Development and Gender Differences in Dynamic and Kinetic Visual Acuities in Children from 8 to 17 Years of Age

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This study was conducted to elucidate the development and gender differences in dynamic and kinetic visual acuities in children from 8 to 17 years of age. The subjects were 867 boys and girls. The test parameters were static visual acuity, kinetic visual acuity, and dynamic visual acuity and the test was done using a method that allowed evaluation of many subjects in a short time. The speed at which the target moved started at 40 rpm and was reduced gradually thereafter in measurement of dynamic visual acuity. In measurement of kinetic visual acuity, the target moved at 30 kilometers per hour. The results indicated that the dynamic visual acuity improved gradually with age and a significant (p<0.01) gender difference was noted. However, there were no changes or gender difference in kinetic visual acuity. Therefore it was understood that there was a difference in the developmental patterns for dynamic and kinetic visual acuities.

Keywords: development, dynamic visual acuity, kinetic visual acuity, static visual acuity, gender difference

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Measurements of static and dynamic visual acuities drop with aging (Suzumura, 1971; Ishigaki & Miyao, 1994). SVA is thought to be almost constant until about 40 years of age after which it decreases gradually (Mayer & Dobson, 1982; Pitts, 1982), whereas DVA and KVA are thought to start to decrease at an earlier age and more greatly than SVA. On the other hand, few studies have reported how DVA and KVA develop. The only study, authored by Ishigaki & Miyao (1994), tested DVA on men and women from 5 to 92 years of age and reported that the highest values were obtained in the subjects with average ages of 15 years; however, because the subjects’ ages were grouped in 5-year intervals, the report did not provide a detailed breakdown. They also reported that the only gender difference was observed between men and women in the group with average age of 5 years.

It is thematically interesting to examine how DVA and KVA develop until the time of high school when a person’s mind and body are developing continuously. The acuities are expected to reach a peak at a certain age, and further, they develop rapidly in a certain period. By examining such development patterns and gender differences, it may be possible to get basic data for research related to mechanisms and training of DVA and KVA. Another theme would be to establish the norm for each age and/or each gender. Further, because DVA is considered as a different ability from KVA, the development is presumed to differ between them.

Thus, the purposes of the present study were to elucidate the development patterns and gender differences in DVA and KVA for subjects aged 8 to 17 years. A method that allows for testing many subjects in a relatively short time was employed.

2. Research approach

2.1. Subjects

Subjects were boys and girls from 8 to 17 years of age. About 90% of the subjects belonged to a junior sports club, private sports club, or school club and had habits of exercising. The sports which the subjects participated in were randomly selected. DVA, KVA, and SVA were tested on all subjects. The present study was carried out with the approval of the Research Ethics Committee of Juntendo University Graduate School of Health and Sports Science. The guardians of all subjects signed a letter of consent allowing participation in the tests.

2.2. Testing method

The subjects using vision correctional devices were tested while wearing their usual glasses or contact lenses. Whether subjects were tested with or without correctional devices was recorded. All tests were conducted on both eyes.

DVA was tested with the HI-10 (Kowa Co. Ltd.) which is a motorized instrument that rotates a mirror lying on a turntable. A Landolt ring (hereinafter referred to as a C ring) was projected by a slide projector and was reflected by the mirror onto a 120 cm semicircular screen. The reflected C ring was moved from left to right on the screen. The screen was located 80 cm away from the subject. The size of the C ring target was a visual angle of 40 minutes, which was expected to be large enough to exclude the influence of how much the SVA was. Subjects were instructed to lay their chin on the chin seat and not to move their head while their eyes followed the C ring. The moving speed of the target started at 40.0 rpm and subsequently decreased gradually until the C ring was at the center of the screen. As soon as the subjects could see the orientation of the gap in the C ring (left, right, bottom, or top), they pushed a button to answer the orientation. If the answer was correct, the rotating speed at which the button was pushed became the DVA score to be recorded.

KVA was tested with the AS-4D (Kowa Co. Ltd.). For testing of KVA, the C ring was set to come directly towards the subjects, upsizing, from a distance of 50 m at a velocity of 30 km per hour until it was 2 m in front of the subjects. The subjects were instructed to push a button as soon as they could resolve the orientation of the gap. The C ring stopped moving at the same time as the button was pushed, and concurrently the light was turned off. Resolving the C ring at a distance of 30 m was comparable to a vision of 1.0, and the vision was evaluated based on the distance at which the orientation of the gap could be resolved.

The orientations of the gap of the C ring were all decided randomly. In the tests of DVA and KVA, 2-3 practice repetitions were performed, and then 5
repetitions were obtained and averaged as the test value. If the number of wrong answers reached 3, the test was re-conducted from the beginning after giving the subject a rest period.

SVA was tested using the same measurement instrument as KVA. Although the test values of SVA and KVA were decimal numbers, the spacing of the values was not thought to correspond to that of the acuity because the decimal numbers are the reciprocals of the minimum visual angle (Kato, 1989). To avoid the concern that simple logarithmic conversion may yield non uniform outputs of positive (+), negative (−), and zero (SVA = 1.0) values, the test value was multiplied by 10 and then subjected to logarithmic conversion followed by statistical processing. The test values obtained from the 5 repetitions during the KVA testing were processed with geometric mean.

Also, to assess KVA itself, the difference between SVA and KVA (SVA-KVA) was calculated with reference to previous studies (Suzumura, 1971; Watanabe, et al., 1981) after logarithmic conversion.

2.3. Analysis and statistical processing

For each age, mean and standard deviation of the test values from the whole subjects and boys and girls separately were calculated. DVA and the difference between SVA and KVA (SVA-KVA) were subject to two-way analysis of variance using gender and age as the factors. For multiple comparison, Tukey’s post-hoc test was used. Further, Pearson’s correlation coefficients were calculated among SVA, difference between SVA and KVA (SVA-KVA), and DVA. The correlation coefficient was also calculated between the testing values SVA and KVA themselves. The statistical significance level was 5%.

3. Results

The number of subjects at each age and the number and percentage of those being treated with vision correctional devices are shown in Table 1. All testing results were grouped by gender and age and are shown in Table 2.

As a result of two-way analysis of variance, the main effects of the factors age and gender were significant for DVA (F value for age = 19.67, p < 0.01; for gender = 77.62, p < 0.01). Tukey’s post-hoc test showed Age 8 was significantly different from the other ages (Age 8 vs 9, p < 0.05; Age 8 vs 10-17, p < 0.01), Ages 9 and 10 were significantly different from Ages 12 to 17 (Age 9 vs 12-17, p < 0.01; Age 10 vs 12, p < 0.05; Age 10 vs 13-17, p < 0.01), Age 11 was from Ages 13 and 15 to 17 (Age 11 vs 15, p < 0.05; Age 11 vs 13 and 17, p < 0.01), and Age 12 was significantly different from Age 16 (p < 0.05). Also, differences between boys and girls, except for Ages 11 and 15, were significant (for Age 14, p < 0.05; Age 8, 9, 10, 12, 13, 16, and 17, p < 0.01).

For the difference between SVA and KVA, in contrast, the main effects and interaction of the factors age and gender were not significant.

The results of the correlation analyses were r = −0.141 for SVA vs SVA-KVA [SVA value itself vs difference] (p < 0.01), r = 0.100 for SVA vs DVA (p < 0.05), r = −0.034 for SVA-KVA vs DVA [difference vs DVA value itself], and r = 0.846 for SVA vs KVA (p < 0.01).

4. Discussion

Previous studies (Burg, 1966; Suzumura, 1971; Ishigaki & Miyao, 1994) have reported that DVA started to decrease gradually with increasing age at about 20 years of age and KVA did so at about 26-30 years of age. However, few studies have reported the development of DVA and KVA. Ishigaki and Miyao (1994) have reported the DVA of subjects 20 years and younger, but the subjects were grouped by 5-year intervals and the discussion on the development was therefore not be detailed. The results of the present study demonstrated that DVA developed gradually until age 17. This presumably meant that it did not developed rapidly at a certain period but developed gradually in the subjects of the present study. However, the subjects of the present study exhibited an obvious decrease in the DVA, but it did not lead to definite identification of a peak in ability. If a study were made in the future to identify such a peak, it would be useful to review the results of the present study taking the ability peak into account.

DVA is thought to be affected by the power of the retina, peripheral awareness, oculomotor abilities, psychological characteristics, and other factors (Hoffman, et al., 1981). Among them, oculomotor abilities were considered to be associated. The typical oculomotor abilities, i.e. saccadic and pursuit eye movements, are also thought to develop during adolescence (Ross et al., 1993; Ross et al., 1994; Tajik-Parvinchi et al., 2003; Jazbec, et al., 2006) and
further the DVA developed during the same period.

In addition, an obvious gender difference was observed in the DVA. Regarding this, the type of exercise was unlikely to differ greatly between the boys and girls, and living conditions such as habits of regular exercise would not be the only affecting factor. Inherent ability differences may be important; it is necessary to further study the gender difference, if only because there are no reports on gender difference in oculomotor abilities.

On the other hand, KV A ability was found to be almost constant during the period from 8 to 17 years of age, and no gender difference was observed during this time. The test values of KV A and SV A were both evaluated as decimal numbers, and the test value of KV A itself was affected strongly by SV A. Similarly, the

Table 1. Number of subjects and vision correction devices.

<table>
<thead>
<tr>
<th>Age</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>Total</th>
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<td>N (%)</td>
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<td></td>
</tr>
<tr>
<td>All subjects</td>
<td>glasses</td>
<td>36</td>
<td>95</td>
<td>121</td>
<td>83</td>
<td>117</td>
<td>119</td>
<td>59</td>
<td>59</td>
<td>116</td>
<td>867</td>
</tr>
<tr>
<td>Contact lens</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>3 (2.6)</td>
<td>6 (5.0)</td>
<td>11 (18.6)</td>
<td>18 (30.5)</td>
<td>37 (31.9)</td>
<td>17 (27.4)</td>
<td>92 (10.6)</td>
</tr>
<tr>
<td>Non-</td>
<td>35 (97.2)</td>
<td>92 (96.8)</td>
<td>113 (93.4)</td>
<td>72 (86.7)</td>
<td>99 (84.6)</td>
<td>98 (82.4)</td>
<td>43 (72.9)</td>
<td>37 (62.7)</td>
<td>78 (67.2)</td>
<td>43 (64.9)</td>
<td>710 (81.9)</td>
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</table>

<table>
<thead>
<tr>
<th>Boys</th>
<th>N (%)</th>
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<tbody>
<tr>
<td>glasses</td>
<td>18</td>
<td>60</td>
<td>75</td>
<td>44</td>
<td>60</td>
<td>77</td>
<td>44</td>
<td>60</td>
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<tr>
<td>Contact lens</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
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<td>1 (5.0)</td>
<td>4 (16.7)</td>
<td>13 (23.2)</td>
<td>9 (25.7)</td>
<td>30 (6.4)</td>
</tr>
<tr>
<td>Non-</td>
<td>17 (94.4)</td>
<td>60 (100)</td>
<td>72 (96.0)</td>
<td>38 (86.4)</td>
<td>55 (91.7)</td>
<td>58 (78.4)</td>
<td>17 (85.0)</td>
<td>19 (79.2)</td>
<td>43 (76.8)</td>
<td>25 (71.4)</td>
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<table>
<thead>
<tr>
<th>Girls</th>
<th>N (%)</th>
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<tbody>
<tr>
<td>glasses</td>
<td>18</td>
<td>35</td>
<td>46</td>
<td>39</td>
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<td>39</td>
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<td>60</td>
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<tr>
<td>Contact lens</td>
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<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>3 (5.3)</td>
<td>3 (6.7)</td>
<td>10 (25.6)</td>
<td>14 (40.0)</td>
<td>24 (40.0)</td>
<td>8 (29.6)</td>
<td>62 (15.5)</td>
</tr>
<tr>
<td>Non-</td>
<td>18 (100)</td>
<td>32 (91.4)</td>
<td>41 (89.1)</td>
<td>34 (87.2)</td>
<td>44 (77.2)</td>
<td>40 (88.9)</td>
<td>26 (66.7)</td>
<td>18 (51.4)</td>
<td>35 (58.3)</td>
<td>18 (66.7)</td>
<td>306 (76.3)</td>
</tr>
</tbody>
</table>

Table 2. Mean and standard deviation of Static, Kinetic and Dynamic Visual Acuity in all subjects, boys and girls.

<table>
<thead>
<tr>
<th>Age</th>
<th>8</th>
<th>9</th>
<th>10</th>
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<td>M</td>
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<td>Boys</td>
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<tr>
<td>Girls</td>
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correlation coefficient between SVA and KVA was as high as 0.846. To assess KVA itself, the difference between SVA and KVA was utilized as has been done in previous studies (Suzumura, 1971; Watanabe, et al., 1981); that is, for a smaller difference, KVA ability is higher. Although the mean value at age 8 tended to be lower than at other ages, no obvious gender difference and age-related change were observed. Watanabe, et al. (1981) studied the KVA of those aged 5 to 11 years and reported that the KVA developed well until about 8 years of age. Although the results of the present study were obtained by slightly different testing methods than Watanabe et al. used, from discussion of both reports, KVA may be considered as not changing greatly after about the third grade at elementary school but before this it develops well. In addition, the KVA was, at least, never considered to be lower than the mean of Age 8 or to decrease gradually, even though the test values varied to some extent.

From the results of the present study alone, it was difficult to adequately discuss the mechanisms of DVA and KVA. Further, their mechanisms have not been adequately examined because of differences in interpretations of results and the lack of studies. DVA developed during the same period as the oculomotor abilities and was found to differ between genders, whereas KVA was found to exhibit no gender difference and had no change - this would potentially provide the future investigative researches with some clues. Furthermore, considering these results, the DVA and KVA should be considered as distinct abilities, even though they are both an ability to discern a moving target. The correlation coefficient between the DVA and KVA was poor. Especially when testing and evaluating DVA in this age group, researchers may need to take into account the norm for age and gender. However, many of the subjects in the present study had habits of regular exercising, and there would be a possibility that the test values of the present study might tend to be higher in them than those who had no regular exercising habits because exercising habits have been reported to affect visual functions (Ishigaki & Yoshii, 2001). Another possibility that should be considered is that exercising might affect visual functions in addition to developing the mind and body, and this may be a research issue for further investigation.

A number of studies on training in DVA and KVA have been reported (Yamada & Morita, 1969; Long & Rourke, 1989; Long & Riggs, 1991; Kohmura & Yoshigi, 2004). Base on the relationship between competitive ability and visual functions in sports (Rouse, M. W. et al., 1988; Ishigaki & Miyao, 1993; Kioumourtzoglou et al., 1998), improvement of DVA and KVA may be expected to contribute to improvement of competitive ability. Given DVA develops gradually until about 17 years of age, it may be possible to develop DVA more efficiently during this period. Kohmura et al. (2007) have reported that the DVA of junior high school students developed through training; although an earlier period was presumed to be important for the KVA, coaches of sports and physical education may anyway need to examine the menus of training and practices taking into account the period when the DVA and KVA develop.

The statistics on the vision correctional devices showed that about 20% to 40% of the subjects aged 13 to 17 years of age used something, easily indicating that correction was presumed to suppress drop of the SVA. Although some studies on vision correctional devices have been conducted (Sado, 1998; Komori et al., 2007), statistics on their effects in boys and girls at these ages is not readily available. In the present study, the percentage of device users was higher for girls and both boys and girls tended to wear contact lenses rather than glasses from about 14 years of age. In addition, girls were presumed to switch to contact lenses earlier than boys.

The purpose of the present study was to elucidate the ability development patterns and gender differences of DVA and KVA itself, and consequently DVA and even the statistically-processed KVA were not related highly to SVA (SVA vs DVA: \( r = 0.100; \) SVA vs SVA-KVA: \( r = -0.141 \)). However, SVA strongly affected KVA (SVA vs KVA: \( r = 0.846 \)), so coaches of physical education and sports may need to pay attention to this; e.g. by providing guidance for the correction of SVA, or to raise competitive ability and prevent injury. Edagawa et al. (1995) have pointed out that a SVA of about 1.2 and at least 0.7 are required for high performance in sports.

In the present study 8-year-olds were the youngest subjects; this was based on the results of preliminary tests. The methods and instruments that were adopted here have been generally used. However, when subjects in the second grade or lower at elementary school used the instruments and methods, frequently they pushed the button before the orientation of the gap of the C ring became accurately resolvable, or they required repeated retests due to 3 or more wrong answers.
Watanabe et al. (1981) have devised measurement instruments and methods to get more reliable test values, e.g. by increasing the number of test repetitions, when testing on preschoolers. Therefore, to test DVA and KVA of preschoolers and early elementary school children including studies on development, the measurement methods and conditions need to be carefully considered.

5. Conclusion

Results of the present study showed that DVA developed gradually until 17 years of age and differed between genders; on the other hand, KVA was almost constant and did not differ between genders. Thus, although both DVA and KVA are the ability to discern a moving target, they exhibited different developmental patterns and were presumed to be distinct abilities.

References


Perceptual and Motor Skills, 86: 899-912.


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• Japan Ergonomics Society
• Japanese Society of Clinical Sports Medicine