Article ‣ # A Standardized Procedure and Normative Values for Measuring Binocular Dynamic Visual Acuity

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ABSTRACT

Background: Binocular dynamic visual acuity (BDVA) is the ability to differentiate fine details in a moving object such as seams on a pitched baseball or the rotation of a tennis ball, both of which can travel up to speeds exceeding 100 miles per hour. BDVA is one of many binocular visual measurements to examine binocular function. This study was designed to provide a standardized procedure for measuring BDVA and normal values for a sample population. Previous studies have used different techniques for measurement, and thus have no normative data for comparison.

Methods: The BCVA attachment to the Bernell Rotation Trainer was used to measure BDVA in 22 subjects (10 females and 12 males) between the ages of 23 and 30. Only subjects with a refractive error between +1.00 D and -7.00 D (spherical equivalent) and with best-corrected visual acuity of 20/20 or better were able to participate in the study. BDVA was recorded at three different rotation speeds (29 RPM, 24 RPM, and 16 RPM). At each RPM, accuracy and the time to completion of all nine lines were measured. The subjects were also asked to complete a questionnaire designed to evaluate factors that may influence the BDVA results.

Results: A decrease in RPM resulted in a corresponding decrease in the subject's completion time and an increase in accuracy. The same trend was seen when comparing males and females; however, the females' accuracy was lower and the time was greater when compared to the males, but these were not statistically significant.

Conclusions: This was the first study designed to use the Bernell Rotation Trainer to quantitatively measure BDVA in a standardized way. Our results showed similar trends in both males and females. In addition, this study provides a strong foundation for future research, such as comparing BDVA of athletes and non-athletes, or comparing athletes with different skill levels, or comparing athletes who participate in different sports.

Keywords: Bernell Rotation Trainer, binocular dynamic visual acuity (BDVA), sports performance, sports vision

Introduction

Binocular dynamic visual acuity (BDVA) is used to see fine details on a moving object, which is an important concept in sports vision.[1] This is extremely useful in sports; for instance, judging the speed, the rotation, and the path of a tennis ball during a tennis match or looking at baseball seams' rotation to determine the speed and type of a pitch. BDVA is one of many binocular visual measurements to examine a person's binocular visual functions. Laby et al.[2] measured the visual acuity, stereoacuity, and contrast sensitivity in professional baseball athletes. They showed that there are many aspects of the visual system that are involved with performing well at baseball. They found that having excellent performance in these three factors is important in baseball players. Bahill and LaRitz et al.[3] examined the ability of a batter to watch and hit a pitch. They demonstrated that the best batters were able to follow the pitch only up to approximately 5.5 feet from home plate. Due to the velocity of the pitch, the athlete was unable to track the ball at a closer distance. Perhaps if an athlete has an increase in BDVA, they might have a greater chance at hitting the ball with the bat.

A hit tennis ball and a baseball pitch can easily reach speeds of over 100 miles per hour.[4] In a standard optometric examination, static visual acuity is routinely measured; however, BDVA may be a more appropriate skill to assess as it better relates to sports. In addition, BDVA is important for other standard tasks such as driving, military actions, or law enforcement.

It has previously been shown that there are many different parameters that can affect BDVA, including target luminance, angular velocity, and time exposure of the target.[5-10] These are controllable by the doctor or patient, but there are also others that may be out of the patient's control. These include the resolving power of the retina, peripheral awareness, oculomotor abilities, and physiological functions that affect interpretation of visual information.[3]

Previous methods of BDVA measurement, which used a moving target projected onto a wall, were used in the studies by Morris et al.,[10] Rouse et al.,[11] Tetsuo et al.,[5] and Miyao et al.[9] While advantages to this method exist, such as a larger viewable target with a larger area for the target to move, disadvantages include the low transportability and high cost devoted to having such equipment. By establishing normal recorded values with the Bernell Rotation Trainer, further research with BDVA can continue using a more transportable, economical, and standardized method of measure.

Since BDVA can be influenced by many factors, precautions were incorporated into this study in order to limit erroneous results. Additional error producing factors include:

1. *Static Visual Acuity:*
   Nakatsuka et al.[6] and Weissman et al.[7] found that there is a significant relationship between BDVA and static visual acuity. Both of these studies found that as static visual acuity decreased, binocular dynamic visual acuity also decreased.

2. *Alcohol Level:*
   Furuta and Ishigaki[8] found a relationship between BDVA and alcohol level. Thirty minutes after a subject consumed 16.5 mL of alcohol, there was an improvement in BDVA accuracy. This study showed a slight improvement in BDVA after drinking alcohol.

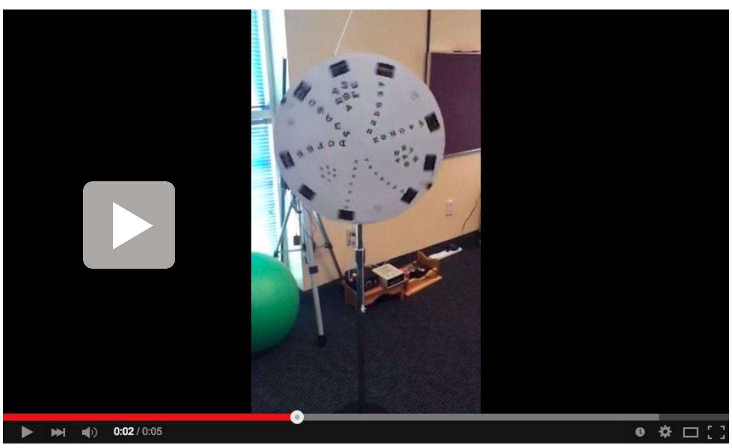
The purpose of our study was to compute a set of normative values to be used in further research of binocular dynamic visual acuity and for evaluation of patients performing this test in therapy.

Our goals for this study were; a) to design a procedure that results in reproducible and quantitative data, and b) to establish a set of normal values for BDVA measurement using the

Figure 1: *Testing with the Bernell Rotation Trainer*

Figure 2: *Close-up of the Bernell Rotation Trainer*

Bernell Rotation Trainer that can be used as a comparison in later studies (Figure 1).



The Bernell Rotation Trainer in action.

Methods

This study consisted of 22 subjects (10 females and 12 males) between the ages of 23 and 30, minimizing age effects on BDVA. Optometry students or their family members were used. All subjects read and signed an informed consent form approved by the Midwestern University Institutional Review Board.

Three separate testing stations were used as follows:

A) Questionnaire (Appendix 1)

Based on previous studies of dynamic visual acuity, a questionnaire was designed and administered to determine factors that may influence the measurement of BDVA such as alcohol use,[8] pregnancy, history of ocular trauma, or previous visual training.[12] Any subjects who consumed alcohol within 24 hours prior to the measurements, who had corrected binocular visual acuity of worse than 20/20, or who had a history of ocular trauma or previous vision training were excluded from the study.

B) Autorefractor

A Huvitz HRK-7000A autorefractor was used to determine the refractive status of the patient without cycloplegia. Only subjects who had refraction between +1.00 to -7.00 (spherical equivalent) were included.

C) Subject response

Preliminary testing included monocular confrontation visual fields, distance and near static visual acuity, stereopsis, accommodative facility, and modified Thorington. Any subjects with abnormal visual fields by confrontation, binocular visual acuity of worse than 20/20, or modified Thorington results that fell outside of Morgan's expected norms were excluded from the study.

Figure 3: Control bob for the Bernell Rotation Trainer

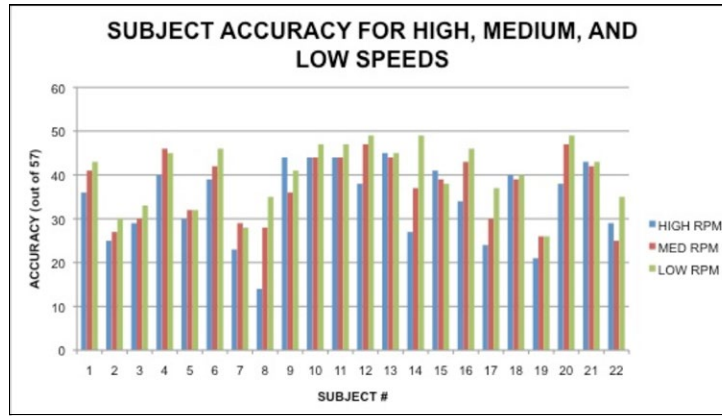


Figure 4: *Raw data for accuracy at high, medium, and low RPMs for each subject*

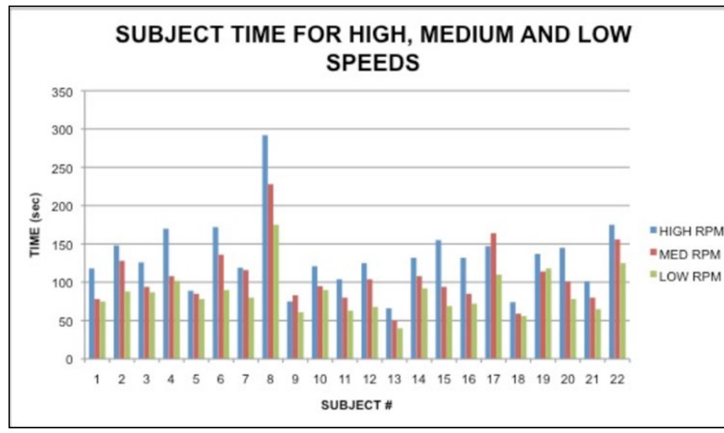


Figure 5: *Raw data for time at high, medium, and low RPMs for each subject*

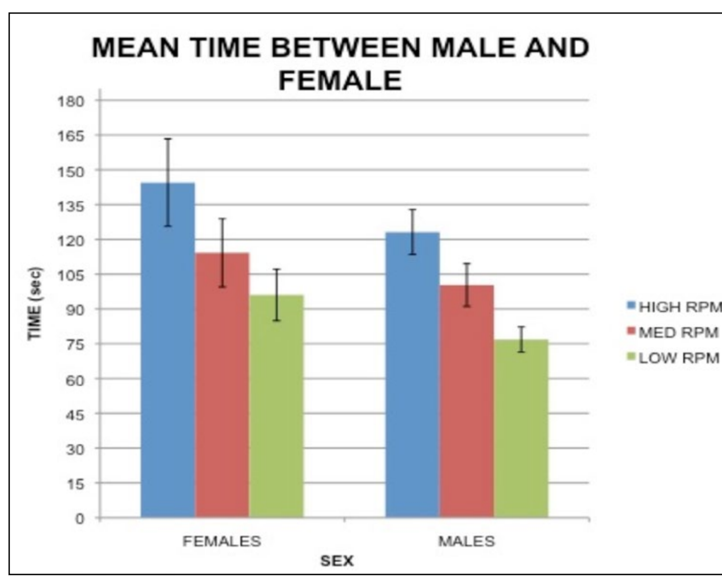


Figure 6: *Mean time comparison between males and females*

The Bernell Rotation Trainer binocular dynamic visual acuity attachment (product number BCDVA) consists of nine sets of letters and numbers arranged into three optotype sizes (20/40, 20/30, and 20/20 at 20 ft test distance) (Figure 2). Within each optotype group, the first line was linear, the second line was rotated, and the third line was spiraled. The same instructions were given to each subject verbally and included: a) there would be letters and numbers on the chart, and they could read them in any order they wanted; b) they were to read the letter/number grouping that corresponded to the number that the administrator called out; and c) if they felt light-headed or nauseous, they should inform the administrator, and the test would be stopped.

The subject was then instructed to stand 20 ft away from the rotator, and testing began with the rotation speed set at 29 RPM. The subject was told to read the optotype sets from 1 through 9, while the administrator timed and recorded the accuracy of the subject's responses and the number of correct optotypes at that particular speed (a perfect score would be 57 out of 57 optotypes). The procedure was repeated for the testing speeds of 24 RPM and 16 RPM (Figure 3). These speeds were chosen since they were already labeled on the controller. In between each RPM speed, the subject was told to count backwards by 3s for 15 seconds[14] in order to minimize any effect of memorization of letters.

The Data Response Form (Appendix 2) was used, and the time required for all nine rows of letters at each RPM, as well as the number of letters corrected, were recorded.

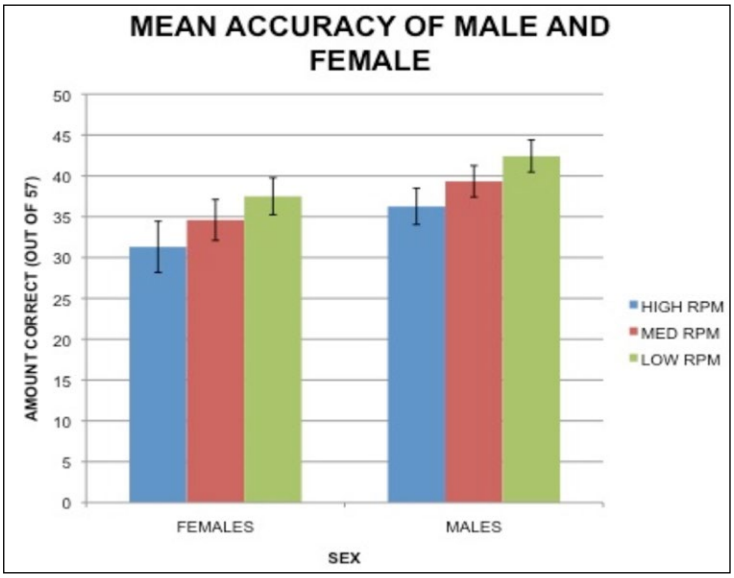


Figure 7: *Mean accuracy comparison between males and females*

Table 1: Tests of Normality- Shapiro-Wilk

	Sex	Time			Accuracy		
		Statistic	df	Sig.	Statistic	df	Sig.
High RPM	Female	.825	10	.029	.957	10	.751
	Male	.944	12	.557	.871	12	.068
Medium RPM	Female	.768	10	.006	.892	10	.178
	Male	.973	12	.940	.910	12	.210
Low RPM	Female	.873	10	.107	.915	10	.314
	Male	.975	12	.958	.865	12	.056

Results

Group Statistics

Using the raw scores measured for each RPM, accuracy was calculated as the number correct out of 57 possible correct responses on the BDVA attachment (Figure 4). At the high RPM (29 RPM) setting, the mean accuracy for males was 36.25 (63.6%) and for females was 31.30 (54.9%). At the medium RPM (24 RPM), males had a mean accuracy of 39.33 (69.0%), and females had a mean accuracy of 34.60 (60.7%). At the low RPM speed (16 RPM), males and females had a mean accuracy of 42.42 (74.4%) and 37.50 (65.8%), respectively (Figure 5).

The mean time to complete the activity at the high RPM was 123.17 seconds for males and 144.50 seconds for females. The mean time for the medium RPM was 100.33 seconds for males and 114.20 seconds for females. The mean time for the low RPM was 76.83 seconds for males and 96.00 seconds for females (Figures 6 & 7).

Tests of Data Normality

Prior to further analysis, Shapiro-Wilk tests for normality were performed on both the accuracy and time measurement sets for both males and females. Since this was a small data set, Shapiro-Wilk tests were used as shown in 1. All data sets showed normal distribution, except the High RPM and the Medium RPM measurements for females, where Shapiro-Wilk p-values of 0.029 and 0.006 were found, respectively, possibly due to small sample size.

ANOVA

One-way ANOVA testing was performed on the RPM-accuracy correlation and the RPM-time correlation. Both were found to be statistically significant, indicating that both the time ($F(2,22) = 52.593$, $p<0.001$) and accuracy ($F(2,22) = 15.081$, $p<0.001$) are directly dependent on RPM.

Unequal Variance Independent Samples T-test

An Unequal Variance Independent Samples T-test was performed comparing the accuracy and test time for males and females. The null hypothesis was that no difference existed between males and females for both accuracy and test time.

The p-values for accuracy were p=0.215 at the high RPM, p=0.151 at the medium RPM, and p=0.116 at the low RPM, indicating no statistically significant difference between males and females for accuracy. The p-values for time scores at the high RPM (p=0.332), at the medium RPM (p=0.436), and at the low RPM (p=0.146) also indicated no statistically significant difference between males and females for time scores.

Discussion

This study presented a standard method for measurement of binocular dynamic visual acuity (BDVA) and resulted in normative data for a sample population of young adults. This methodology and these results could be the basis for future studies comparing athletes to non-athletes and for comparing results among athletes of different sports.

This study also found that there was no statistical difference between male and female time and accuracy scores. The ANOVA analysis showed that time and accuracy was highly correlated with the RPM.

Conclusion

This data can be used as a basis for further studies on BDVA measurement using the Bernell Rotator Trainer. Larger samples of subjects could be studied, including athletes. Such studies may involve the comparison of specific subgroups of the population such as athletes and non-athletes, between athletes at different ages or competition levels, or between athletes of different sports or different abilities in the same sport.

Acknowledgement

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Appendix 1

Subject Questionnaire

Subject #_____________

1. Age: ______

2. Sex: [ ] Male [ ] Female

3. Are you currently pregnant?
   [ ] Yes [ ] No [ ] N/A

4. While playing your sport do you wear any of the following?
   [ ] Glasses
   [ ] Contact Lenses
   [ ] Prescription goggles
   [ ] None

5. Have you consumed any alcohol within the last 24 hours?
   [ ] Yes [ ] No

6. How often do you play video games?
   [ ] Daily [ ] Weekly [ ] Rarely [ ] Never

7. Have you ever had any type of visual training?
   [ ] Yes [ ] No

   If you answered yes to question 7, when and why did you receive this training?

8. Have you ever had an eye injury? [ ] Yes [ ] No

   If you answered yes to the above question, please explain the injury and when it happened.

9. How long have you been playing your sport?

Appendix 2

Subject Responses for DVA

Subject Number:

Proctor:

High RPM

1D C F 6 E - 2P 3 A 5 C - 34 E P 5 3 F 8

4Z 2 D 5 3 P - 5E 6 Z C 4 F - 6Z 8 4 5 E 7 P

7F 6 O E 2 P D - 8O T E 7 3 C P - 97 E F T 4 P O

Time:__________________ Accuracy: /57

Medium RPM

1D C F 6 E - 2P 3 A 5 C - 34 E P 5 3 F 8

4Z 2 D 5 3 P - 5E 6 Z C 4 F - 6Z 8 4 5 E 7 P

7F 6 O E 2 P D - 8O T E 7 3 C P - 97 E F T 4 P O

Time:__________________ Accuracy: /57

Low RPM

1D C F 6 E - 2P 3 A 5 C - 34 E P 5 3 F 8

4Z 2 D 5 3 P - 5E 6 Z C 4 F - 6Z 8 4 5 E 7 P

7F 6 O E 2 P D - 8O T E 7 3 C P - 97 E F T 4 P O

Time:__________________ Accuracy: /57

Refractive Status

OD:

OS: