1, we would observe the vision during horizontal acceleration in perspective. As for the experiment 2, the retrospective chart reviews were performed. Written informed consent was obtained from them, their parents or guardians. The refractive errors were measured using Nidek ARK-510A (NIDEK, Co. Ltd., Japan) auto-refractor directly in each case. The participants with any history of ocular pathology (e.g. amblyopia, strabismus, cataract, glaucoma and uveitis) or systemic diseases such as hypertension, diabetes, cardiac or respiratory illness were excluded from the investigation. Only the right eyes of all subjects were enrolled in experiment 1 and 2.

Experiment 1: To investigate the short term effect of vibration

The experiment 1 was performed in Taiwan High Speed Rail Laboratory in Yanchao District (Taiwan, ROC) in September 2014. Total 20 participants were enrolled including 10 males and 10 females into experiment 1. The age of subjects was between 20 and 26 years old (the mean age is about 22.5 ± 2.8 years old).The refractive error were between + 0.50 and – 0.50 D (patients with astigmatism over ± 1.00 D would be ruled out) and their bare vision all achieved 20/20 (so call " static vision"). No vestibular nerve and other cranial problems were found. The common cold medication and alcohol drinking were prohibited before 3 days before study. All subjects stood on the platform one by one and received the test of visual acuity (Fig 1). At the beginning, horizontal acceleration of the platform was created by machine and the degrees of speed and accelerating force were monitored with a local measuring unit (LMU) system. In this study, we designed two types of acceleration (> and <0.1G) (G: Gravity). The moving direction was also divided into lateral (left to right) direction (Gx) and antero-posterior direction (A-P direction) (Gy) (Fig 2). During moving vehicle, every volunteer with unstable posture was required to cover the left eye and read the letters on holding Rosenbaum screener vision card. All the results were recorded and the accelerating platform stopped slowly. Then, another volunteer went up the quiet platform and repeated the previous procedures again.

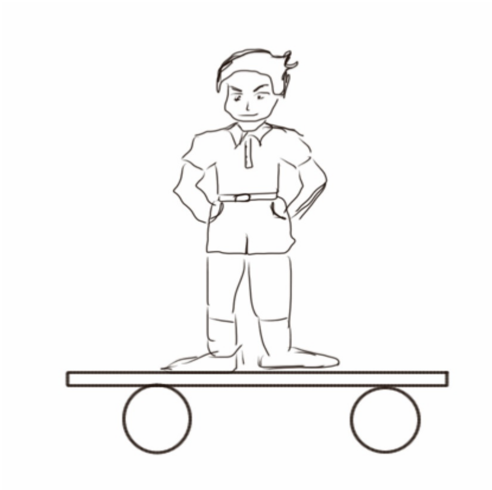

Fig. 1: In experiment 1, every participant stood one the accelerating platform. The irrregular vibration was created by machine and the speed and acceleration were monitoring by LMU system. During moving, every volunteer was asked to test the vision of right eye by vision screener vision card.

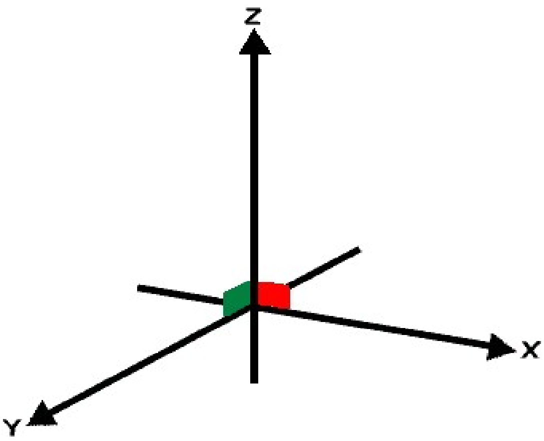

Fig. 2 The picture showed three direction (X-, Y-, and Z axis), and the force from Z axis is very important for the aircrews, especially military pilots because they may experience and endure the higher gravity. (The axis of Gz is from head to foot; the physiological impaction to aircrews is most emphasized in aerospace medicine)

In this study, we made use of vision cards to measure the vision of right eyes. The advantage is convenient to carry, and the measured distance is very short (35 cm). In clinical, it can be easily used to examine the vision of the immobile patients in ICU or traumatic peoples. The results can be converted to the equivalent of the Snellen chart (measured at 6 m) and the results revealed 20/20, 20/25, 20/30, 20/40, 20/50 , 20/70, 20/100, 20/200, 20/400 and 20/800. Before the test, we had already checked the vision on the ground, and it represented the static vision. The visual acuity in the vibrated platform was called dynamic vision.

Experiment 2: To investigate the long term effect on the change of refraction during horizontal acceleration and irregular vibration for one year

In experiment 2, we tried to discover the impaction on the changes of refractive errors from horizontal acceleration and irregular vibration induced by various vehicles in school children after one year by the retrospective medical records. All the subjects were all diagnosed with myopia who had visited Kaohsiung Armed Forces General Hospital (Taiwan, ROC) from January 2012 to January 2013. The inclusion criteria include the outpatients should receive regular follow-up (one time in each month). The total 60 students including elementary school and senior high school were enrolled and only refraction of right eyes was recorded. The mean age of students is about 11.3± 0.8 years old. We recorded the refractive error and bare vision in each subject. The mean refraction of 60 students was between -0.5 and - 0.75 D. If astigmatism was greater than ± 1.0 D, the subject will be excluded. Besides, the students all lived in Kaohsiung city (Southern Taiwan, ROC). According to the daily methods of going to school, they were divided into 3 groups. In group 1, 20 volunteers (10 boys and 10 girls) were walking to school. In group 2, total 20 students (5 boys and 15 girls) went to school by cars or buses every day. In group 3, total 14 boys and 6 girls were going to school by KRT (Kaohsiung Rapid Transit) System. All the three groups of students went to the schools needed around 20 minutes. Because of the relatively lower myopia, no child was treated by spectacles, contact lens and orthokeratology. According to their statement, these children in group 2 and 3 may sometimes read books or play smartphones during the accelerating vehicles. We only discovered the refractive changes of myopic progression in every group at the baseline (January 2012) and one year later (January 2013).

In clinics, vision is measured at 6 meters or 20 feet and minimum legible letters are identified by the Snellen chart. For example, a patient with good bare vision is described as 6/6 (measured at 6 meters) or 20/20 (measured at 20 feet). However, we can't use the summary of isolated findings from Snellen chart for analysis. Thus, visual acuity is well-designed for transformation to another visual scales (Log MAR). To illustrate, the letters in 20/20 line is equal to 0.00 Log MAR and the letters in 20/25 line is similar to 0.10 Log MAR. Therefore, the Log MAR chart is very common method of measuring visual acuity in many researches. Data can be gathered to generate statistics that can be easily used for analysis of systemically following the geometric progression).

All statistical analyses were performed using IBM SPSS statistics version 21 (Armonk, NY: IMB Corp). The results are expressed as the mean ± SD. Pair t-test was used to compare the refractor error changes before and after one year. If the *P* value was lower than 0.05, the results were accepted as statistically significant.

Results

Experiment 1: All bare vision (Right eyes) of the 20 subjects revealed 20/20 on the ground. When horizontal acceleration and irregular vibration occurred (acceleration force < 0.1G in X-axis or Y-axis), their bare vision remained unchanged. That is to say that the static visual acuity are equal to dynamic visual acuity when vibration < 0.1G. However, horizontal acceleration was higher than 0.1 in Gy. Their dynamic vison significantly decreased (from 0.02 log MAR to 0.19 log MAR) ($p < 0.05$). If the Gx was higher than 0.1 G. the dynamic vison may become worse than G force from Y-axis (mean vision from 0.02 log MAR to 0.25 log MAR) ($p < 0.05$).

Nevertheless, Gx force > 0.1G (lateral direction) happened, the dynamic BCVA of 50% (10/20) subjects showed one line of letters that may drop (from 20/20 to 20/25). Besides, Gy force > 0.1G (A-P direction), the vision of 40% (8/20) subjects would show the reduction of 2 lines of letters (from 20/20 to 20/30). In addition, most of the subjects may complain about different levels of discomfort in reading whether G force > 0.1 G from X or Y axis. Thus, we supposed boldly that people in horizontal acceleration and irregular vibrating cars, boats or airplanes (lateral acceleration > 0.1 G) may decrease the visual acuity of passengers (1-2 lines of letters depend on X or Y axis). To be more precisely, the majority of all participates may feel ocular strain and even headache while reading in the accelerating platform.

Experiment 2: In group 1 (walking), the mean refraction of 20 students was about - 0.25 D, and after one year only - 0.75 D (no statistical significance) was found ($P > 0.05$). In group 2 (by cars or buses), the mean refractive errors were - 0.25 D and it rapidly and significantly raised to -2.00 D after one year ($P < 0.05$). In group 3 (by Kaohsiung RTS), the levels of mean refractive error increased from - 0.25 to - 1.00 D apparently ($P<0.05$) (Table 1).

Therefore, our results demonstrated that the younger students in vibrating vehicles even reading books or playing smartphones in moving cars or rapid transit carriage may results in unstable position and further decreased the vision within a short time and enhance myopic progression in long time (one year later) .To our surprise, the progression of myopic shift increased rapidly (mean: - 1.75 D) in group 2 (by cars or buses) and group 3 (mean: - 1.0 D) (by rapid transit system) in the crowing city.

Discussion

Now myopia is becoming the major ocular disorder in human. Except for East Asian areas such as Taiwan and Singapore, 25-50 % of older adults in the USA and Europe were noted and the rate is still increasing〔18〕. Therefore, myopia has become the important topics in WHO recently. Indeed, higher degrees of myopia are associated with several sight-threatening complications, which included macular degeneration, choroidal neovascularization (CNV), retinal detachment (with macular hole), glaucoma and cataract which were all the ophthalmologists worrying about〔19,20〕. All of these myopia-related complications may bring about the permanent visual impairment or blindness, and tend to occur in young adult. The widespread prevalence and the rising rates, the associated visual morbidity and consequent diminution of quality of life and social disability, and the substantial costs make the issue of myopia a significant public health problem. Thus, prevention of myopia progression in schoolchildren is of critical importance to reduce the visual morbidities associated with high myopia.

Table.1 Demographics for the subjects (in experiment 2)

Characteristics	Group1	Group2	Group3
Age	12.5 Y/O	11.8 Y/O	12.3 Y/O
M/F	10/10	5/15	14/6
Refraction (before)	-0.25±0.25 D	-0.25±0.25 D	-0.25±0.25 D
Refraction(after)	-0.75±0.25 D	-2.00*±0.50 D*	-1.00±0.25 D*
Methods to school	Walking	By buses or cars	By RTS

In group 1, 2 and 3, the average time to schools were about 20 minutes in every group *P<0.05, presented the results significantly.

In Taiwan, myopia prevalence was found to increase with age, the prevalence of myopia increased from 20 % at the primary school level to 81% at the junior high school level in 2000. At the senior high school level, the prevalence even appeared to increase to a level of 84%. Without any treatment, Shih et al reported that the mean progression of the myopic children was 0.91 D per year〔21〕. Chou et al. also demonstrated that the myopic shift with 0.14D per month in high myopic children without any therapy〔22〕. Yen et al. recorded comparable myopic progression of -0.914D in one year when using saline instillation as the control treatment〔13〕. According the classification of Chia et al, the level of myopia progression in each eye was further categorized as mild (< 0.5 D), moderate (0.5-0.99 D), or severe (≧1.0 D) 〔23〕. Sam et al. reported that the prevalence of myopia in the Singapore Cohort Study of Risk Factors for Myopia study (1999-2003) was noted to be 28%, 32%, and 43% in 7-, 8-, and 9-year-old children, respectively, with a subsequent 3-year cumulative myopia progression of -2.4D, -2.0D, and -1.7 D in each group, respectively〔24〕. Thus, how to halt or slow the myopic progression became a challenge to all the ophthalmologists. Indeed, there are many methods including othokeratology, intraocular pressure (IOP) agents, bifocal or muti-focal glasses and even auricular acuopoint stimulation were adapted〔25〕. Now the use of the nonspecific anti-muscarinic medication (atropine)is the most likely effective treatment to slow myopia progression〔26〕.For example, 4% of children in the 0.5% atropine group, 17% in the 0.25 % atropine group, and 33% in the 0.1 % atropine still had fast myopic progression(> -1.0D)〔27〕. Initially, the atropine acts to retard the accommodation facility, affect remolding of the sclera (increase collagen cross-linkage within the sclera), limit scleral growth and axial length〔28〕. However, the use of atropine still may not effectively inhibit the disease progression in clinics.

At present, the exact mechanism of myopia remains unclear. If the real impaction on the myopic formation were confirmed, we could more easily control this problem. Some studies showed that the prevalence of myopia appears higher heritability recently. For example, Chen et al. had proposed that the mutation of COL9A2 gene was the predominant pathogenesis of myopia in Han Chinese population〔29〕. Besides, Dirani et al. had demonstrated that high myopia is hereditable, where genetic predisposition seems to be a key factor〔30〕. Stone et al. found that constant light would affect the anterior segment in chickens producing corneal flattening and hyperopia. Thus, they believed that abnormal circadian rhythms of life-style maybe leads to the refractive change in school children〔31〕. Rose et al. addressed that physiologic mechanisms may create myopia as a consequence of optically misguided emmetropization〔32〕. Animal experiments were to prove the abnormal eyeball growth. For example, Diether el at. noted that visual filed is affected by the lens or diffuse, only the corresponding half of the scleral shows the growth change resulting in local, predominately off-axis myopia〔32〕. Simth et al. also indicated that the retinal can modify the adjacent sclera in response to changes in retinal image quality on a local basis which further bring about the formation of myopia in the rhesus monkey studies〔34〕. Early study in 1964, Catania had predated the possible influence of the structure of the environment on eye growth in the form of lower filed myopia, a phenomenon first described in pigeons〔35〕. Until 1985, Fitzke et al. showed a more detailed analysis that the refractive error of the pigeon eyes is essentially uniform off-axis in the superior visual field but developed the progressive myopia up to 5 Diopters which closely followed the geometric distance from the pigeon’s eyes on the ground suggesting it is an adaptive phenomenon〔36〕. Lower field myopia is a phenomenon that has been found in the ground feeding birds species and amphibians, but not in raptor bird species that spend little time on the floor〔37,38〕. In addition, crowding circumstances may also result in myopia shift in animals. Young demonstrated that rearing monkeys in highly restrictive visual environments would lead to myopic changes〔39〕. Miles et al. also reported that rearing in low ceiling conditions creates the inverse of lower field myopia with development in the superior field associated with local expansion of the inferior sclera〔40〕.In human, time spent in restrictive environments such as submarines or underground ballistic missiles installations has been found to associate with increased rates of myopia as compared to military personnel in more usual working environments〔41〕. Recently, it appears reasonable to suggest, however, that some newly emerging risk factors for myopia progression, such as Internet and computer use may have a minor influence on children 6-12 years of age〔29〕.

Nevertheless, the concrete data about on the visual change and myopia progression during unstable moving position had never been reported. To our knowledge, our research is the first one to describe the decreased levels of visual acuity at the moment of acceleration and the changeable degrees of myopic shift after long time in the world. As is well-known patients with the impact of un-stable vibration and acceleration likely to cause blurred vision many years ago, the associated degrees and types is still a mystery to us. In the past, many researchers including the specialists in NASA had focused on the Z-axis force (from head to foot) which pays an important role in various airplanes and space shuttle. Higher +Gz stress may affect the aircrews in the fly because a lot of blood will be accumulated in the lower part of body. Their vision showed a transient reduction under rapid acceleration (about 5G) immediately in our previous studies〔42,43〕, however, if higher sustained G force (8 - 9G) induced by the acceleration of fighters persisted over 43 seconds, their brains and eyes would lack enough blood supply and cause severe ischemia and hypoxia. Hence, military pilots may experience black image, peripheral vision loss, gray image, total blindness, conscious loss and suddenly involuntary coma. Nevertheless, vibration and acceleration from the axis of X or Y which affect the human vision was rare discussed. Indeed, the force from these two directions was very popular. For example, anecdotal evidence gained from race car drivers, who require specific strength training regimes to tolerate the 4-5 Gy loading encountered during cornering. Besides, many moving vehicles in our daily activity would create the effects of X- and Y-axis on the surface of earth. So far, the exact data of impaction from X and Y axis on human vision is still unknown.

On the ground, vibration, especially whole body vibration, was considered as the source of Gx or Gy forces which were very common in daily activities. When unstable vibration of human body occurs, it will cause series of physiological effects, finally resulting in muscle contraction. When the length of muscles is stretched into longer or faster, the contraction of muscles will become more intense. WBV can stimulate muscle spindles, then enhance the circulatory ability of blood flow, and finally improve muscle power, human explosive force and balance training. In clinics, some doctors used vibration from acceleration to treat patients with anxious status and muscle spasm because of decreasing the spasticity and rigidity, and increase muscle tone. In addition, body vibration may also enhance the muscle strength, power, flexibility and even bone mineral density. Low frequency vibration could increase the peripheral circulation, the muscle blood flow and reduce the resistance index〔44〕. Bruyere et al. reported that the residents older aged from 63 to 92 years old living in nursing home who received vibration significantly improved the gait, balance, and the quality of life〔45〕. Now whole body vibration has been proven to elicit improvements in isometric/dynamic leg muscle strength and Therefore, vibration was very commonly used in the field of physical medicine and rehabilitation〔46〕. Besides, it was also used to the training of various athletes (e.g. Various players of jump, boxing, vertical jump, skier, field hockey) to enhance their performances〔47,48〕.

In experiment 1, we could find out the visual acuity may loss 1-2 lines of letters during vibration (> 0.1G). Literature revealed that various types of vibration may impact the uncomfortable sensation on the human. For example, the shaking forces in central part (Nantou city in Middle Taiwan) of 921 earthquakes were measured as 1.5 G of the horizontal force (Gx or Gy) and 0.3 G of the vertical force (Gy) in 1999. Under huge disaster, human may feel very severely dis-comfortable. Besides, several transportation systems such as airplanes, trains, sea vessels, and various cars would induce the vibration that may affect most of the passengers. The low-frequency vibrations to the whole body contact area such as the sea of the trucks, tractors, buses, or other vesicles, or the floor of a workplace. In addition, it may also refer to the vibration exposures found in many occupational setting such as heavy construction, forklift operation, and vehicle operation, and farming. There are two types and sources of occupational diseases in segmental and whole body vibration. Segmental vibration is transmitted through the hands and arms, and is known to cause specific health effects such as Raynaud's syndrome. Vibration may be transmitted through the body's supporting surfaces such as the legs when standing and the back and buttocks when sitting. Along with musculoskeletal problems, exposure to occupational whole body vibration also presents a health risk to the psychomotor, physiological, and psychological systems of the body〔49,50〕.In addition, short term exposure to vibration in the 2-20Hz range at 1 m/sec ^{2}, may bring about abdomen pain, headache, chest pain, nausea, loss of equilibrium, muscle contraction with decreased performance in precise manipulation tasks, shortness of breath, and influence on speech〔50〕. Furthermore, long-term exposure can cause disc displacement, degenerative spinal changes, lumbar scoliosis, and herniated discs)〔51,52〕. In experiment 1, we can conclude that the greater vibration may induce visual loss about 1 to 2 lines of letters in short-term. Besides, we also found that the moderate to severe vibration may accelerate the myopic progression in longer time (one year later) in experiment 2. In fact, the role of the retina and retinal image in controlling human were well-known〔53〕. The first evidence in humans that a degraded retinal image can produce myopia came from the natural experiments offered by a range of ocular diseases and the phenomenon was found naturally in clinical situations〔54〕. Clinical disorders that prevent the formation of the clear retinal image were found to replicate the experimental conditions that had been seen to produce deprivation myopia in animal models. For example, Rabin et al. published that refractions of 73 infants with a range of clinical diseases that prevented from of the clear image and myopic shift compared to normal infants〔55〕. Therefore, we confidently supposed that the unstable vibration-induced improper and blurred image on the retina which maybe lead to vision loss during vibration and the myopic change in longer time in school children after one year.

Recently, light exposure and physical activity in myopic children were well studied in clinical and laboratory levels〔56〕. Feldkaemper et al. found that the wide spatial distribution of dopaminergic by local retinal deprivation. Besides, the protective of light on retinal protective effect of outdoor activity on myopia development in children seems to be partly medicated by the stimulatory effects of light on retinal dopamine production and release〔57〕. It is a hypothesis that dopamine release is reduced within hours of fitting optic devices which result in increased rate of axial elongation, which is the structure of basis of myopia〔58〕. In experiment 2, the students went to schools in Group 1 had more exposure time than group 2 and 3 who should be more prone to myopic shift as the rule of Feldkaemper, however, the results were just opposite. Thus, in some articles about the limitation of the time outdoor and distance viewing and relaxed accommodation outdoor is not the critical factor in the prevention from myopia were addressed〔59〕. On the other hand, many cross-sectional studies had reported a significant association between less outdoor and sport activities and the presence of myopia. Yazar et al. found that myopic participants have significantly lower 25(OH) D_3 concentrations. The prevalence of myopia was significantly higher in individuals with vitamin D deficiency compared to the normal individuals. Thus, sun exposure is also important〔61〕. Thus, the benefits of outdoor activities were controversial.

In daily activity, the impact of vibration from X and Y axis plays the more important role in the rail-mounted vehicles on the ground. Especially the high speed rail and Rapid transit system in many countries are all concern about this problem. For instance, Taiwan High Speed Rail is introduced and set up from Japan (Shinkansen) and its benefits and conveniences are well-appreciated. On the knowledge, taking into consideration the intensity of the vibration, they appeared to offer to a good basis for assessing whether the certain stress represents a health hazard for the spine column or not. The current international standard for WBV (ISO 2631/1-1985) is based upon data available from both practical experience and laboratory experiments with short-term exposure (Table 2). For example, G-axis force of high speed rail is 0.001 G in normal condition. When the carriage moved in high speed, the people feel good. However, in rapid acceleration and deceleration (peak to peak) stage, Gy force may reach to 0.03 - 0.06 G. Mild discomfort was probably found in some passengers and no apparent vision loss according to our study. Nevertheless, if the emergence occurred and Gy > 0.1 G, visual acuity may drop mildly (nearly one line of letters). As to the Taipei and Kaohsiung MRT in Taiwan, the sitting position of passengers and the moving direction is vertical. In other word, Gx force is predominate in the vibrated travelers. The peak phase of speeding-up and slow-downing G force of these two types of MRT is around 0.12 G. In addition, the distance form one station to next station (in Taipei and

Kaohsiung) is relative short. The repeated fast moving and stopping of the carriage, Gx force may decrease the vision (about 2 lines of letters) of the travelers proven in our experiment 1. In this situation, the passengers may feel headache and ocular strain when they used the mobile phones, I-Pads and portable computers during moving vehicles.

Table 2. The effects of irregular vibration and acceleration to people were defined by the international standard organization (ISO). The below data were from ISO 2631-1 (1997) adopted by Taiwan High Speed Railway to limit the degrees of vibration and acceleration for safety concern.

<0.03G	No sensation
0.03～0.07G	Very mildly discomfortable
0.07～0.1G	Mildly discomfortable
0.1～0.16G	Moderately discomfortable
0.16～0.25G	Severely dis-comfortable
>0.25G	Very severely discomfortable

There are no researches about the horizontal acceleration and unstable vibration-induced myopic progression in the past. In experiment 2, we found that the refractive changes of children walking to school were not apparently change after one year follow-up. However, the ones who went to school by City MRT showed myopic shift (mean increase of - 0.75D after one year). Some studies had revealed that the acceleration of cars, buses and trunks is between 0.02-009 G in road. However, if the vehicles waited for the traffic light signs in the streets, the mechanical vibration even reached 0.15G〔62〕.In addition, the traffic jam usually happened in the big and crossing city (ex. Kaohsiung in Taiwan) and the repeatedly speed up, slowing down and prolonged waiting may increase the incidence of Gx (or Gy). Although the majority of the vibration measured in Chen’s study had showed 0.02 to 0.05 G in 94 % of urban taxis in Taipei city〔63〕, the longer time of exposure, the accumulative effects in the traffic jam and the relatively higher levels of acceleration cannot be ignored. Thus, we found that the schoolchildren taken the cars or buses to school showed significantly myopia progression (mean increase of -1.75 D in one year) in experiment 2. The students in group 2 and 3 were usually found to read books or used smartphones which may induce the blurred retinal image in short time and mild blurred vision. We strongly believed that the remarkably myopic change may be the summations of vibration and near-sighted reading in long time. The similar reports that myopic prevalence in children has been correlated with increasing urbanization were found in some literature〔84,85〕. Rural populations have been observed in epidemiological studies to have very low levels of myopia as compared to urban populations. For example, Garder et al. found that rural schoolchildren have a report myopia prevalence of only 2.9%, as compared to myopia rate in Taiwanese cities of 12 % at the age of 6 increasing to 84% by age 16-18〔66,67〕. Children who spent little time outdoors, physical activities and relative large amount on near-work were more likely to be myopic than the control group (Odds ratio: 2.6)〔68〕. Most current theories relating to hereditary and environmental factors, working conditions and near-sighted work, as well as their combinations were established before〔69〕. We conjectured that the above results may be due to the primary mechanisms of oscillopia〔70〕. Besides, Zhang et al. also found that the urban environment may be one risk factor for myopia. They thought that higher population density appears to be associated with myopic risk independent of academic activity, time spent outdoor, familial educational level, or economic development, factors that have been thought to explain higher myopia prevalence among urban children〔71〕. Mechanisms for this apparent association should be sought. According to our studies, the accelerating force induce vibration of various traffic vehicles in urban and cities than more walking in countries may explain further difference of development of myopia in other studies.

Although several limitations and invisible confounding factors such as protective methods of UV light, total exposure time outdoor, and the exact near work time including reading and using the 3 C production, we could not accurately check the detailed points and enough information in experiment 2. As to the statement of Guggenheim et al., they found a significant association between incident myopia and both physical activity levels and questionnaire-derived outdoors time〔72〕. In our study, we omitted the associated effects and only focused on the impaction of horizontal acceleration and irregular vibration. To our knowledge, this is the first study to evaluate the above factors on myopic development. Although the studies designed may be not perfect, it, however, acts as a pioneer about more risk factors for myopia progression and vision change.

Conclusion

Prevention of myopia progression in schoolchildren is of critical importance to reduce the visual morbidities associated with myopia in later life. To date, myopia had become a public problem for human. We suggested that acceleration force and irregular vibration induce the unstable human body may also plays an important role of myopic progression and results in mild reduction of vision and ocular fatigue while reading and using the smartphones and portable computers during moving vehicles depend on the exposure time. Therefore, the human had better close eyes and take a rest during any accelerating and vibration transportation.

References

1. Pan CW, Ramamurrthy D, Saw SM. Worldwide prevalence and risk factors for myopia. Ophthalmic Physiol Opt. 2010; 32: 3-16.
2. Lam CS, Lam CH, Cheng SC, Chan LY. Prevalence of myopia among Hong Kong Chinese school children: changes over two decades. Ophthalmic Physiol Opt. 2012; 32: 17-24.
3. Wantanabe S, Yamashita T, Ohba N. A longitudinal study of cycloplegic refraction in a cohort of 350 Japanese schoolchildren. Ophthalmic Physiol Opt. 1999; 19: 22-9.
4. Wu HM, Seet B, Yap EP, Saw SM. Lim TH, Chia KS. Does education explain ethnic differences in myopia prevalence? A population-base study adult male in Singapore. Optom Vis Sci. 2001; 78: 234-9.
5. Edwards MH. The development of myopia in Hong Kong children between the ages of 7 and 12 years: a five-year longitudinal study. Ophthalmic Physiol Opt.1999; 19:286-94.
6. Jung SK, Lee JH, Kakizaki H, Jee D. Prevalence of myopia and its association and education level in a 19-year-old male conscript in Seoul Korea. Invest Ophthalmol Vis Sci. 2012; 53: 5579-83.
7. Lin LL, Shih YF, Hsiao CK. Cheng CJ. Prevalence of myopia in Taiwanese schoolchildren: 1983 to 2000. Ann Acad Med Singapore. 2004; 33: 27-33.
8. Yen MY, Liu JH, Kao SC, Shiao CH. Comparison of the effect of atropine and cyclopentolate on myopia. Ann Ophthalmol. 1989; 21: 180-7.
9. Cheng HC, Hsieh YT. The effect of low concentration atropine combined with auricular acupoint stimulation in myopia. Complementary Ther Med. 2014; 22(3): 449-55.
10. Tang SM, Rong SS, Young AL, Tam PO, Pang CP, Chen LJ. PAX6 gene associated with high myopia: a meta-analysis. Zhonghua Yi Xue Yi Chuan Xue Za Zhi. 2014; 31(2): 129-33.
11. Wang H, Yang M, Su S, Kang L, Zhu R, Shi J, Guan H. Association of ZNF644, GRM6 and CTNND2 genes polymorphisms with high myopia. Zhonghua Yi Xue Za Zhi. 2014; 94(17):1289-93.
12. Aller TA. Clinical management of progressive myopia. Eye (Lond). 2014; 28(2): 147-53.
13. Yen MY, Liu JH, Kao SC, Shiao CH. Comparison of the effect of atropine and cyclopentolate on myopia. Ann Ophthalmol. 1989; 21: 180-7.
14. Allen, E.M.; Weir-Jones, I.; Motiuk, D.R., et al. Acceleration perturbations of daily living. Spine. 1994, 19(11), 1285-90.
15. Seidel, H. Selected health risks cause by long-term, whole-body vibration. Am J Ind Med. 1993, 239(4). 589-604.

16 Griffin MJ, Lewis CH. A review of the effects of vibration on visual acuity and continuous manual control, part I: visual acuity. J Sound Vibration. 1987; 56: 383-413.

17 Krauskoff J. Effect of retinal image motion on contrast thresholds for maintained vision. J Opt Soc Am. 1957; 47(8): 740-4.

18 Wang Q, Klein BE, Klein R, Moss SE. Refractive status in the Beaver Dam Eye Study. Invest Ophthalmol Vis Sci. 1994; 35(13): 4344-7.

19 Eye Disease Case-Control Study Group. Risk factors for idiopathic rhegmatogenous retinal detachment. Am J Epidemol. 1993; 137(7): 749-57.

20 Mitchell P, Hourihan F, Sanbach J, Wang JJ. The relationship between glaucoma and myopia: the Mountain Eye Study. Ophthalmology. 1999; 106(10): 2010-5.

21 Shih YF, Chen CH, Chou AC, Ho TC, Lin LLK, Hung PT. Effects of different concentrations of atropine on controlling myopia in myopic child. J Ocul Pharmacol Ther. 1999; 15(1): 85-90.

22 Chou AC, Shih YF, Ho TC, Lin LLK. The effectiveness of 0.5% atropine in controlling high myopia in children. J Ocular Pharmacol Ther. 1997; 13(1): 61-7.

23 Chia A, Chua WH, Cheung YB. Wong WL, Lingham A, Fong A, Tan D. Atropine for the treatment of children myopia: safety and efficacy of 0.5%, 0.1%, and 0.01% doses (Atropine for the treatment of myopia 2). Ophthalmology. 2012; 119(2): 347-54.

24 Li SM, Wu SS, Kang MT. et al. Atropine slows myopia progression more in Asian than white children by meta-analysis. Optom Vision Sci. 2014; 91(3): 342-50.

25 Lee JJ, Fang PC, Yang IH, Chen CH, Lin PW, Lin SA, Kuo HK, Wu PC. Prevention of myopia progression with 0.05 % atropine solution. J Ocul Pharmacol Ther. 2006; 22(1): 41-7.

26 Saw SM, Gazzard G, Au Eong KG, Tan DT. Myopia: attempts to arrest progression. Br J Ophthalmol. 2002; 86(11): 1306-11.

27 Prepas SB. Light, literacy and the absence of ultraviolet radiation in the development of myopia. Med Hypotheses. 2008; 70: 635-7.

28 Chen R, Gong B, Li Q, Zeng G, Hao F, Li N, Shi Y, Zhang D. Analysis of COL9A2 gene mutation in a Chinese Han population with pathologic myopia. Chin J Med Genet. 2014; 31(2): 129-33.

29 Dirani M, Chamberlin M, Shekar SN, et al. Heritability of refractive error and ocular biometrics. The genes in myopia (GEM) twin study. Invest Ophthalmol Vis Sci. 2006; 47(11): 4756-61.

30 Stone RA, Lin T, Desai D, Capehart C. Photoperoid, early post-natal eye growth and visual deprivation. Vision Res. 1995; 35: 1195-1202.

31 Rose KE, Tullo AB. Myopia. Br J Ophthalmol. 1998; 82(10): 1220-1.

32 Diether S, Schaeffel F. Local changes in eye growth induced by imposed local refractive error despite active accommodation. Vision Res. 1997; 37(6): 659-68.

33 Smith 3 rd EL, Hung LF, Huang J, Blasdel TL, Humbird TL, Bockhorst KH. Effects of optical defocus on refractive development in monkeys: evidence for local, regionally selective mechanisms. Invest Ophthalmol Vis Sci. 2010; 51(8): 3684-73.

34 Catania AC. On the visual acuity of the homing pigeon. J Exp Anal Behav. 1964; 7: 361-6.

35 Fitzke FW. Hayes BP. Hodos W, Holden AL, Low JC. Refractive sectors in the visual field of the pigeon eye. J Physiol. 1985; 369: 33-44.

36 Hodos W, Erichsen JT. Lower-field myopia in birds: an adaption that keeps the ground in focus. Vision Res. 1990; 30: 653-7.

37 Murphy CJ, Howland M, Howland HC. Raptors lack lower-field myopia. Vision Res. 1995; 35(9): 1153-5.

38 Young FA. The effect of restricted visual space on the refractive error of the young monkey eye. Invest Ophthalmol. 1963; 2: 571-7.

39 Miles FA, Wallman J. Local ocular compensation for imposed local refractive error. Vision Res. 1990; 30(3): 339-49.

40 Greene MR. Submarine myopia in minuteman launch control facility. J Am Optom Assoc. 1970; 41: 1012-6.

41 Seidel H, Harazin B, Pavlas K, Sroka C, Richter J, Bluthner R, Erdmann U, Grzesik J, Hinz B, Rothe R. Isolated and combined effects of prolonged exposures to noise and whole body vibration on hearing, vision and strain. In Arch Occup Environ Health. 1988; 61(1-2): 95-106.

42 Horng CT, Liu CC, Kuo DI, Shieh PC, Wu YC, Chen JT, Tsai ML. Changes in visual function during the Coriolis illusion. Aviat Space Environ Med. 2009; 80: 360-3.

43 Tsai ML, Liu CC, Wu YC, Wang CH, Shieh PB, Lu DW, Chen JT, Horng CT. Ocular response responses and visual performance after high-acceleration force exposure. Invest Ophthalmol Vis Sci. 2009; 50: 4836-9.

44 Warman G, Humphries B, Purton J. The effects of timing and application of vibration on muscular contraction. Aviat Space Environ Med. 2002; 37(2): 119-27.

45 Bruyere O, Wuidart MA, Di PE, Goulay M, Ethgen O, Richy F, Reginster JY. Controlled whole body vibration to decrease fall risk and improve health-related quality of life of nursing home residents. Arch Phys Med Rehabil. 2005; 86(2): 303-7.

46 Rubin C, Turner AS, Bain S, Mallinckrodt C, McLeod K. Anabolism low mechanical signals strengthen long bone. Nature. 2001; 412(6847): 603-4.

47 Issurin VB, Tenenbaum G. Acute and residual effects of vibratory stimulation on explosive strength in elite and amateur athletes. J Sports Sci. 1999; 17(3): 177-82.

48 Bosco C, Cadinale M, Tsarpla O. Influence on vibration on mechanical power and electromyogram activity in human arm flexor muscles. European J Appl Physiol. 1999; 79: 306-11.

49 Butler CA, Griffin MJ. Motion sickness during fore-and-aft oscillation: effect of the visual scene. Avait Space Environ Med. 2006; 77(12): 1236-43.

50 Perrin P, Lion A, Bosser G, Gauchard G, Meistelman C. Motion sickness in rally car co-drivers. Aviat Space Environ Med. 2013; 84: 473-7.

51 Klosterhalfen S, Muth ER, KellermannS, Meissner K, Enck P. Nausea induced by vection drum:

contributions of body position, visual pattern, and gender. Avait Space Environ Med. 2008; 79(4): 384-9.

52 Boshuizen HC, Bongers PM, Hulshof CT. Self-reported back pain in fork-lift truck and freight-container tractor drivers exposed to whole body vibration. Spine. 1992; 17(1): 59-65.

53 Siedel H, Harazin B, Pavlas K, Sroka C, Richter J, Bluthner R, Erdmann U, Grzesik J, Hinz B, Rothe R. Isolated and combined effects of prolonged exposures to noise and whole body vibration on hearing, vision and strain. Int Arch Occp Environ Health. 1988; 6: 96-106.

54 Flitcroft DI. The complex interactions of retinal, optical and environmental factors in myopia etiology. Prog Retin Eye Res. 2012; 31(6): 622-60.

55 Rabin J, Van Sluyters RC, Malach R. Emmetropization: a vision-dependent phenomenon. Invest Ophthalmol Vis Sci. 1981; 20: 561-4.

56 Read SA, Collins MJ, Vincent SJ. Light exposure and physical activity in myopic and emmetropic children. Optom Vis Sci. 2014; 91(3): 330-41.

57 Feldkaemper M, Schaeffel F. An update view on the dopamine in myopia. Exp Eye Res. 2013; 114: 106-19.

58 Megaw PL, Boelen MG, Morgan IG, Boelen MK. Diurnal patterns of dopamine release in chicken retina. Neurochem Int. 2006; 48: 17-23.

59 French AN, Ashby RS, Morgan IG, Rose KA. Time outdoors and the prevention of myopia. Exp Eye Res. 2013; 114: 58-68.

60 Rose KA, Morgan IG, IP J, Kifley A, Huynh S, Smith W, Witchell P. Outdoor activity reduces the prevalence of myopia in children. Ophthalmology. 2008; 115: 1279-85.

61 Yazar S, Hewitt AW, Black LJ, McKnight CM, Mountain JA, Sherwin JC. Et.al. Myopia is associated with lower vitamin D status in young adults. Invest Ophthalmol Vis Sci. 2014; 55: 4552-9.

62 Dupuis H, Zerlett G. Whole body vibration and disorders of the spine. Int Arch Occup Health. 1987; 59: 323-6.

63 Chen JC, Chang WR, Shih TS, Chen CJ, Chang WP, Dennerlein JT, Ryan LM, Christiani DC. Predictors of whole body vibration levels among urban taxis drivers. Ergonomics. 2003; 46(11): 1075-90.

64 Yang RJ, Sheu JJ, Chen HS, Lin KC. Huang HL. Morbidity at elementary school entry differs by sex and level of residence urbanization: a comparative cross-sectional study. BMC Pubic Health. 2007; 7: 358

65 Zhan MZ, Saw SM, Hong RZ, Fu ZF, Yang H, Shui YB, Yap MK, Chew SJ. Refractive errors in Singapore and Xiamen, China – a comparative study in school children aged 6 to 7 years. Optom Vis Sci. 2000; 77: 302-8.

66 Garner LF, Kinnear RF, McKellar M, Klinger J, Hovander MS, Grosvenor T. Refraction and its components in Melanesian schoolchildren in Vanuatu. Am J Optom Physiol Opt. 1988; 65:

182-9.

67 Frederick DR. Myopia. BMJ. 2002; 324: 1195-9.

68 Wist ER, Brandt TH, Krafczyk S. Oscillopsia and retinal slip. Brain. 1987; 106: 153-68.

69 Atkin A, Bender MB. Ocular stabilization during head movement. Arch Neurol Chicago. 1968; 19: 559-66.

70 Donovan L, Sankaridurg P, Ho A, Naduvilath T, Smith EL III, Holden BA. Myopia progression rates in urban children wearing single-vision spectacles. Optom Vis Sci. 2012; 89: 27-32.

71 Zhan MZ, Saw SM, Hong RZ, Fu ZF, Yang H, Shui YB, Yap MK, Chew SJ. Refractive errors in Singapore and Xiamen, China– a comparative study in school children aged 6 to 7 years. Optom Vis Sci. 2000; 77: 302-8.

72 Guggenheim JA, Northstone K, McMahon G, Ness AR, Deere K, Mattocks C, Pourcain BS, Williams C. Time outdoors and physical activity as predictors of incident myopia in childhood: a prospective cohort study. Invest Ophthalmol Vis Sci. 2012; 53: 2856-65.