Paper

The Role of Soccer in Slowing the Decline of Visual Function Caused by Aging: a Study of Young and Middle-aged Subjects

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The general decline of visual function is one of the many physical changes that occur as a result of the aging process. This study was conducted to identify the effects that daily soccer activity has on the following eight visual functions: static visual acuity (SVA), kinetic visual acuity (KVA), dynamic visual acuity (DVA), contrast sensitivity (CS), depth perception (DP), ocular motor skill (OMS), visual reaction time (VRT), and eye/hand coordination (E/H). Young and middle-aged subjects were examined in this study. Two findings were confirmed. First, decrease in KVA, DVA, VRT and E/H with age was observed. Next, results suggest that soccer blunted the decrease with age or improved the function of DVA and OMS. Future studies should include the effect of innate ability on the visual function and use longitudinal study methods to more precisely clarify the effects of daily soccer activity on visual function.

Key words : visual function, aging, exercise habit

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1. Introduction

Aging and health are influenced by genetic factors and external conditions such as nutrition, environment and exercise. There are, therefore, significant differences in the effects of aging and the status of health among individuals at the same chronological age. Tanaka (1999) attempted to estimate vital age biologically. Tanaka and Hiyama (1994) reported that improvement of lifestyle through diet and exercise significantly improved vital age.

It is estimated that approximately 70% of information used in daily life and greater than 99% of information used while engaged in sporting activity is visual (Shoke, 2002). Similar to the majority of physiological functions, though with some variation by specific item, vision is known to reach a peak between 15 and 20 years of age, and decline thereafter (Ishigaki and Miyao, 1994). However, Ishigaki and Yoshii (2001) reported that exercise during childhood increased visual function, which suggests the potential benefit of developing the habit of exercise and participation in sports in preventing the deterioration of visual function and contributing to the improvement of quality of life. However, while some investigators have examined visual function, such studies have focused on specific functions rather than on visual function as a whole.

Soccer enjoys immense popularity around the globe and is played by individuals both young and old. According to the Visual Performance Skill Importance Scores for Individual Sports established by the American Optometric Association – Sports Vision Section (AOA-SVS), soccer requires seven out of nine visual functions (level 4 or 5 on a 5-point scale). While soccer requires highly developed visual function, it is also thought that participation in games contributes to the development of visual function. Available studies on visual function, however, focus on differences by performance level (Ishigaki, 1990) and the relationship between visual function and performance (Kato and Inoue, 2001). Therefore, there may be significant benefit in clarifying the impact of participation in sports that require highly developed visual function on changes in visual function due to aging.

In this study, we examined the role of soccer in slowing the decline of visual function caused by aging in young and middle-aged subjects based on eight visual functions.

2. Method

2.1. Subjects

Mashimo (2002b) reported that the ideal corrected binocular visual acuity in non-ball sports is 1.2 to 1.5, and at least 0.7 in ball sports. Subjects of this study were males with uncorrected or corrected binocular static visual acuity of 0.8 or higher. Subjects were classified into four groups; young subjects with no exercise habit, young subjects who play soccer three or more times per week (playing one hour or more each time), middle-aged subjects with no exercise habit, and middle-aged subjects who play soccer one or two times per week (playing one hour or more each time).

Subjects were 24 young subjects who play soccer but do not participate in other sports (age: 20.2±1.9, frequency: 4.9±0.7 times per week) (Young Soccer Group), 20 young subjects who do not have the habit of regularly exercising (age: 22.3±1.8) (Young Non-exercise Group), 20 middle-aged subjects who play soccer but do not participate in other sports (age: 44.5±2.8, frequency: 1.2±0.4 times per week) (Middle-aged Soccer Group), and 25 middle-aged subjects who do not have the habit of regularly exercising (Middle-aged Non-exercise Group). Corrected visual acuity was measured for playing soccer for Young and Middle-aged Soccer Groups, and for daily work for Young and Middle-aged Non-exercise Groups. Six subjects in the Young Soccer Group had corrected vision using contact lens, and seven subjects in the Young Non-exercise Group had corrected vision using contact lenses (five subjects) and eyeglasses (two subjects). Eight subjects in the Middle-aged Soccer Group had corrected vision using contact lenses (five subjects) and eyeglasses (three subjects), and 10 Middle-aged Non-exercise Group subjects had corrected vision using contact lenses (three subjects) and eyeglasses (seven subjects).

In accordance with the Declaration of Helsinki, we explained the purpose of this study to all individuals and only enrolled those who gave informed consent.

2.2. Measurement Items

The Japan Sports Vision Academy was established in 1987. The association established eight measurement items based on the correlation between individual sports performance skills and 17 visual performance skills required for sports created by the AOA-SVS (Mashimo, 1994). This study adopted the eight measurement items established by the Sport Vision Research Association of Japan. The adopted measurement items are described below.

1) Static visual acuity (SVA)

Static visual acuity (SVA) is a basic visual function. Measurement of SVA involves having the subject identify the smallest target possible. If the subject can correctly identify a Landolt ring printed with a line measuring 1.5mm wide, 7.5mm in diameter, and a 1.5mm gap from 5 meters away, SVA is recorded as 1.0. The measurement in this study was conducted for both eyes utilizing the AS4A Kinetic Vision Tester (Kowa Company, Ltd.).

2) Kinetic visual acuity (KVA)

Kinetic visual acuity (KVA) is the ability to recognize an incoming target. KVA was measured utilizing the AS4A Kinetic Vision Tester. The AS4A shows a Landolt ring coming toward the subject at a speed of 30km per hour covering a distance of from 50m to 2m from the subject. The target size is set equivalent to a visual acuity of 1.0 at a distance of 30m from the Landolt ring. Subjects were asked to indicate when they recognize the gap in the Landolt ring by activating a switch on the device, and the figures converted from the distance were measured. Subjects were allowed to practice twice each, and then were measured five times. Mean values were calculated for use in analysis

3) Dynamic visual acuity (DVA)

Dynamic visual acuity (DVA) is the ability to recognize a target moving laterally. DVA was measured utilizing the IH10 (Kowa Company, Ltd.). Subjects are required to trace a 90-degree Landolt ring moving from left to right on a hemispherical screen utilizing eye movement only. The speed is set at 40rpm and is gradually decreased. The speed at which the subjects recognize the gap of the Landolt ring was used as a parameter. Subjects were allowed to practice twice before being measured five times. Mean values were calculated for use in analysis.

4) Contrast sensitivity (CS)

Contrast sensitivity (CS) is the ability to recognize subtle degrees of contrast. CS was measured utilizing an E Pattern (spatial frequency: 18c/d) of the Vision Contrast Test System panel (Vistec Consultants, Inc.). Thin vertical lines are drawn in circles in black and white in eight degrees of contrast. CS was evaluated by checking the ability of the subject to judge the orientation of the lines.

5) Depth perception (DP)

Depth perception (DP) is the ability to judge perspective. DP was measured utilizing CP250 (Kowa Company, Ltd.). A rod moves back and forth between two rods fixed in the middle. The gap between the location where subjects recognize the three rods in a line sideways and the central point is measured. Subjects were measured three times, and the DP was evaluated utilizing the average of absolute values of gaps (mm).

6) Ocular motor skill (OMS)

Ocular motor skill (OMS) is the ability to trace rapidly moving objects. OMS was measured utilizing eye movement measurement software (Kowa Company, Ltd.). A green circle (dummy target) measuring approximately 5mm diameter moves fast on a dark green background on a computer display at 0.5 second intervals. Yellow-green circles (main target) appear at a ratio of one to five. Subjects are positioned 30cm from the display and are asked to identify the target using eye movement alone. Subjects press the space key on the keyboard when they identify the main target and correct responses are tallied. Fifty main targets appeared on the display during the test. Each correct response was valued at 2 points, and the rate of correct response was calculated as a percentage.

7) Visual reaction time (VRT)

Visual reaction time (VRT) is the ability to acquire information instantaneously. VRT was measured utilizing spontaneous eye ability measurement software (Kowa Company, Ltd.). A six-digit number was shown on a computer display for 100msec. and subjects were asked to enter the number on the keyboard. Measurements were taken three times and the number of correct responses out of 18 was recorded.

8) Eye/Hand coordination (E/H)

Eye/Hand coordination (E/H) is the ability to quickly respond to identified targets. E/H was measured utilizing AcuVision 1000 (U.S. AcuVision). A total of 120 touch sensors that light in red were installed into a 150×120cm panel. Subjects were asked to press the randomly lighted touch sensors and were evaluated based on the time required to finish pressing all sensors in the series.

2.3. Analysis

We compared group performance by age and participation in soccer. Decimal visual acuity in general does not, however, indicate distance according to function, or normal distribution; therefore, statistical values were calculated by logarithmic conversion rather than arithmetic average. For this reason, decimal visual acuity of SVA and KVA in this study was logarithmically converted, and figures obtained were calculated to obtain mean values and dispersions. Two-way ANOVA was conducted for the eight visual functions adopted utilizing age difference and participation in soccer, and significance was set at 0.5 or lower.

3. Results

With the exception of DP and E/H, the higher the measurement values are, the better the function is. In the case of DP and E/H, because DP measures gaps (mm) and E/H is a measure of time (sec.), the lower the values of these two are, the better the function is.

3.1. Relationships among Measurement Items

Table 1 shows the correlation coefficient of visual functional between items. Strong correlation was seen between logSAV and logKVA ($r=0.670$, $p<0.001$), logSVA and CS ($r=0.481$, $p<0.001$), logKVA and CS ($r=0.400$, $p<0.001$), DVA and E/H ($r=-0.331$, $p<0.001$), and OMS and E/H ($r=0.500$, $p<0.001$).

3.2. Comparison of Results

Table 2 shows results for visual function parameters including mean values and standard deviations for the Young Soccer Group, Young Non-exercise Group, Middle-aged Soccer Group, and Middle-aged Non-exercise Group, with the results of two-way ANOVA on the impact of age difference and participation in soccer. Impact of age difference showed significant difference in logKVA ($p<0.05$), DVA ($p<0.001$), VRT ($p<0.01$), and E/H ($p<0.001$) in Young Groups. Impact of participation

Table 1. Correlation coefficient of visual function evaluation items

	log SVA	log KVA	DVA	CS	OMS	DP	VRT	E/H
log SVA	1							
log KVA	0.670	1						
DVA	0.169	0.250	1					
CS	0.481	0.400	−0.050	1				
OMS	0.235	0.201	0.212	0.075	1			
DP	−0.297	−0.073	0.002	−0.187	−0.114	1		
VRT	0.042	0.100	0.220	−0.027	0.187	0.066	1	
E/H	−0.256	−0.198	−0.331	−0.031	−0.500	−0.060	−0.281	1

Table 2. Visual function parameters among groups

	Youth		Middle		Two-way analysis of variance		
	soccer (n=24)	non-exercise (n=20)	soccer (n=20)	non-exercise (n=25)	age	exe	age × exe
log SVA	0.104 ± 0.101	0.043 ± 0.084	0.020 ± 0.101	0.037 ± 0.074			
log KVA	−0.139 ± 0.145	−0.239 ± 0.179	−0.260 ± 0.124	−0.297 ± 0.214	*		
DVA (rpm)	37.375 ± 0.912	36.109 ± 2.196	35.043 ± 1.722	32.968 ± 3.861	***	**	
CS (point)	6.042 ± 0.806	6.400 ± 0.681	6.350 ± 0.745	6.160 ± 0.943			
DP (mm)	15.380 ± 13.824	10.038 ± 5.328	16.533 ± 17.926	10.996 ± 7.785		*	
OMS (%)	73.250 ± 12.824	68.400 ± 13.667	60.353 ± 16.466	61.200 ± 14.877		**	
VRT (point)	13.667 ± 3.332	16.150 ± 2.601	13.400 ± 2.563	13.200 ± 2.500	**		*
E/H (sec)	84.208 ± 6.433	84.510 ± 3.627	93.100 ± 8.867	91.056 ± 6.014	***		

* p<0.05 ** p<0.01 *** p<0.001

in soccer showed significant difference in DVA (p<0.01) in Soccer Group, DP (p<0.05) in Non-exercise Group, and OMS (p<0.01) in Soccer Group. Significant interaction was seen in VRT (p<0.05) only.

4. Discussions

4.1 Correlation among Measurement Items

Similar to the findings reported by Okubo et al. (2000), this study found a strong correlation among SVA, KVA and CS. SVA had a significant impact on KVA and CS; therefore, it is important to ensure appropriate visual correction for improvement of ability. Similarly, it was also suggested that improvement of DVA may have a significant impact on the improvement of E/H. In addition, the possible impact of OMS on KVA has been predicted (Okubo et al., 2000); however, this study revealed no significant correlation between the two factors; however, it revealed significant correlation between OMS and E/H.

The results of this study suggested that the eight visual functions used to indicate sports vision in Japan are not independent indices, but have mutual effects.

4.2. Impact of Aging and Participation in Soccer

The American College of Sports Medicine recommends that individuals exercise three or more times per week, and Healthy Japan 21, a Ministry of Health, Labour and Welfare (MHLW) project, sets the goal of two or more times per week as the standard. The Basic Sports Plan, a Ministry of Education, Culture, Sports, Science and Technology (MEXT) project, sets the goal of exercising more than one time per week. Research focusing on the characteristics of exercise frequency in the elderly shows that exercising twice or more per week increased the feeling of health and physical fitness (Shigematsu et al., 2007). Due to the characteristics of soccer, however, there are few middle-aged individuals who exercise two or more times per week, we chose individuals who exercise more than one time per week as subjects of this research.

KVA, DVA, VRT, E/H showed significantly lower values in the Middle-aged Group than the Young Group. Similar to many physiological functions, visual functions are also influenced by aging. Suzumura (1971) reported that KVA begins deteriorating from approximately 41 years of age. Ishigaki and Miyao (1994) reported that DVA and VRT in particular reach peak development between 15 and 20 years of age and start deteriorating thereafter. This study also revealed a significantly greater decrease in KVA, DVA, and VRT in the Middle-aged subjects than in Young subjects, which supports the results of previous studies. In addition, it is thought that the strong correlation between E/H and DVA indicated that E/H decreased in response to the decrease of DVA.

A number of studies focusing on sports and visual function have compared top athletes and others. Results have suggested the superiority of top athletes' visual functions (Adam and Wilberg, 1992: Deary and Mitchell, 1989: Graybiel et al., 1955: Ishigaki and Miyao, 1993: Kodama et al., 2000). This study attempted to clarify the impact of participation in soccer on visual functions targeting individuals who enjoy participation in sports without limiting the study to athletes. Previous reports indicate that differences in lifestyle have a significant impact on physiological function in middle-aged individuals while many physiological functions deteriorate with age (Holloszy, 1983), and that improvement of lifestyle based on dietary and kinetic therapies significantly reduced vital age (Tanaka and Hiyama, 1994). Results of this study revealed that DVA and OMS in Soccer Groups were significantly better than in Non-exercise Groups.

According to a comparison of visual function among top athletes in kendo, soccer, baseball, and volleyball, DVA in soccer and baseball athletes was greater than in others (Nabeyama et al., 2000). According to a comparison of visual function by skill level in baseball top athletes, DVA and VRT were significantly higher in the athletes with higher skills (Ishigaki, 1990). The results from previous studies suggest that DVA and VRT are important for athletes in soccer and baseball, and at the same time, it is possible that DVA and VRT in those athletes are developed through exercise. A study targeting children who play baseball reported higher DVA and VRT than in children who did not participate in baseball. It has not yet been clarified, however, whether these findings where the result of baseball exercise (Ishigaki and Yoshii, 2001). As mentioned above, it is suggested that participation in soccer had a potentially favorable impact on the improvement of DVA or the slowing of deterioration of DVA. Meanwhile, the results of this study revealed no impact of participation in soccer on the improvement of VRT in the Young Groups, and participation in soccer once per week revealed no involvement in maintaining VRT in the Middle-age Groups either.

While studies that focus on the measurement of rationality of point of regard in eye movement are available, OMS in these studies has been examined for the purpose of analyzing mechanical abilities such as speed and accuracy in fixing vision on a target (Mashimo, 2002a). OMS is prioritized when chasing a ball on a broad pitch in soccer. The results of this study revealed the possibility that OMS is improved through participation in soccer.

In this study, comparison between groups was carried out utilizing a cross-sectional method. This suggested the necessity of additional longitudinal studies on DVA and OMS, which showed superiority in Soccer Group. Ishigaki and Yoshii (2001) reported on innate visual functions targeting individuals early in life, and pointed out that children with higher visual functions liked to exercise. They also suggested, however, that visual functions may be developed through exercise. They stated the need for further examination of innate individual differences. In order to further scrutinize the impact of participation in soccer in this study, it is necessary to consider innate functions in subjects and their individual differences.

Kato and Inoue (2000) reported a correlation between level of soccer skill and DP, which indicates the importance of DP as a visual function in soccer. However, the results of this study revealed higher DP in the Non-exercise Groups, and did not show participation in soccer to have a favorable impact. Currently, DP is prioritized in driving, and DP measurement is required to obtain a large-vehicle license in Japan. Therefore, it is also assumed that DP is developed on a daily basis by driving. All young subjects in this study drove to school by automobile or motorcycle, and all middle-aged subjects in this study went to work by automobile. In other words, these subjects train in addition to their participation in soccer, which suggests the necessity of further study that includes a wide range of factors.

This study revealed no difference in CS and E/H resulting from participation in soccer. Although a study is available that reports a correlation between sports ability and CS (Darlene et al., 1955), another study reports that the role of CS in player performance is unclear (Zagelbaum, 1996). There are no studies reporting improved CS through training, and this study revealed no significant differences between groups based on participation in soccer. Therefore, participation in soccer is not thought to have an impact on CS. Meanwhile, Kodama et al. (2000) reported correlation between skill in kendo and E/H. However, participation in soccer revealed no impact in this study. This may be due to the fact that E/H is the ability to respond to a recognized target with hands, and that, therefore, kendo, which requires the use of hands holding a bamboo sword, differs from soccer, which requires the use of feet. Edagawa (2001) pointed out that visual field, eye movement, attention, recognition, response rate, and spatial localization exert an impact on E/H. This suggests the need for evaluation over an extremely broad area.

5. Conclusion

We examined changes in visual functions with aging in young and and middle-aged individuals utilizing eight visual functions. The results revealed the following:

(1) KVA, DVA, VRT, and E/H were greater in the Young Groups than the Middle-aged Groups.

(2) DVA and OMS showed potential for improvement or reduced deterioration through participation in soccer.

It is necessary to examine innate abilities in a longitudinal study to clarify the impact of participation in soccer.

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