Original Article

Comparing sports vision among three groups of soft tennis adolescent athletes: Normal vision, refractive errors with and without correction

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Background: The effect of correcting static vision on sports vision is still not clear. **Aim:** To examine whether sports vision (depth perception [DP], dynamic visual acuity [DVA], eye movement [EM], peripheral vision [PV], and momentary vision [MV],) were different among soft tennis adolescent athletes with normal vision (Group A), with refractive error and corrected with (Group B) and without eyeglasses (Group C). **Setting and Design:** A cross-section study was conducted. Soft tennis athletes aged 10–13 who played softball tennis for 2–5 years, and who were without any ocular diseases and without visual training for the past 3 months were recruited. **Materials and Methods:** DPs were measured in an absolute deviation (mm) between a moving rod and fixing rod (approaching at 25 mm/s, receding at 25 mm/s, approaching at 50 mm/s, receding at 50 mm/s) using electric DP tester. A smaller deviation represented better DP. DVA, EM, PV, and MV were measured on a scale from 1 (worse) to 10 (best) using ATHLEVISION software. **Statistical Analysis:** Chi-square test and Kruskal–Wallis test was used to compare the data among the three study groups. **Results:** A total of 73 athletes (37 in Group A, 8 in Group B, 28 in Group C) were enrolled in this study. All four items of DP showed significant difference among the three study groups ($P = 0.0051$, 0.0004, 0.0095, 0.0021). PV displayed significant difference among the three study groups ($P = 0.0044$). There was no significant difference in DVA, EM, and MV among the three study groups. **Conclusions:** Significant better DP and PV were seen among soft tennis adolescent athletes with normal vision than those with refractive error regardless whether they had eyeglasses corrected. On the other hand, DVA, EM, and MV were similar among the three study groups.

Key words: Adolescent athletes, correcting refractive error, soft tennis, sports vision, static vision

Both static vision and sports vision play an important role in the athletic performance in many sports. Static acuity often refers to the ability of our eyes seeing the detail of a stationary object distinctly.[1] Sports vision is the visual abilities necessary for sports,[2] including depth perception (DP), dynamic visual acuity (DVA), eye movement (EM), peripheral vision (PV), momentary vision (MV), etc.

Association between static vision and sports vision is still controversial. Weissman and Freeburne reported that static acuity had a significant linear relationship at the first four speeds (20, 60, 90, 120°/s) and disappeared at the two highest speed (150 and 180°/s) among female college students.[3] Kakiyama *et al.* showed high correlation between static visual acuity (SVA) and kinetic visual acuity among high school rugby players (0.798, $P < 0.001$).[4] Nakatsuka *et al.* have shown high correlation between static and DVA in healthy adults (0.87, $P < 0.001$).[5] On the other hand, Zinn and Solomon found no correlation between static and dynamic responses (Titmus and TNO stereoacuity test).[6] Fergenson and Suzansky showed that DVA (viewed Landolt ring targets that were presented as slide projections on a rear projection screen) and SVA (Landolt ring) were not significantly correlated.[7]

Interestingly, only a few studies were performed to investigate the effect of correcting static vision on sports vision. Kakiyama *et al.* reported that kinetic visual acuity in high school rugby players were significantly improved after their SVA was corrected.[4] Nakatsuka *et al.* reported that significant improvement in DVA was seen when the refractive error was fully corrected, and such improvements were not altered by the manipulation order of static acuity.[5]

In reality, many athletes do not correct their static vision when playing sports. Beckerman and Hitzeman reported that 44.6% young athletes aged 5–19 years old did not correct their refractive error during Junior Olympic.[8] As a coach of soft tennis adolescent athletes, I also observed that many myopic athletes played soft tennis without wearing eyeglasses or contact lens. Their vision data provides us an excellent opportunity to study the effect of correcting static vision on sports vision parameters.

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In this study, sports visions (DP, DVA, EM, PV, and MV) were compared among three study groups of soft tennis adolescent athletes. Group A were those who had normal vision, Group B were those who had refractive error and corrected with eyeglasses, and Group C were those who had refractive error but did not correct with eyeglasses.

Materials and Methods

Study subjects

Soft tennis athletes, who were age 10–13, had been playing soft tennis for 2–5 years, did not have any eye problems, and had not received any visual training within last 3 months, were eligible for this study. This study was approved by the Institutional Review Board of the study institute. All subjects signed the informed consent form after explanation of nature and possible consequences of the study.

Static visual acuity

A Canon CV-20 static visual tester was used. SVA in decimal acuity for both eyes were printed afterward. Because of its geometric nature, SVA was converted to the logarithm of the minimum angle of resolution (LogMAR) chart before averaging and converted back to decimal acuity[9] as below:
- LogMAR = −log (decimal acuity)
- Decimal acuity = antilog (−LogMAR)=$10^{-LogMAR}$

For subjects who wore eyeglasses when playing soft tennis, they took varied visual measurements with eyeglasses. For subjects who did not wear eyeglasses when playing soft tennis, they took varied visual measurements without eyeglasses.

Depth perception

DP was measured using electric DP tester (Takei Kiki Kogyo Co., Ltd., Japan). There are three rods of same height inside the tester. The two rods on both ends are fixed permanently while the middle rod is movable forward (approaching) and backward (receding) the subject at two speeds (25 mm/s and 50 mm/s) [Fig. 1a]. A subject sat at a distance of 2.5 m apart from the tester and looked at the rods through a window (18 cm × 9 cm). He/she was asked to press a switch when he/she saw the straight alignment of the three rods [Fig. 1b]. The absolute deviation between the middle rod and fixed rods was recorded. The smaller the deviation (cm)

was on identification, the better the DP was. Subjects practiced thrice and then started the test. Four DP items (approaching at 25 mm/s, receding at 25 mm/s, approaching at 50 mm/s, receding at 50 mm/s) was given thrice. For each item, the one with the highest value was ignored, and the average of the rest of two deviations was used for analysis.

Dynamic visual acuity, eye movement, peripheral vision, momentary vision

DVA, EM, PV, and MV were measured using the ATHLEVISION software, a commercially manufactured product (ASICS Corporation, Japan). This software was installed in a 15.6 inch laptop computer with liquid crystal display monitor (luminance = 281 cd/m^2, resolution = 1600 × 900, response speed = 16 ms). The room illuminance was in the range between 520 and 710 Lux. Subjects wore the Philly one-piece extrication collar [Fig. 2a] to secure their head stationary, and faced to a 15.6-inch laptop computer 45 cm apart by placing his/her forehead on the restriction bar [Fig. 2b]. The order of giving tests for sports visions was DVA, EM, PV, and MV. There was 1 min break before giving the next tests. Each test had a scale from 1 to 10, and the higher scores represented a better ability.

DVA is the ability to correctly identify moving objects. In the DVA test, the moving number changes twice in either horizontal or vertical midstream. When the start icon was pressed, a subject was asked to read off the quick-moving numbers. If the subject gave the correct numbers, the speed of changing numbers increased (one level up). When giving wrong numbers, the subject took the same speed test again. After subjects continuously made two mistakes, the speed decreased (one level down). When the subject made three mistakes in a row, this test was ended [Fig. 3]. The DVA was computed as below:
- DVA = horizontal DVA + vertical DVA
- Horizontal DVA = DVA (left) + DVA (right)
- Vertical DVA = DVA (up) + DVA (down).

EM is the ability to recognize symbols by quick EM. Symbol ● or ■ is hidden in nine positions (four corners of the squares and one center) on the screen and flashed one at a time in random order. When the start icon was pressed, the subject was asked to answer the ● flashing position. When he/she gave
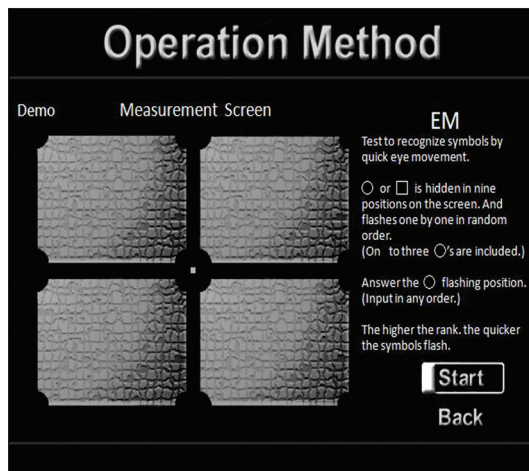

Figure 1: (a) Electric depth perception tester (inside). (b) Measuring depth perception
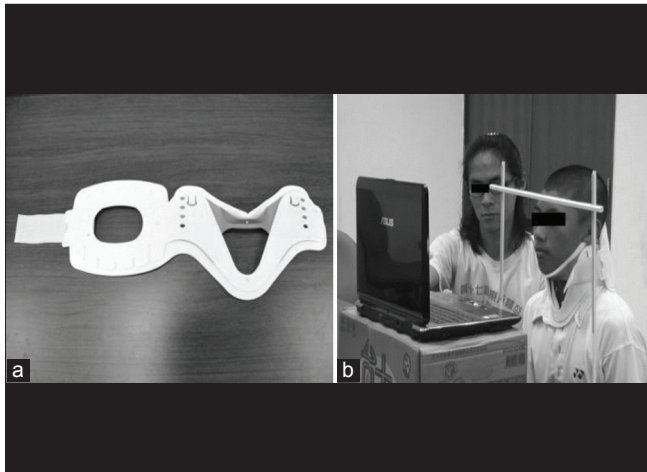
Figure 2: (a) Philly one-piece extrication collar. (b) Measuring sports vision
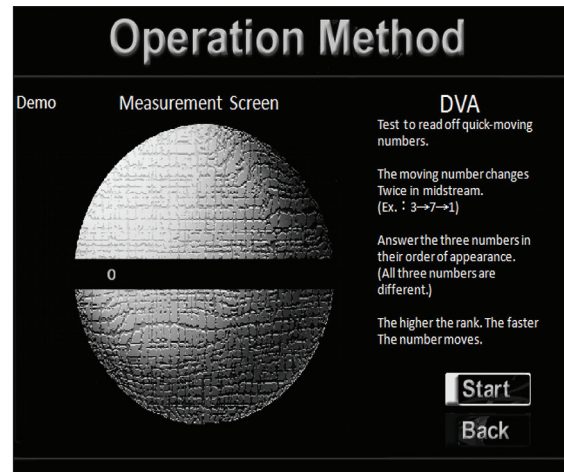
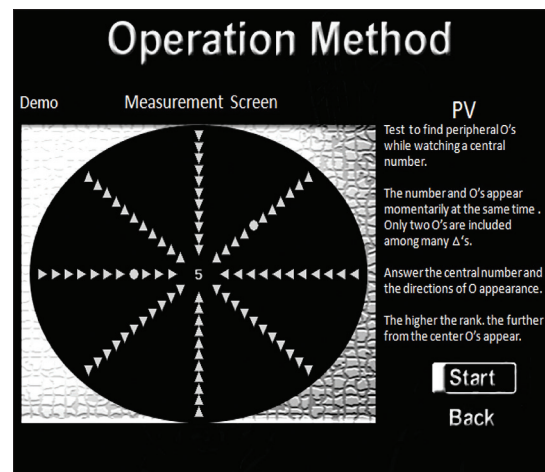**Figure 3:** The screen measuring dynamic visual acuity

Figure 4: The screen measuring eye movement

Figure 5: The screen measuring peripheral vision

the correct answer, the speed increased (one level up). When he/she gave the wrong answer, the speed was decreased (one level down). The test was ended when he/she made three mistakes in a row [Fig. 4].

PV is the ability to view peripheral objects without moving one's eyeballs when staring at a target object. In the PV test, there was an ellipse with eight lines which were made up of many ▲'s with a number appearing in the center. When the start icon was pressed, the central number and only two ●'s which were included among many ▲'s, appeared momentarily at the same time. The subject was asked to watch the central number and find peripheral ●'s. When he/she gave the correct answer, the distance between ● and the center increased (one level up). When he/she gave the wrong answer, the distance was decreased (one level down). The test was ended when the subject made three mistakes in a row, and the score was recorded [Fig. 5].

MV is the ability to recognize symbol patterns displayed momentarily. In the MV test, a 3 by 3 grid was displayed on the screen. Three symbol patterns, which were consisted of two of four symbols (○, X, △, □), were displayed with random order continuously. The subject was asked to find the location

of an assigned symbol in the second symbol pattern. When he/she gave the correct answer, the speed of changing symbols increased (one level up). When he/she gave the wrong answer, the speed of changing symbols was decreased (one level down). The test was ended when he/she made three mistakes in a row [Fig. 6].

Reliability of measurements

Stability of the measurements was assessed by 26 elementary school students who took the measures twice at the same hour on two consecutive days. Good reliability was obtained for the electric DP tester and the ATHLEVISION software. The intraclass correlation coefficients were: Four items of DP = 0.77–0.87, DVA = 0.87, EM = 0.76, PV = 0.90, MV = 0.88.

Statistical analysis

The Chi-square test was made to compare the gender among three study groups. Normality of continuous data was examined using Shapiro–Wilk test.[10] The Kruskal–Wallis test was used to compare sports vision among three study groups. When significance was seen, multiple comparisons were made using the Wilcoxon rank sum test, and the significant level was reset at 0.017 (=0.05/3), based on Bonferroni correction.[11] The significant level was set at 0.05.

Results

From February to June 2012, 73 soft tennis adolescent athletes (37 in Group A, 8 in Group B, and 28 in Group C) were recruited from nine primary schools. Group A and Group B had good SVA. Group C had the worse mean SVA [Table 1].
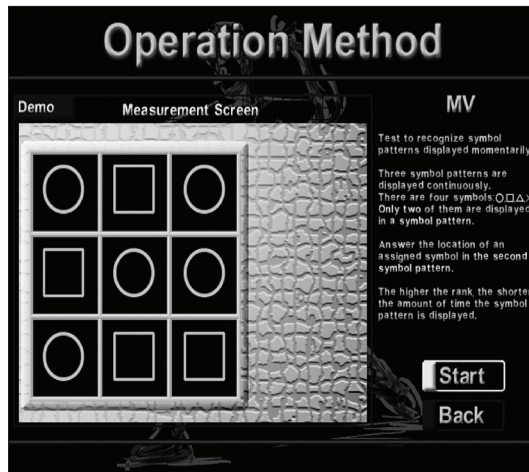

Figure 6: The screen measuring momentary vision

The mean age was 11.7 years old with a range between 11 and 13. The mean duration of playing soft tennis was 3.2 years with a range between 2 and 5 years. Almost half of the athletes won championships at national contests, and 31.5% won the second to the fourth prize at national contests. There was no significant difference in soft tennis ranking among the three study groups. There was no difference in body weight, body height, and body mass index among three study groups [Table 1].

A significant difference in all four items of DP among the three study groups was seen. Group A had significantly better DPs than Group B and Group C [Table 2].

For DVA, significant difference in horizontal ($P = 0.5376$), vertical ($P = 0.1280$) and total ($P = 0.4451$) was not seen among three study groups. There was no significant difference in EM ($P = 0.6310$) and in MV ($P = 0.8850$) among the three study groups. For PV, a significant difference was seen among three study groups ($P = 0.0044$) [Table 2].

Discussion

Depth perception

In this study, DP was measured in a distance of 2.5 m apart. Hence, it is reasonable to see the worst DP in Group C than Group A as Group C did not correct their SVA. Previous studies showed that SVA is correlated with DP.[1] In this study,

Table 1: Demographic, body weight, body height, BMI, and static vision among three groups of soft tennis adolescent athletes (*n*=73)

	Total (*n*=73)	Group A (*n*=37)	Group B (*n*=8)	Group C (*n*=28)	P
Gender (%)					
Male	51 (69.9)	29 (78.4)	4 (50.0)	18 (64.3)	0.2032*
Female	22 (30.1)	8 (21.6)	4 (50.0)	10 (35.7)	
Age (years) (%)	11.7±0.7	11.5±0.6	12.3±0.9	11.9±0.6	0.0026†
11	29 (39.8)	20 (54.1)	2 (25.0)	7 (25.0)	0.0118‡
12	35 (48.0)	16 (43.2)	2 (25.5)	17 (60.7)	
13	9 (12.3)	1 (2.7)	4 (50.0)	4 (14.3)	
Duration of playing soft tennis (years)	3.2±0.7	3.2±0.8	3.6±0.6	3.0±0.5	0.0990†
Soft tennis ranking (%)					
1	35 (48.0)	15 (40.5)	3 (37.5)	17 (60.7)	0.1589‡
2	23 (31.5)	12 (32.4)	3 (37.5)	8 (28.6)	
3	9 (12.2)	7 (18.9)	2 (25.0)	0 (0.0)	
4	6 (8.2)	3 (8.1)	0 (0.0)	3 (10.7)	
Body weight (kg)	39.3±7.4	40.1±8.1	37.7±8.5	38.8±6.1	0.7036†
Body height (cm)	147.3±8.2	147.3±8.4	147.5±11.9	147.3±6.9	0.9923†
BMI (kg/cm^2)	18.0±2.2	18.3±2.5	17.1±1.7	17.8±1.9	0.4836†
Static visual acuity (LogMAR/decimal unit)					
Left eye	0.04±0.28/0.91±2.8**	−0.10±0.08§/1.25±0.8**	−0.11±0.06§/1.28±0.6**	0.27±0.32‖/0.53±3.2**	<0.0001†
Right eye	0.02±0.25/0.95±2.5**	−0.12±0.06§/1.31±0.6**	−0.13±0.05§/1.34±0.5**	0.25±0.26‖/0.56±2.6**	<0.0001†
Mean	0.03±0.24/0.93±2.4**	−0.11±0.05§/1.28±0.5**	−0.12±0.05§/1.31±0.5**	0.26±0.24‖/0.54±2.4**	<0.0001†

*Chi-square test, †Kruskal-Wallis test, ‡Chi-square test for trend, §,‖Multiple comparison: Different symbols represent a significant difference between groups and same symbols represent no difference between groups, **SD of SVA in the decimal unit was expressed as lines in Snellen units. Group A: Had a normal vision, Group B: Had refractive error and corrected with eyeglasses, Group C: Had refractive error but did not correct with eyeglasses. LogMAR: Logarithm of the minimum angle of resolution, Soft tennis ranking - 1: Won first prize at national contests, 2: Won second to fourth prize at national contests, 3: Won fifth prize at national contests or won first to fourth prize at county contests, 4: Won fifth prize or below at county contest or did not won any prize in either national or county contests, SD: Standard deviation, BMI: Body mass index

Table 2: Depth perception, dynamic visual acuity, eye movement, peripheral vision, and momentary vision among three groups of soft tennis adolescent athletes (n=73)

	Total (n=73)	Group A (n=37)	Group B (n=8)	Group C (n=28)	P*
Depth perception (cm)					
Approaching at 25 mm/s	1.23±0.74	0.97±0.55†	1.21±0.29†‡	1.59±0.90‡	0.0051
Receding at 25 mm/s	1.15±0.89	0.77±0.63†	1.44±0.98‡	1.56±0.97‡	0.0004
Approaching at 50 mm/s	1.37±0.95	1.03±0.67†	1.82±0.86‡	1.69±1.14‡	0.0095
Receding at 50 mm/s	1.06±0.77	0.78±0.52†	1.05±0.92†,‡	1.43±0.86‡	0.0021
Dynamic visual acuity					
Horizontal	5.58±1.55	5.84±1.62	5.38±0.92	5.29±1.58	0.5376
Vertical	5.45±1.84	5.41±1.77	4.50±0.93	5.79±2.06	0.1280
Total	11.03±2.79	11.24±2.84	9.88±1.25	11.07±3.03	0.4451
Eye movement	2.36±1.10	2.32±1.08	2.63±0.74	2.32±1.22	0.6310
Peripheral vision	3.56±1.88	4.30±1.58†	2.50±2.00‡	2.89±1.87‡	0.0044
Momentary vision	2.32±1.60	2.19±1.47	2.88±1.96	2.32±1.68	0.8850

*Kruskal-Wallis test, †,‡Multiple comparison: Different symbols represent significant difference between groups and same letters represent no difference between groups. Group A: Had normal vision, Group B: Had refractive error and corrected with eyeglasses, Group C: Had refractive error but did not correct with eyeglasses

Group C had worse DP than Group B, although a significant difference was not reached. We suspect that the magnitude and duration of refractive error was worse in Group B and in Group C. Hence Group B wore eyeglasses, and Group C did not wear eyeglasses. Not enough statistical power due to small sample size may be another reason for the insignificance of DP between Group B and Group C.

The speed[12] and mode (approaching or receding)[13] of the moving object are two important determinants of DP, as has been demonstrated previously.[14] In this study, we saw the shorter deviation of DP in receding mode than the approaching mode in both speeds. This implies that detecting a deviation from receding mode is easier than approaching mode in a distance of 2.5 m apart, which concurs with an anisotropic response to motion in depth in the human visual system.[15] In this study, better DP in a slower speed (25 mm/s) than in faster speed (50 mm/s) was seen in approaching mode, but not in receding mode. It is not clear why slow speed displayed worse DP in receding mode. A bigger sample size and more investigation on this issue are needed for future study.

Dynamic visual acuity, eye movement, momentary vision

It is well-known that individuals with refractive error do not have problems seeing things nearby. In this study, other sports vision parameters were measured at a distance of 45 cm apart. Hence, we did not see significant differences in DVA, EM, and MV among the three study groups. Nakatsuka et al. have shown significant improvement in DVA (80 cm apart) after the refractive error was fully corrected (20/20) regardless the order of correction. The distance of 45 cm (this study) and 80 cm (Nakatsuk's) is good reason for the discrepancy between ours and Nakatsuk's.[5]

Peripheral vision

On the other hand, we saw that PV is significantly better among Group A than Group B and Group C in this study, despite the fact that PV was measured at a distance of 45 cm apart. Regarding the difference in PV between Group A and Group C, the difference may be related to a disparate focal length between the central and peripheral retina. The axial elongation of myopic eyes leads to a worse PV while accommodating at center in Group C. The difference in PV between Group A and Group B may be related to a visual field restriction of the spectacle frame and/or a disparate focal length peripherally in axial myopic eyes.[16] Bakaraju et al. found that pantoscopic tilt of the correcting lens may induce dioptic change of refraction and astigmatism, and such effect becomes worse peripherally.[17]

Not wearing eyeglasses among adolescent athletes with refractive error

In this study, 77.8% (=28/[8 + 28]) of adolescent athletes with refractive error did not wear eyeglasses when playing soft tennis, higher than the finding in a previous survey of young athletes (44.6%).[8] In this study, the reasons why Group C did not wear eyeglasses when playing soft tennis were (1) uncomfortable, (2) their parents thought their refractive error was an accommodation spasm.

Sports vision affects sport performance

Visual ability plays an important part in many activities, especially sports performance in athletes. However, there is no significant difference in soft tennis ranking among the three study groups in this study. It is possible that the athletes were still very young, and their magnitude of refractive error was not very serious. Unfortunately, onset time and magnitude of refractive error was not measured in this study.

Buckolz et al.[18] consider good DP as an important visual requirement in playing tennis, especially when driving the ball. When the DP is not good, it is difficult to judge both the velocity and spatial distance of an incoming ball and may make mistakes in hitting the ball. Within a very short time, a soft tennis player needs to judge the position and direction of an incoming ball by using their DVA and DP. Simultaneously, find out the dead space of the opposite player by the aids of PV and EM, and adjust the swing force and direction of their racquets with the help of MV to hit back the ball. In comparison with other sport, soft tennis players need better sports vision to achieve a higher performance. In this studies, an abnormal SVA with or without correction had a significant impact in DP and PV. Further study is required to investigate such effects on the real games.

Limitation

First, our sample size was too small, and this is particularly serious for Group B and Group C. On the other hand, we obtained the prevalence of refractive error and proportion of not correcting refractive error in soft tennis adolescent athletes. Second, duration and degree of refractive error in Group B and Group C was unknown. Third, we could not compare our findings to others, because there is little or no standard measurement of sports vision.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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