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Association of sports vision with age, gender, and static visual acuity among nonathletic population

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Abstract:

PURPOSE: Excellent vision is essential to performing well in sports. Sports vision includes visual, perceptual, cognitive, and oculomotor tasks that enable athletes to process and respond to what is seen. We aimed to examined how sports vision parameters – dynamic visual acuity (DVA), eye movement (EM), peripheral vision (PV), and momentary vision (MV) – varied with age and sex and assessed how static visual acuity (SVA) affect sports vision performance.

MATERIALS AND METHODS: Sports vision was assessed at 45 cm distance at best-corrected SVA in 310 nonathletic participants (age, 6–60 years). Among these 310 participants, 108 university students underwent their sports vision test at 45 cm and 2.5 m distance, with and without glasses. The 4 sports vision parameters were measured by Athlevision software package installed to a laptop. Two-way analysis of variance (ANOVA) was used to compare sports vision performance in relation to age group and sex. Repeated-measures ANOVA with 1 within-factor (4 conditions) were used to analyze how sports vision varied among the near/far distance with/without glasses conditions.

RESULTS: DVA increased during childhood, peaked during the 20s or 30s, and gradually decreased during middle age ($P < 0.0001$). DVA was significantly better in males than in females ($P = 0.0001$). The other 3 sport vision parameters – EM, PV, and MV – exhibited similar age trends ($P < 0.001$) but did not differ between two sexes. The university students with mild myopia had similar DVA, EM, and PV at both near and far distances, with and without correction; but moderate or severe myopic students with uncorrected vision had worse DVA, EM, and PV at 2.5 m than at 45 cm.

CONCLUSION: Low SVA in uncorrected myopia significantly interferes the performance in sport vision tests applied in this study, especially in far distance. Improve static vision, such as myopic correction, may significantly improve sports vision, which is important in athletic performance and safety.

Keywords:

Age, nonathletic, sex, sports vision, static visual acuity

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Introduction

Excellent vision is essential to performing well in sports. Sports vision includes visual, perceptual, cognitive, and oculomotor tasks that enable athletes to process and respond to what is seen.[1] Research on sports vision is in its infancy, although sports vision is widely recognized as crucial in athletic performance. Topics of interest in sports vision include dynamic visual acuity (DVA), eye movement (EM), peripheral vision (PV), and momentary vision (MV). Existing evidence suggests that although DVA typically declines with age, participation in sports helps maintain it.[2] In addition, sex differences in DVA have been frequently studied, and DVA appears to be better in males. Other aspects of sport visions are not as well-understood.

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Myopia is the most prevalent ocular disorder in Taiwan. Nationwide surveys in Taiwan indicate that myopia prevalence has progressively and significantly increased in recent decades. At present, more than 80% of Taiwanese adolescents have myopia. While playing sports, persons with myopia must decide whether to wear eyeglasses, which, although a hindrance, improve static vision. Many athletes choose not to correct their static vision when playing sports. We previously reported that 78% of 36 adolescent soft-tennis athletes with refractive error did not wear eyeglasses when competing.[3]

The association between static vision and sports vision is unclear. Older studies reported controversial results while recent studies reported a definite correlation between static and dynamic vision. Jorge and Fernandes reported that elite football player that used visual correction to practice sports performed better than not using.[4] Not many investigated the correlation between static vision and other sport vision parameters such as EM, MV, and PV. Deng *et al.* reported that the effect of myopic defocus on static vision differed from the effect on dynamic vision[5] and hypothesized that dynamic vision is related not only to refractive system but also to other factors, as well. Many tests of sports vision are performed at relatively close distances (at 45 cm, e.g., in our previous study of DVA, EM, PV, and MV).[3] These distances are far shorter than those encountered in most sports. Therefore, sports vision tests at farther distances might yield different results for participants with myopia.

This study examined how sports vision parameters (DVA, EM, PV, and MV) vary in relation to age and sex in nonathletic population. We also examined the effect of static visual acuity (SVA) on sports vision by requesting participants to perform the relevant assessment at near distance (45 cm) and far distance (2.5 m), with and without glasses.

Materials and Methods

Ethical approval

The participants were 6–60 years of age, had normal refractive errors or myopia (including anisometropia), no eye disease, and had not received any visual training during the previous 3 months. We recruited participants from Chang Gung Memorial Hospital (CGMH), Linkou, Taiwan and Chang Gung University, Taiwan. The study was approved by the Institutional Review Board of the study institute (approval number: 201601220B). All participants signed the informed consent form (ICF) after the nature and possible consequences of the study were explained to them. The parents of pediatric participants signed the ICF.

Measurements

All participants underwent cycloplegic refraction (those from CGMH) or auto-refractometric examination (university students) and refractive correction to determine their refractive state and the best-corrected SVA of each eye. All participants also underwent various sports vision tests at near distance (45 cm) with best-corrected vision. For university students (age of 18–24), the sports vision tests were measured at near distance (45 cm) using a 15.6-inch laptop computer and far distance (2.5 m) using an 86.7-inch projector screen, with and without eyeglasses.

Static visual acuity assessment

For university students who took the auto-refractometric examination, the SVA test was measured by a Canon CV-20 static visual testing device. Its procedure is similar to that of a standard visual acuity test, except that the examiners' responses are recorded through a joystick of the machine to show the 4 directions of the Landolt C, or a button to express their inability to see the gap of the C letter. The size of the C and its gap are reduced until a person can no longer distinguish them or make a specified rate of errors, i.e., the endpoint of this test. The minimum perceivable angle of this gap is taken as measure of the SVA. Due to its geometric nature, SVA was converted to the logarithm of the minimum angle of resolution (LogMAR) before averaging and conversion back to decimal acuity,[6] as follows:

- LogMAR= −log (decimal acuity)
- Decimal acuity = antilog (−LogMAR) =10 − LogMAR

Participants were classified into five refractive states: emmetropia (a spherical equivalent [SE] in both eyes of ≥ −0.50 diopters [D]), mild myopia (−2.50 D ≤ SE<−0.50 D and an SE difference between eyes of < 2.50 D), moderate myopia (−5.00 D ≤ SE<−2.50 D and an SE difference between eyes of < 2.50 D), severe myopia (SE<−5.00 D and an SE difference between eyes of < 2.50 D), and anisometropia (1.00 D ≥ SE>−9.00 D and an SE difference between eyes of ≥ 2.50 D).

Sports vision assessment

Sports vision (DVA, EM, PV, and MV) were measured using a commercially available software package (Athlevision; ASICS Corporation, Japan) installed on a 15.6-inch laptop computer with an LCD display (luminance, 281 cd/m^2; resolution, 1600 × 900; response speed, 16 m). Room illuminance was 520–710 lux. Participants wore a Philly 1-piece extrication collar to keep their head stationary [Supplement 1a and 1b]. The forehead was placed on a bar, to maintain a distance to the display of 45 cm. For the participants recruited from the university, all sports vision tests were repeated at the farther distance by flashing the images on an 86.7-inch projector screen 2.5 m away from the participant.

The Athlevision software was preprogrammed to test sport visions (DVA, EM, PV, and MV). Each task was scored on a scale of 1–10, with higher scores representing better performance. The task started with level 1 (the easiest). When the participant answered correctly, the complexity (speed, variability) of the test will increase by 1 level. When the answer was incorrect, the complexity (speed and variability) will decrease by 1 level. The test ended when the participant made 3 consecutive mistakes. The order of sports vision testing was DVA, EM, MV, and PV, with a 1-minute break between tests.

DVA is the ability to correctly identify moving objects. In the DVA test, a moving number changes twice in a horizontal or vertical stream. When the start icon was pressed, the participant was asked to read off the quick-moving numbers [Supplement 2a]. DVA was calculated as

DVA = (left + right + up + down)/4

EM is the ability to recognize symbols by quick EM. A symbol, ● or ■, is hidden at 9 positions (1 symbol at each corner of a 2 × 2 grid of squares) on the screen and flashed 1 at a time, in random order. When the start icon was pressed, the participant was asked to provide the position of the flashing ● [Supplement 2b].

PV is the ability to view peripheral objects without moving the eyeballs when staring at a target object. In the PV test, there is an ellipse with 8 lines composed of many ▲ symbols, and a numeral in the center. When the start icon is pressed, the central numeral and only 2 ● symbols, which were included among the many ▲ symbols, appear simultaneously for a moment. The participant was asked to watch the central number and find the peripheral ● symbols [Supplement 2c].

MV is the ability to recognize momentarily displayed symbol patterns. In the MV test, a 3 × 3 grid of symbols is displayed. Three symbol patterns consisting of 2 out of 4 symbols (○, X, △, □) are continuously displayed, in random order. The participant was asked to identify the location of an assigned symbol in the second symbol pattern [Supplement 2d].

Reliability of sports vision

The measurement reliability was assessed in previous study by Chang *et al*., whereby 26 elementary school students who underwent testing twice at the same hour on 2 consecutive days. The intraclass correlation coefficients were 0.87 for DVA, 0.76 for EM, 0.90 for PV, and 0.88 for MV.[7]

Statistical analysis

The data were analyzed using statistical software SAS 9.4. For participants aged 6–60 years, the independent *t*-test and Chi-square test was used to compare the age and visual acuity grouping between male and female participants, respectively. The 2-way analysis of variance (ANOVA) was used to compare sports vision performance in relation to age group and sex. The procedure of 2-way ANOVA was: (1) interaction between age and sex is examined; (2) if interaction is significant, main effect of age and main effect of sex is meaningless because sports vision performance (dependent variable) varies in different sex depends on different age group, or vice versa; and (3) if interaction is insignificant, main effect of sex and age is meaningful, for instance, when the main effect of sex is significant, we can simply mention that sports vision performance differs between two sexes without worrying which age group is belonging to.[8] For participants aged 18–24 years, a forest plot of sport vision was produced to graphically display the means and 95% confidence intervals for 4 conditions (near/far distance with/without glasses) among the 5 vision groups. Only 2 conditions (near/far distance) were assessed for eye emmetropic participants. Repeated-measures ANOVA with 1 within-factor (4 conditions) was used to analyze how sports vision varied among the four conditions. The significance level was 0.05 in all statistical tests.

Results

Association of sport vision with age and sex at age 6–60 years (n = 310)

One hundred males and 210 females aged 6–60 years were recruited. The males were younger than the females (mean age: 23.86 ± 12.97 years and 27.8 ± 12.55 years, respectively; P = 0.011). Refractive condition did not significantly differ (P = 0.215) between sexes [Table 1].

Two-way ANOVA revealed that there was no age and sex interaction for DVA (P = 0.8248). DVA was significantly associated with age: it increased in males and females from childhood, peaked between 20 and 39 years of age, and gradually decreased during middle age (P < 0.0001). The association with age was similar for males and females, but males had significantly better DVA than females (P = 0.003) [Figure 1a].

Two-way ANOVA also revealed that there were no age and sex interaction for EM, PV, and MV (P = 0.9614, P = 0.6611, P = 0.6399, respectively). EM, PV, and MV had a similar association with age, namely, an increase from childhood until about the age of 25 years and a subsequent decline later in life (three P < 0.001). However, EM, PV, and MV did not differ by sex (P = 0.9470, P = 0.9878, P = 0.0567, respectively) [Figure 1b-d].

Table 1: Demographic characteristics of male and female participants aged 6-60 years (*n*=310)

	Males (*n*=100)	Females (*n*=210)	*P*
Age (years)	23.86±12.97	27.8±12.55	0.011*
Visual acuity			
Normal	24 (24)	36 (17.14)	0.215
logMAR/decimal unit	0.02±0.26/0.96±2.61	0.02±0.16/0.96±1.65	
Mild myopia	30 (30)	49 (23.33)	
logMAR/decimal unit	0.45±0.37/0.36±3.73	0.36±0.38/0.44±3.76	
Moderate myopia	26 (26)	62 (29.52)	
logMAR/decimal unit	0.90±0.19/0.13±1.88	0.89±0.21/0.13±2.06	
Severe myopia	15 (15)	50 (23.81)	
logMAR/decimal unit	0.95±0.14/0.11±1.41	0.95±0.12/0.11±1.17	
Anisometropia	5 (5)	13 (6.19)	
logMAR/decimal unit	0.61±0.48/0.25±4.84	0.76±0.41/0.18±4.13	

logMAR=Logarithm of the minimum angle of resolution. Independent t-test was used to compare the age between males and females; Chi-square test was used to compare the visual acuity grouping between males and females

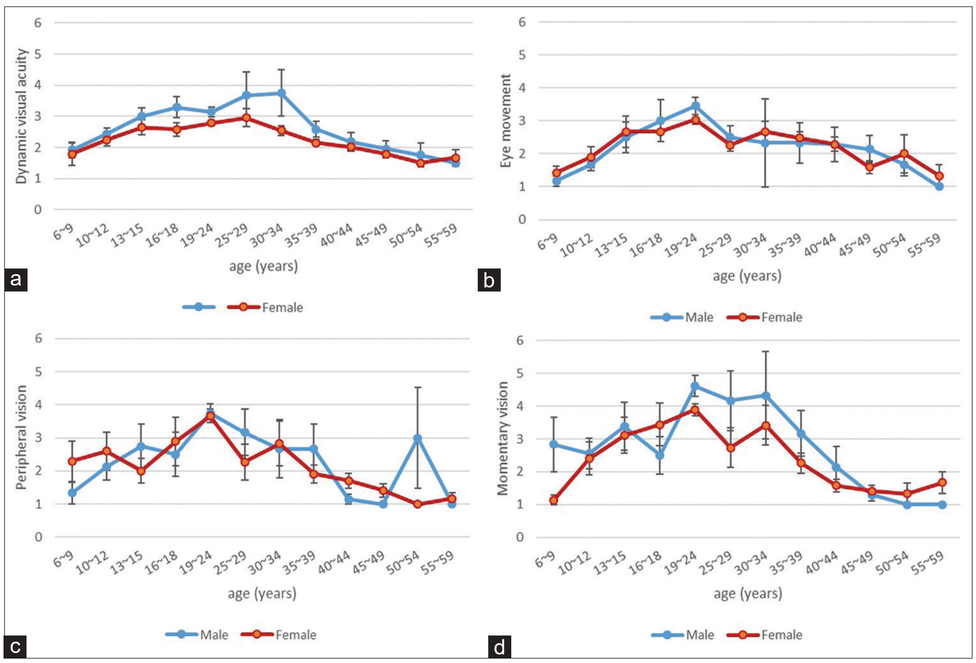

Figure 1: (a) Age trend of dynamic visual acuity (mean ± standard error) in males and females aged 6-60 years (*n* = 310). (b) Age trend of eye movement (mean ± standard error) in males and females aged 6–60 years (*n* = 310). (c) Age trend of peripheral vision (mean ± standard error) in males and females aged 6–60 years (*n* = 310). (d) Age trend of momentary vision (mean ± standard error) in males and females aged 6–60 years (*n* = 310)

Effect of static visual acuity on sports vision at age 18–24 years (*n* = 108)

Among the university students (*n* = 108), the mean age was 20.31 ± 0.79 years and 72.2% was female [Table 2]. Among these 108 young adults, 17 were emmetropic, 26 had mild myopia, 24 had moderate myopia, 32 had severe myopia, and 9 were anisometropic. There was no significant difference in refractive error groups between males and females ($P = 0.517$).

Figure 2a shows DVA performance for best-corrected and uncorrected vision at 45 cm and 2.5 m among the 108 young adults. Young emmetropic adults had similar DVA scores at the near (2.86 ± 0.28) and far distances (3.09 ± 0.38) ($P = 0.27$). For those with mild myopia, there was no significant difference in DVA for the 4 conditions ($P = 0.26$). For those with moderate and severe myopia, DVA was worse without glasses than with glasses ($P < 0.0001$, $P < 0.0001$, respectively), at the near and far distances. In other words, these two subgroups performed significantly worse when they did not wear glasses during the test, regardless of distance. Among those with anisometropia, DVA did not significantly differ for the 4 conditions ($P = 0.76$).

Figure 2b shows EM performance for best-corrected and uncorrected vision at 45 cm and 2.5 m among the 108 young adults. Young emmetropic adults had similar EM at the near (3.24 ± 0.72) and far distances (3.59 ± 0.68) ($P = 0.45$). Among those with mild myopia, there was no significant

Table 2: Demographic characteristics male and female participants aged 18-24 years (*n*=108)

	Males (*n*=30), *n* (%)	Females (*n*=78), *n* (%)	*P*
Age	20.53±0.68	20.23±0.82	0.264
Visual acuity			
Normal	4 (13.33)	13 (16.67)	0.517
logMAR/decimal unit	0.07±0.31/0.86±3.12	0.00±0.06/1.01±0.63	
Mild myopia	10 (33.33)	16 (20.51)	
logMAR/decimal unit	0.55±0.39/0.28±3.91	0.27±0.35/0.53±3.52	
Moderate myopia	4 (13.33)	20 (25.64)	
logMAR/decimal unit	0.88±0.24/0.13±2.39	0.88±0.18/0.13±1.79	
Severe myopia	9 (30)	23 (29.49)	
logMAR/decimal unit	0.91±0.18/0.12±1.77	0.94±0.14/0.12±1.38	
Anisometropia	3 (10)	6 (7.69)	
logMAR/decimal unit	0.51±0.61/0.31±6.11	0.52±0.52/0.30±5.23	

logMAR: Logarithm of the minimum angle of resolution; Independent t-test was used to compare the age between males and females; Chi-square test was used to compare the visual acuity grouping between males and females

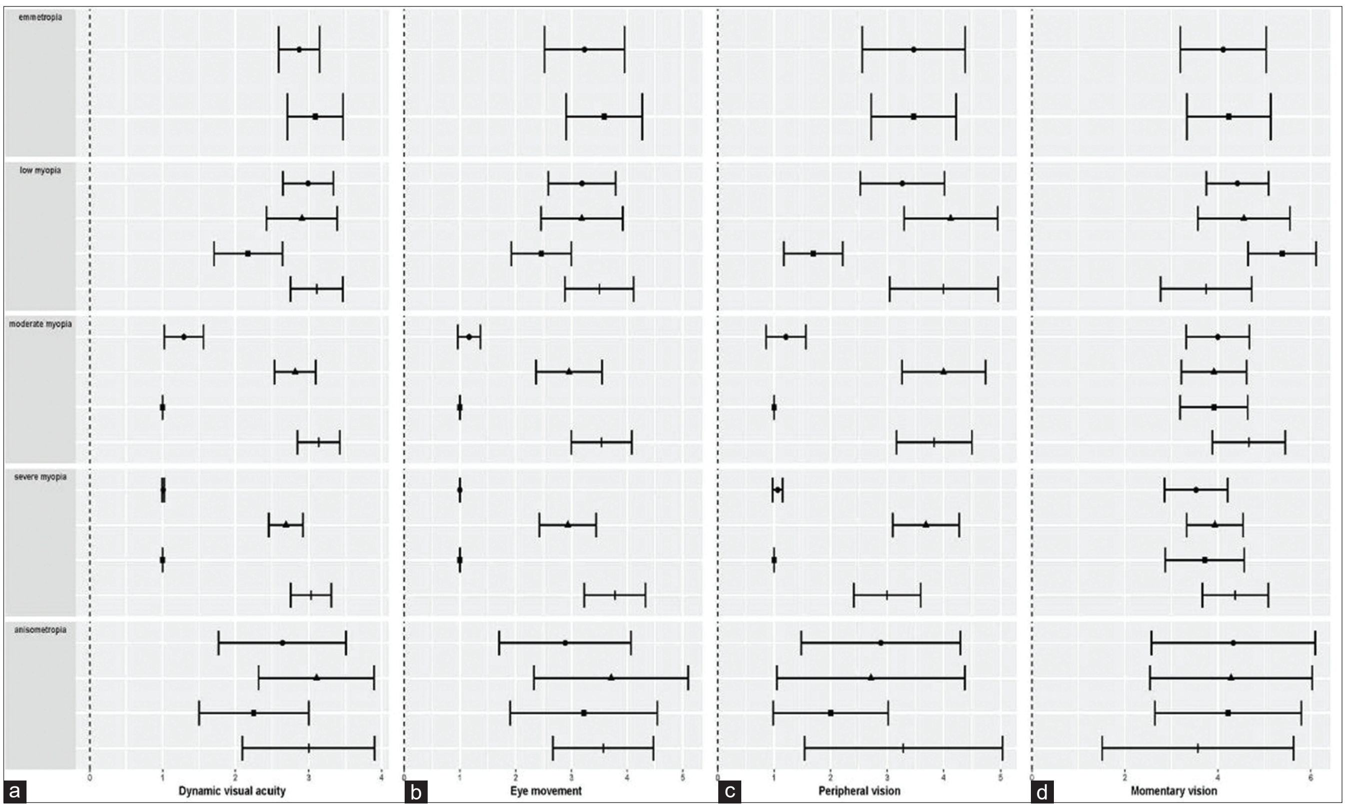

Figure 2: (a) Forest plots of (a) dynamic visual acuity, (b) eye movement, (c) peripheral vision, and (d) momentary vision, with means and 95% confidence interval, measured under 4 conditions. Circles indicate near distance (45cm) without glasses, triangles indicate near distance with glasses, squares indicate far distance (2.5m) without glasses, and crosses indicate far distance with galsses among young adults with various refractive errors (*n*=108)

difference in EM for the 4 conditions (*P* = 0.51). Among those with moderate and severe myopia, EM was worse without glasses than with glasses (*P* < 0.0001, *P* < 0.0001, respectively) at both distances. In other words, these two subgroups performed significantly worse without glasses, regardless of distance. Among those with anisometropia, EM did not significantly differ for the 4 conditions (*P* = 0.93).

Figure 2c shows PV performance for best-corrected and uncorrected vision at 45 cm and 2.5 m among the 108 young adults. Young emmetropic adults had similar PV at the near (3.47 ± 0.91) and far distances (3.47 ± 0.75) (*P* = 0.99). Among those with mild myopia, PV was significantly worse at 2.5 m without glasses than for the other conditions (*P* = 0.01). For those with moderate and severe myopia, PV was worse without glasses than with glasses (*P* < 0.0001, *P* < 0.0001, respectively), at near and far distances. These two subgroups performed significantly worse when they did not wear glasses during the test, regardless of distance. For those with anisometropia, PV did not significantly differ in relation to test condition (*P* = 0.95).

Figure 2d shows MV performance for best-corrected and uncorrected vision at 45 cm and 2.5 m among the 108 young adults. Young emmetropic adults had similar MV at the near (4.12 ± 0.92) and far distances (4.26 ± 0.9) (P = 0.88). Among those with mild, moderate, and severe myopia and those with anisometropia, there was no significant difference in MV for the 4 test conditions (P = 0.15 for mild myopia, P = 0.95 for moderate myopia, P = 0.15 for severe myopia, and P = 0.56 for anisometropia).

Discussion

Association of sport vision with age and sex at age 6–60 years (n = 310)

In this study, we saw DVA significantly increased from childhood in males and females, peaked in the 20 and 39 years of age, and gradually decreased during middle age. The association with age was similar for males and females, but males had significantly better DVA. For the other 3 sports vision parameters – EM, PV, and MV – showed similar age trends, namely, an increase from childhood until the early 20 s and a subsequent decline at later age. However, males and females did not differ in EM, PV, or MV. Hence, it is reasonable to have separate sport race for difference age and sex group to have a fair competition.

For DVA, the age effect and sex difference is consistence with other studies.[9] Vanston and Strother highlighted in their study that sex difference presented in visual processing, with evidence from behavioral, neurophysiological, and neuroimaging studies.[10] Age-related change in DVA in older adults is believed to be caused by decreased retinal illumination rather than by age-related changes in underlying EMs.[11] DVA was challenged more and more recently in more sophisticated task such as running on treadmill.[12] Age effect is more significant as complexity of the task increased.

For EM, we saw an increase from childhood until about the age of 25 years and a subsequent decline later in life, but no difference in males and females. Lee *et al*. also studied the age effect on EM and analyzed more detail by looking into gaze direction. Age-related decline in EM was also reported where upward gaze decline most rapidly.[13] Dowiasch *et al*. debated that the age-related EM changes do not transfer to the real world although their laboratory study also showed significant effect of age on saccade parameters. Dowiasch *et al*. concluded that there was compensation from additional sensory cues, such as head-movement or vestibular signals to this age-related EM deterioration.[14]

For PV, we also saw an increase from childhood until about age 25 years and a subsequent decline later in life, but no difference in males and females. Muiños *et al*. reported that young and older people performed similarly for a PV tasks but young individuals processed faster with minimal cues.[15]

For MV, we also saw an increase from childhood until about age 25 years and a subsequent decline later in life, but no difference in males and females. MV appears to involve the temporary visuospatial memory system, a specialized short-term memory system. Such visuospatial working memory capacity also increases during the child development and declines with age during adulthood.[16,17] Working memory appears to differ between males and females: females consistently show greater activation of limbic (e.g., the amygdala and hippocampus) and prefrontal structures (e.g., the right inferior frontal gyrus), and males show the activation of a distributed network that includes more parietal regions.[18]

Effect of static visual acuity on sports vision at age 18–24 years (n = 108)

We previously investigated sports vision among adolescent soft-tennis athletes with normal vision and those with corrected and uncorrected refractive error and found that performance on DVA, EM, and MV was similar among the three groups.[3] Despite the high prevalence of myopia and severe myopia in Taiwan, the majority of our previous participants had mild or moderate myopia. Without eyeglasses, most were able to view the computer display and had results on sports vision assessments that were similar to those for persons with normal vision or corrected refractive error. However, when viewing a projector screen at 2.5 m, all the myopic participants (with moderate-to-severe myopia) could not do the test in DVA (the score was 1), EM (the score was 1), and PV (the score was 1), but not MV, when they did not wear glasses.

For myopic persons, the range of clear vision depends on myopia severity and age. Among college students (with an average amplitude of accommodation of 10 D), the range of clear vision (for a target with a visual angle of 1 min of arc) is between infinity and 10 cm for emmetropic persons, between 40 and 8 cm for – 2.5 D of myopia, between 20 and 6.6 cm for – 5.0 D of myopia, and between 10 and 5 cm for –10.0 D of myopia. Therefore, persons with low to moderate myopia can have good static vision at near distances but not at far distances. Good uncorrected performance on computer-based sports vision tests should thus not be regarded as equivalent to good uncorrected performance during competition (at far distances). However, with correction, these college students with myopia can have a range of clear vision (infinity to 10 cm) similar to that of emmetropic athletes.

To maintain the visual angle of testing targets in the present study, we used a 15.6-inch laptop computer at 45 cm and an 86.7-inch projector screen at 2.5 m to measure sports vision. When the target size is larger, the range of clear vision is greater. Because the target size in MV testing is about 10 times that of the other 3 sports vision tests, MV performance was independent of myopia severity. Ball size differs across sports, and myopic persons usually do not require correction to play sports with large balls. A study of retinal defocus during basketball shooting found that free-throw performance was significantly reduced only under conditions of +10.00 D lens defocus (equivalent to myopia of −10.0 D).[19]

Few studies have investigated the effect of anisometropia on sports vision. One report studied the relationship between kinetic visual acuity and dynamic stereoacuity and the effects of anisometropia on kinetic visual acuity and dynamic stereoacuity assessment.[20] Kinetic visual acuity was significantly higher for men than for women. Dynamic stereoacuity attributable to kinetic visual acuity; kinetic visual acuity; and dynamic stereoacuity attributable to anisometropia did not significantly differ between sexes and were not strongly correlated. In our study, anisometropia had little effect on sports vision performance. We hypothesized that participants whose 1 eye with emmetropia or low myopia performed relatively well without correction in sports vision tests.

There is a rich literature studying the effect of binocular visual functions among patients with anisometropia. One study showed that the presence of amblyopia has more impact than the amount of anisometropia in causing the deterioration of visual acuity and binocularity.[21] Subjects with amblyopia were excluded in this study; therefore, our anisometropic cases were expected to have some degree of binocularity and could perform well in sports vision test without correction. This is also supported by a study investigated the effect of myopic and hyperopic anisometropia on binocular vision. The study reported that individuals with myopic anisometropia had normal or subnormal stereopsis.[22] Nowadays, a certain portion of patients with presbyopia or cataract were corrected with contact lens or surgery to have monovision, an acquired anisometropia.[23] Such patients also showed minimal compromise in their binocularity, such as stereo acuity, and had a high degree of satisfaction.

While static vision depends mainly on the quality of the eyes and is not trainable, sports vision depends on coordination between the brain and eyes in recognizing objects captured by the eyes. Like many physical abilities, this coordination can be improved and enhanced by effective training. Based on the finding in this study, we suggest correcting the static vision in most sports, especially when refractive error is correctable.

Limitation

First, unlike tests of static vision, sports vision tests are not standardized. Therefore, it is difficult to compare results obtained with different measuring methods. Second, many athletes and coaches now use computer software to measure or train athletes' abilities. It is important to note, however, that computer use presents a very different environment from that in most sport, especially the very short reading distance encountered when using a computer. Third, larger sample sizes and more experiments are needed to draw definitive conclusions. For example, the relationship between low SVA and low sport vision is probably more complicated and is affected by the complex coordination between the brain and eyes. Therefore, further behavioral, neurophysiological, and neuroimaging studies are needed to describe the whole story.

Conclusion

In this study, we used 4 different sports vision tests to assess a wide range of age/sex groups in nonathletic population and noted a significant age-dependent distribution pattern. When using the same testing method to compare the effect of 2 viewing distances for the same participant, we found that low SVA in uncorrected myopia significantly interferes the performance in sport vision tests applied in this study, especially in far distance. Improve static vision, such as myopic correction, might improve sports vision and further improve athletic performance and safety.

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Conflicts of interest

The authors declare that there are no conflicts of interests of this papers.

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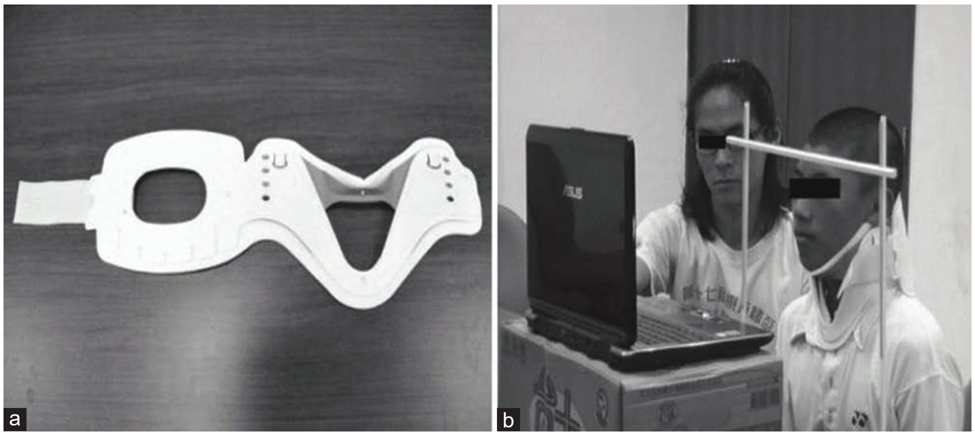
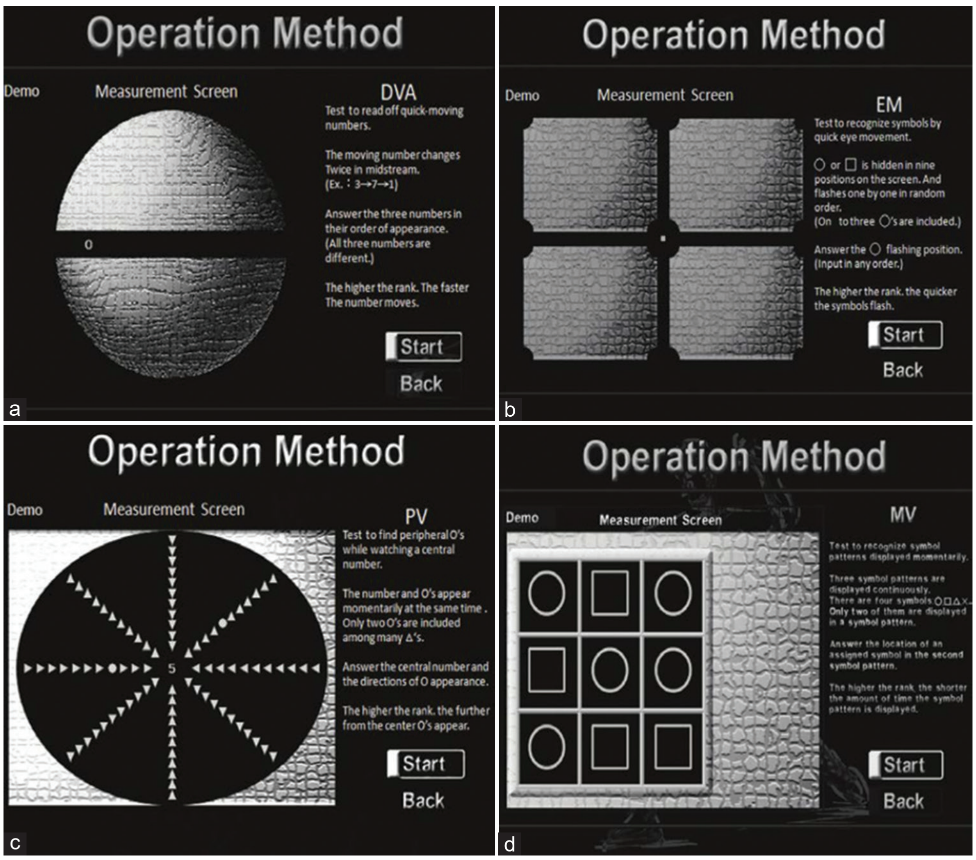
Supplement Figures



Supplement Figure 1: (a) Philly 1-piece Extrication collar. (b) Measuring sports vision



Supplement Figure 2: (a) The display for measuring dynamic visual acuity. (b) The display for measuring eye movement. (c) The display for measuring peripheral vision. (d) The display for measuring momentary vision