2018

Effectiveness of a Low-Budget Sports Vision Training Program for Improving Batting Statistics of an NCAA Division I Baseball Team

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EFFECTIVENESS OF A LOW-BUDGET SPORTS VISION TRAINING PROGRAM FOR IMPROVING BATTING STATISTICS OF AN NCAA DIVISION I BASEBALL TEAM

BY

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A thesis submitted in partial fulfillment of the requirements for the

Master of Science

Major in Nutrition and Exercise Science

Specialization in Exercise Science

South Dakota State University

2018

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This thesis is approved as a credible and independent investigation by a candidate for the Master of Science in Nutrition and Exercise Science and is acceptable for meeting the thesis requirements for this degree. Acceptance of this does not imply that the conclusions reached by the candidate are necessarily the conclusion of the major department.

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ACKNOWLEDGEMENTS

To perform and complete a research project takes an entire team of dedicated members. I would like to first thank my advisor, Dr. Mary Beth Zwart. She helped me to find a topic that I could be passionate about as well as put in a very large amount of work into a small amount of time tin order to help me complete this project. I am extremely grateful for having her direction, dedication, and support throughout the entirety of this research process. I would also like to thank Dr. Lee Weidauer for his work with me on the statistical analysis of my data. His time and effort allowed me to develop a thesis with empirical support. I am very thankful for having had his guidance at times as well during the course of my research. I would also like to thank my students Reid and Kelsi who took time out of their hectic school year to help me perform of the study exercises with the subjects. Your help was extremely valuable and it made this project a much easier process than having to do it without you. I would also like to thank coaches Rob Bishop, Brian Grunzke, Mitch Mormann, and Danny Higginbotham. Your support and help to get the team to their vision training appointments was incredibly valuable to the validity of this study. Finally, I would like to acknowledge and thank South Dakota State University's Department of Health and Nutritional Sciences for the equipment donations that made this study possible.

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ABSTRACT

EFFECTIVENESS OF A LOW-BUDGET SPORTS VISION TRAINING PROGRAM FOR IMPROVING BATTING STATISTICS OF AN NCAA DIVISION I BASEBALL TEAM

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Context: Sports vision training (SVT) has been increasing in popularity among many dynamic reactive sports. Dynamic reactive sports require extremely accurate detection and discrimination of visual stimuli in order to execute a precise motor response. Manual interception, locomotion, and depth judgement are found to be the most important visuomotor abilities with interceptive sports such as baseball. Baseball is a highly visually demanding sport, especially offensively. The effectiveness of the batter is dependent on his/her ability to locate, track, and swing at a projectile in ~0.2 seconds. This presents the opportunity to implement an SVT program with a baseball team as a means to improve sports performance. Due to the expensive nature of visuomotor training equipment however, it was crucial that we were able to achieve the same improvements with a low-cost program that we would see with an expensive SVT program. **Objective:** The purpose of this study is to determine if a low-budget SVT program can be used to improve target visuomotor abilities as well as improve batting and fielding statistics of an NCAA division I baseball team. **Design:** Analytical observational study. **Participants:** 30 NCAA baseball players. The average age was 20.6 ± 2.6 years, the average height was 184.1cm ± 11.5cm and the average years of baseball experience was 15.5 ± 2.5 years. **Intervention:** A low-cost SVT program was implemented at the beginning of the 2018 spring baseball season. The program utilized accommodative flippers, a brock string, saccadic eye movement, near-far movement, visually-guided manual interception training, and an EYEport II. **Main Outcome Measures:** Stereopsis scores for gross depth perception and EyeGuide Focus scores for smooth-motor pursuit. **Results:** Stereopsis measurement increased significantly from baseline to mid-season and mid-season to post-season ($p<0.05$). The average stereopsis measurement improved from 37.3 ± 24.7cm to 53.3 ± 25.6cm after six weeks of vision training. Stereopsis measurements improved from 53.3 ± 25.6cm to 73.9 ± 29.9cm in the following eighteen weeks of vision training. EyeGuide measurement improved significantly from pre to post SVT ($p<0.001$). Mean baseline EyeGuide measurements were 19764.2 ± 7508.2 and improved to 15465.3 ± 5922.4 after completing the entirety of the baseball season and the twenty-four weeks of the SVT program. **Conclusion:** The results of this study would imply that implementation of a low-budget SVT program is a viable option for improving the key skills necessary for enhancing sports performance in baseball. We were able to determine that our SVT program was able to improve DP, manual interception, and locomotion through tracking stereopsis and smooth-motor pursuit measurements. Although we did see slight improvements in slugging percentage, on-base percentage, and in defensive errors between the 2017 and 2018 seasons, none were statistically significant enough to definitively state that our SVT program improved the performance of an NCAA division I collegiate baseball team.

CHAPTER 1

Introduction

Sports vision training (SVT) has been increasing in popularity among many dynamic reactive sports. Dynamic reactive sports require extremely accurate detection and discrimination of visual stimuli in order to execute a precise motor response.[1] There are many researchers that have provided results displaying the ability to train the various attributes of sports vision.[1-5] It is documented that SVT can improve sport performance and may even contribute to injury prevention.[5] In a study by Gao et al[2], it is shown that athletes had an increased ability to more accurately execute complex visuomotor tasks when compared to non-athletes. The same study reveals that success of athletes involved in sports requiring interceptive actions could be determined by analyzing three key visuomotor skills.[2] Success in dynamic reactive and interceptive sports requires that the athletes be able to manually intercept a visual target, navigate toward the target, and to accurately judge the depth of the target.[2] The skills of manual interception, locomotion, and depth judgement are all included in the act of batting in the sport of baseball.

Baseball is a sport of particular interest due to the immense demand for visual acuity and advanced sense of interceptive action.[2,4,5] The vision-intensive nature of baseball is found throughout the game, but is especially prominent when considering the visual ability of a batter. A baseball can be pitched in excess of ninety miles per hour resulting in the ball reaching home plate in less than half of a second.[5,6] Considering the amount of time it takes to swing a bat, there remains ~0.2 seconds for the batter to make a decision as to whether or not they should swing. The batter must spot the ball, determine its speed and trajectory, and then finally make the decision to swing the bat or not.[5]

Researchers have found that the velocity the ball travels at, it is physiologically impossible to track the ball completely through its trajectory.[6-10] Even with the inability to track the full flight of a baseball, baseball batters at both collegiate and professional levels still manage to hit the ball with exceptional consistency. This suggests that the batter must use other visual cues to accurately strike a baseball with a bat. Although the entire flight-path of the baseball cannot be followed, De Lucia et al[8] recorded that a batter can track two-thirds of the trajectory. Furthermore, Reichow et al[11] found that early pitch recognition was critical in success of hitting a baseball. The capability of the batter to recognize and intercept the ball during the first two-thirds of its trajectory, combined with accurate depth judgement and locomotion, would significantly increase their chances of successfully hitting the baseball. Many SVT exercises are centered around enhancing these three visuomotor abilities, which enhance decision-making ability leading to better at-bats.

As a way to improve batting, SVT must focus on strengthening depth perception (DP), visual recognition speed and accuracy, and improving anticipation skills.[2,5,12] These skills have been chosen as the focus of sports vision enhancement as they have been shown to improve both fielding and batting statistics in collegiate baseball teams.[4,5] DP is used by both fielders and batters to estimate where the ball will travel. Through training the skills of visual convergence and accommodation, DP has been found to improve.[4,5] Visual recognition is improved through training the speed, accuracy, and efficiency of the eyes through saccadic eye movements.[2,4,5]

The length of time it takes for visuomotor training to be effective is also a component to consider when designing an SVT program. SVT programs have been found to be ineffective when only performed for four weeks.[3] When the vision training program was extended to eight, twelve, and twenty-four weeks, there were significant improvements in both visuomotor exercise and sport-specific performance.[4,5,13] Although there is limited information available on how many times a week this training should be performed, Clark et al[4,5] has recorded that two twenty-five minute sessions twice per week in the pre-season and one session per week in-season was effective. After looking through the literature, an SVT program was found to be effective when utilizing a minimum of eight exercises throughout the study.[2,4,5,14] The most common tools and equipment used were Dynavision D2, saccades, near-far training, EYEport, a brock string, and accommodative flippers.[1,2,4,5,14-17]

Various combinations of these tools and equipment used to train sports vision have been shown to be effective at augmenting visuomotor skills and enhancing sports performance.[2-5,9,11,16-25] Many of the devices used to train vision (like the Dynavision D2) are quite expensive and may not be affordable to some sports teams. This presents an opportunity to research if a low budget SVT program can present significant improvements in sports performance without the use of the more expensive equipment. Identifying an inexpensive vision training protocol that can improve sport performance will allow for more populations of athletes to enhance their competitiveness. The primary aim of this study was to use low-cost interventions to improve targeted aspects of sports vision including depth judgement, visually-guided manipulation, and locomotion. A secondary aim was to augment the batting statistics of a division I collegiate baseball team by improving the aforementioned visuomotor skills. Finally, a tertiary aim of this study was to examine fielding statistics to determine if the number of errors made by our subjects would decrease after implementing a SVT program. Our hypothesis was that a low-cost SVT program will improve the targeted visuomotor skills, leading to higher batting statistics and a lower number of fielding error.

Delimitations/Limitations

The delimitation of this study is the amount of current literature supporting the exercises chosen to improve visuomotor ability. The limitations of this study include changes in batting averages due to athlete's individual experience, increased number of away games, weather considerations, equipment used for this study compared to that in the literature, and possible experimenter learning curve that may have resulted in different training experiences for different subjects.

Assumptions

This study assumes that maximum effort was given when performing the visuomotor training exercises and that all subjects performed the required number of training periods.

Hypothesis

Hypothesis 1: We hypothesis that target visuomotor skills will improve after implementing a season-long, low-budget, sports vision training program

Hypothesis 2: We hypothesize that our subjects will have improved batting statistics in the experimental year compared to the control year.

Hypothesis 2: We hypothesis that the number of fielding errors committed by our subjects will decrease in the experimental year compared to the control year.

CHAPTER 2

Methods

Human Subjects

The training of the athletes was performed similar to the methods described by Clark, et al[4] for all team members. The goal of visual training was to train and improve visuomotor abilities in all participants shown through stereopsis measurement and EyeGuide testing. All participants were given a verbal description of the study protocol as well as the possible risks and rewards of participating in the study. Each participant was also given a written description of the study protocol, a detailed timeline of the study, and an explanation of each of the study exercises and measurements. No specific defensive training was done outside of their standard practices. Consent forms were signed by all participants in the study and the activity was approved by the Institutional Review Board in compliance with all human subjects' rules.

Six weeks prior to the regular season, vision training sessions were initiated including accommodative flippers, brock string, EYEport II, near-far training, saccadic eye-movement training, and visually-guided manual interception training.

Participants

Thirty-two members of the South Dakota State University Division I intercollegiate baseball team participated in this study (n=32). All thirty-two participants were male, were similar in age (20.6 ± 2.6 years), similar in height (184.1cm ± 11.5cm), and similar in years of experience playing baseball (15.5 ± 2.5 years). All participants were apparently healthy at time of recruitment. Vision training and testing was given to all players on the roster. Seventeen of the thirty-two participants who underwent SVT were offensive players and had at least one at-bat during the 2018 baseball season. The batting statistics of these seventeen players were used to compare to the previous year's team statistics as well as to the conference statistics from both the 2017 and 2018 seasons.

Inclusion Criteria

All participants' vision was tested using the Snellen eye chart to ensure adequate eye-sight to perform visual training[26,27]. Participants stood ten feet from Snellen eye chart and read as far as they could down the chart as possible. Participants performed this with both eyes open, with their right eye closed, and with their left eye closed. Participants who wore prescription eyewear during sports participation (contacts or glasses), wore their eyewear during testing. We included all participants with 20/20 vision or better with or without corrective lenses.

All participants were also tested for both red-green and blue-yellow color blindness. They were dismissed from participation in the study if they displayed a dominant color-blind trait.

Exclusion Criteria

Participants were excluded from participation in the study if they had an eye injury in the past three months that resulted in their removal from activity, if they had vision that was worse than 20/20 with the use of corrective lenses, and/or if they presented with a dominant color-blind trait. Subjects were removed from the study if they missed more than five SVT sessions, if they received an injury to the eye that removed them from participation in activity, suffered a concussion in the year prior, or if they wished to withdraw from the study.

Vision Training Program Design, Tools, and Equipment

All exercises and skills were conducted in a circuit-training method with two repetitions of each exercise/skill at one minute per repetition. A thirty-second rest was given in between each exercise/skill. In accordance with Clark et al.[4], basic visual skill development was initiated during the first three weeks of training to develop oculomotor strength and convergence and divergence movement of the eyes. The remaining weeks of the training periods progressed to include more sport-specific function and visual-training ability.

Two vision training periods were organized in which all subjects participated. The subjects were split into twelve groups of three. All groups received the same training on the same days. The first period was during the spring pre-season (six weeks) and consisted of two sessions per week of five exercises per session. The second training period was conducted during the 2018 spring season (twelve weeks). This period also consisted of two training sessions per week involving five exercises per session. The training sessions were designed and implemented using the several vision training tools including the accommodative flippers, brock string, EYEport II, Snellen eye charts, and a visually-guided manual interception training wall. All exercises excluding the EYEport II were done in two, sixty-second repetitions with a thirty second rest period between each repetition.

Stereopsis measurements and smooth eye pursuits were taken as baseline measurements. The stereopsis measurement was done using the stereo-fly test and the EyeGuide Focus was used to track and measure smooth eye pursuits.

Accommodative Flippers

A set of accommodative flippers were utilized to train the reflex action of the eyes. Accommodation is the ability of the eye to adjust to, and focus on, an object that is near after looking at a distant object and vice versa. The flippers were used as a warm-up exercise to allow the eyes to prepare for the vision training session that the participant was about to go through. The subjects were progressed from the weakest power of ±0.50 to the strongest power of ±1.50 through the training periods. The participant stood approximately ten feet from a Snellen eye chart and were instructed to look through one side of the accommodative lenses. After the subject was able to focus on the first row of letters on the Snellen eye chart, they were instructed to flip the lenses and again try to focus on, and clearly see the first row of letters on the eye chart. This was repeated three times to allow for a proper warm-up of the eyes.

Figure 1. Accommodative Flippers

Brock String

We created a Brock string from string that is twelve feet in length and has five different colored wooden beads spaced approximately two feet apart from each other. This device is used to develop skills of convergence and divergence and to disrupt suppression of one of the eyes[5]. For training sessions utilizing the Brock String, one end of the string was held on the tip of the subject's nose while the other was fixed twelve feet away at a slight downward angle. The participant was given a verbal cue to focus on a particular bead. They were instructed to alternate fixation and focus from one bead to the next while also trying to focus on the sensation of convergence. During the second period of training, the subjects were made to perform the exercise on an uneven surface. This was achieved by having the subject stand on a foam pad or on a bosu ball.

Figure 2. Brock String

Saccadic Eye Movement Training

Saccadic eye charts were used to help develop rapid eye movement for the subjects. This exercise replicated quick, concurrent movement of both eyes in the same direction. This exercise was intended to facilitate scanning, fixation, and rapid eye movement which are common and necessary for successful participation in athletics, especially those using a projectile of some kind[27].

We adapted our method of training from Clark et al.[5] Each player was positioned eight feet away from the saccadic eye chart and centered between two saccadic charts positioned five feet from the center line. Each chart was constructed on a standard 8.5 x

11-inch sheet of paper and each chart had ten letters in a thirty-six-point font per horizontal line with ten horizontal lines on the chart.

Each subject was instructed to keep their head still and move only their eyes. They were then asked to read the first letter of the first line on the left chart and then switch to read the first letter of the first line on the right chart. They continued in a pattern like this following with the second letter of the first line, the third letter of the first line, and so on. After the subject completed reading out each letter in the first line, they continued the same pattern on into the second line, and then the third until the one-minute time period was finished. Variations were added to this exercise by having the subjects read in the same pattern, but from right-to-left. The exercise was also made more difficult by having the participants stand on one leg, on foam padding, or on a bosu ball.

Figure 3. Saccadic Eye Chart

W	I	N	K	I	W	O	D	V	H
P	Z	S	R	C	Z	D	G	V	P
L	Q	V	R	N	B	D	O	H	P
Z	T	K	C	W	P	D	X	Z	H
Q	B	E	H	G	J	R	V	C	T
A	A	H	Z	C	K	O	N	D	S
V	R	W	K	D	Z	R	G	P	L
Q	W	B	V	C	S	N	J	A	Q
B	P	T	Y	W	Y	B	M	Z	D
J	H	O	U	R	P	W	X	C	K

Near Far Vision Training

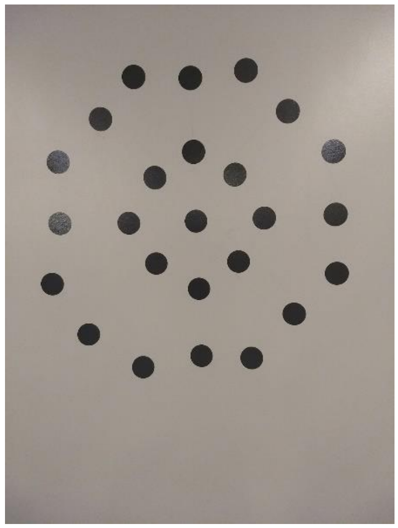
A set of saccadic eye charts were constructed to perform near-far training. The near chart was constructed on a 3.5 x 2.5-inch sheet of paper and the large chart was constructed to the same dimensions as listed above for saccadic eye movement training. The small chart has ten letters in a twelve-point font per horizontal line with ten horizontal lines on each chart. The far chart was positioned at eye level with the subject who was standing ten feet from the chart. The subject was instructed to hold the near chart in one hand approximately twelve inches from their nose. The player was further instructed to maintain a stable head position and use only their eyes to shift focus from the near chart to the far chart and back again following the same pattern as the saccadic eye movement training. The subject was prompted to ensure both eyes came into focus on both targets when alternating from chart-to-chart. This exercise was meant to train the eyes to focus from a near object to a far object (and vice versa) accurately and quickly. This emulates the act of focusing on a baseball that is pitched to them.

Visually-Guided Manual Interception Training

We instructed each participant to stand fifty centimeters in front of a wall that had twenty-four markers taped to it in a circular fashion (124 cm width x 8 cm height). The heights of all participants were averaged in order to set the markers permanently on the exercise wall at an average eye-level for all participants. The center of the markers were placed at 180cm from the ground to be at an average height for all participants. During training using this exercise, each subject stood approximately thirty-five centimeters from the wall. A laser-pointer was used to "light up" a marker. As each marker was "lit up", the subject was instructed to tap the marker as quickly as they could. After each marker was touched, the researcher running the exercise would quickly move the laser pointer to illuminate another marker. This was done for thirty seconds and the total number of "hits" was recorded as a way to track any improvement in reaction speed for the subjects.

This exercise was meant to mimic devices such as Dynavision or an AS-24 digital saccadic fixator and was included as it has been found to help improve visual-motor skills, specifically reaction time[4,23].

Figure 4. Laser Target Board



EYEport II

The EYEport II Vision Training System trains the speed, accuracy, and efficiency of the eyes to improve vision[20]. This is an electronic device with red and blue lights. Red and blue light create opposing effects in the eyes. Alternately looking at these colors creates a rocking action that stimulates and relaxes the eye's aiming and focusing mechanisms[5]. This device was progressed from slow speed to high speed as the vision training advanced for each person. The lights also were progressed from a continuous pattern to a random pattern. The EYEport II was placed in either a vertical and horizontal, or a right-left, left-right diagonal position in addition to a final near-far positioning. Each player was progressed based on their individual progression throughout each training period[4,5]. Each player performed one repetition with the device in each position for just over one and one-half minutes during each session the EYEport was used.

Figure 5. EYEport II

Outcome Measures

Stereopsis Measurement

As in the study performed by Clark et al[5], we used stereopsis as the dependent variable to track visual training progression. Vision training is the independent variable in this study. We measured depth perception before, during, and after training. This measurement of stereopsis was accomplished using the stereo fly method described by Clark et al.[5]. This test allows for evaluation of fine depth perception and gross stereopsis.

This measurement was taken by having the subject wear polarized glasses and placing them in front of a picture of a hologram housefly at a distance of thirty-five centimeters from their nose. They were then instructed to look at the picture and notify the experimenter if "the fly's wings appeared to be standing up at them and in three dimensions?" After a positive response, the subject was prompted to "reach out and pinch the tip of the fly's right wing with their thumb and forefinger and hold that position." The distance between the photo and the center of the pinch wat then recorded with a millimeter ruler. A larger number in millimeters is indicative of a better stereopsis measurement. Each subject was instructed to pinch the tip of the fly's wing two times, one for practice and to get comfortable with the test, and the second to be recorded for data analysis.

Baseline stereopsis measurements were obtained in January of 2018 prior to beginning their 2018 pre-season training and conditioning and prior to the start of their vision training. A second measurement was taken six weeks after beginning vision training. A final measurement was taken at the end of the regular season at eighteen weeks from the first stereopsis measurement.

Figure 6. Stereo Fly Test

EyeGuide Focus

This device is used to track smooth-eye pursuits. We used this as a baseline measurement for each participant in conjunction with the stereopsis as a secondary baseline measurement. This measurement is done by having each participant rest their head approximately twelve inches in front of an iPad screen that is opened to the EyeGuide Focus App. The subject is fitted with a headband that has a camera attached to it that tracks movement of the pupil in the eye. The pupil of the right eye was used for each participant. Each subject then was prompted by the app to follow a white dot on the screen in a figure-8 pattern for a total of 7 seconds. The app does not record the first or the last second of eye movement to ensure that the patient can lock on to the moving dot.

Smooth-eye pursuits are a very important skill for those who participate in activities where they must track objects through time and space[4,5,10,28]. Therefore, it is important to track that improvements for this skill are occurring with visuomotor training. EyeGuide measurements were taken when stereopsis baseline measurements were taken and again after the final day of visuomotor training approximately eighteen weeks later.

Baseline smooth-motor pursuit measurements were taken in January of 2018 prior to beginning their 2018 pre-season training and conditioning and prior to the start of SVT. This measurement was repeated once more at the end of the regular season when all vision training had been finished.

Figure 7. EyeGuide Focus Vision Screen

Figure 8. EyeGuide Focus Headrest

Data Management

All data used for analysis in this study was obtained from publically available sources where college baseball statistics are found. The main sources for the data presented and discussed in our study are as follows:

https://sdstate_ftp.sidearmsports.com/custompages/www.gojacks.com/fls/15000/stats/2017_BS/teamcume.htm

https://sdstate_ftp.sidearmsports.com/custompages/www.gojacks.com/fls/15000/stats/2018_BS/teamcume.htm

http://www.thesummitleague.org/sports/bsb/2017-18/teams?sort=&r=0&pos=eh

http://thesummitleague.org/sports/bsb/2017-18/teams?sort=&r=0&pos=h

http://thesummitleague.org/sports/bsb/2017-18/teams?sort=&r=0&pos=f

http://thesummitleague.org/sports/bsb/2016-17/teams?sort=&r=0&pos=h

http://thesummitleague.org/sports/bsb/2016-17/teams?sort=&r=0&pos=eh

http://thesummitleague.org/sports/bsb/2016-17/teams?sort=&r=0&pos=f

Data used in the tables presented in this study and for data analysis were extracted from the above referenced URLs.

Data gathered for stereopsis and EyeGuide Focus measurements were saved in an excel file in a password-protected computer. After all data was collected, each subject was assigned a number and their data was analyzed by a researcher separate from the one who collected the data and assigned the number to each subject.

Data Analysis

Statistics were analyzed from the 2017 season and the 2018 season. This was done to maximize the consistency of active players across all teams. Only batting statistics of the experimental team and the teams within their specific collegiate conference were analyzed for this study. Data were analyzed using repeated measures ANOVA with post-hoc comparisons being performed using Tukey's HSD.

CHAPTER 3

Results

Summary of Demographic Data

Recruited athletes were all male and were all similar in age (20.6 ± 2.6 years), height (184.1cm ± 11.5cm), and number of years of baseball experience (15.5 ± 2.5 years). The majority of the participants were right eye dominant (81% vs. 19%). A smaller portion of the study population used some form of optical correction (34% vs. 66%). Most participants were right-handed (81% vs 19%). None of the participants in the study had sustained a concussion in the previous two years. Ninety three percent of the training sessions were completed by the participants.

Thirty-two participants were originally recruited to for this study. One participant was excluded from the study due to a chronic eye injury and one participant withdrew from the study due to scheduling conflicts. The final number of participants that we collected data from was thirty (n=30). No participants were removed from participation due to poor vision, color-blindness, or due to being absent from greater than five SVT sessions.

Of the thirty recruited athletes, seventeen had at least one at-bat during the 2018 season. The offensive statistics analyzed in this study were from those seventeen study participants.

Adverse Reactions

At the beginning of the vision training program, 2 participants noted eye strain and headaches. These participants were monitored and the symptoms resolved within 24 hours following the daily vision training. By the third training sessions, these participants no longer had the symptoms and continued with the vision training program.

Summary of Results

Data were analyzed using repeated measures ANOVA with post-hoc comparisons being performed using Tukey's Honest Significant Difference (HSD).

Stereopsis measurement increased significantly from baseline to mid-season and mid-season to post-season ($p<0.05$). Table 1 shows the means and standard deviation at each of the visits for stereopsis measurements. The average stereopsis measurement improved from 37.3 ± 24.7cm to 53.3 ± 25.6cm after six weeks of vision training. Stereopsis measurements improved from 53.3 ± 25.6cm to 73.9 ± 29.9cm in the following eighteen weeks of vision training.

EyeGuide measurement improved significantly from pre to post SVT ($p<0.001$). This was analyzed by paired t-test since there were only two time points. EyeGuide measurements are shown in table 2. Mean baseline EyeGuide measurements were 19764.2 ± 7508.2 and improved to 15465.3 ± 5922.4 after completing the entirety of the baseball season and the twenty-four weeks of the SVT program.

We examined the statistics from the games played only within the study group's collegiate sports conference. The batting average for the study group went from 0.296 in the 2017 season to 0.295 in the 2018 season (batting average is hits/at bats, excluding walks, fielder's choice and sacrifice).[4] The rest of the conference had a batting average of 0.243 for the 2017 season and a batting average of 0.261 for the 2018 season. The number of games played in the 2017 season was similar to the amount of games played in the 2018 season (30 games played in 2017 vs 27 games played in 2018). The number of at-bats was also similar for both the 2017 and 2018 seasons for the study group (1072 and 954 respectively). The number of runs-batted-in (RBI) improved by 5% in the 2018 season from the 2017 season. Doubles, triples, and home runs all increased in the 2018 season for the study group. Slugging percentage improved from 0.394 in the 2017 season to 0.423 in the 2018 season. Slugging percentage a reflection of hits with extra bases.[4] On-base percentage improved from 0.394 in 2017 to 0.423 in the 2018 season.

Fielding percentage improved from 0.966 in the 2017 season to 0.969 after the 2018 season. The amount of errors decreased from 38 in the 2017 season to 32 in 2018.

Data Tables

Table 1: Mean and standard deviation for steriopsis

Time Period	**Value (std dev)**
Baseline	37.3 (±24.7)
Mid-Season	53.3 (±25.6)
Post-Season	73.9 (±29.9)

Table 2: Mean and standard deviation for EyeGuide Focus

Time Period	**Value (std dev)**
Pre-SVT	19764.2 (±7508.2)
Post-SVT	15465.3 (±5922.4)

Table 3: Baseball statistics representing all Study Group games and their opponents' performance during those games

Group	**BA**	**Gp-Gs**	**AB**	**Runs**	**Hits**	**2B**	**3B**	**HR**	**RBI**
2018 SG	0.295	27-27	954	191	281	45	9	20	170
2018 Op	0.261	27-27	926	171	242	37	8	18	155
2017 SG	0.296	30-30	1072	195	317	52	4	15	176
2017 Op	0.243	30-30	996	146	242	40	6	20	128

Table 4: Baseball statistics representing all Study Group games and their opponents' performance during those games

Group	TotBase	Slg%	OB%	BB	HBP	K
2018 SG	404	0.423	0.418	171	39	238
2018 Op	349	0.377	0.366	143	20	230
2017 SG	422	0.394	0.393	155	24	228
2017 Op	354	0.355	0.343	125	32	213

Table 5: Baseball statistics representing all Study Group games and their opponents' performance during those games

Group	E	Fld%
2018 SG	32	0.969
2018 Op	47	0.953
2017 SG	38	0.966
2017 Op	49	0.957

CHAPTER 4

Discussion

It has been found that sports vision training programs can lead to improved performance in the sport of baseball.[4,5] These improvements have been found to occur with improved depth perception, manual interception, and locomotion.[2,4,5,8] Our current study developed exercises that would both train these key skills, and be affordable to the average sports team. Our hypothesis was that a low-cost SVT program would improve these target visuomotor skills and lead to improved sports performance through higher batting statistics and lower defensive errors.

Our first aim was to improve visuomotor ability. Utilizing six different exercises, we were able to target and train the key skills deemed necessary to improve sports performance by Clark et al.[4,5] We were able to find a significant improvement in stereopsis scores at both our six week measurement, and at our twenty-four week measurement. This was important in determining that our SVT program was effective at targeting the skills necessary to improve performance in baseball. This marks that depth perception and convergence was targeted, trained, and improved. These results are similar to previous studies by Clark et al[4,5] that implemented visual training programs that aimed to improve depth judgement, visually-guided locomotion, and manual interception. After vision training, stereopsis scores both improved from pre-season to post season as well as from year to year.[5]

We utilized EyeGuide Focus as a secondary outcome measurement in our study. EyeGuide is a device that is used to measure dynamic visio-motor synchronization, or smooth pursuit of the eyes.[29,30] The eye guide uses a small camera that is mounted to a headset. This camera then tracks the movement of the subject's pupil as they track a target on the EyeGuide Focus screen. The measurement taken is the deviation of the pupil from the path of the moving target. We came to utilize this as an outcome measure because of its unique ability to track these small movements and give accurate measures of one of our target ocular motor parameters.[29,31] To our knowledge, our study is the first of its kind to utilize EyeGuide Focus as an outcome measurement for tracking improvements in visuomotor ability. We found improvements in our study group's post-SVT program EyeGuide measurements when compared to the pre-SVT program measurements. This improvement marks an improvement in smooth-motor eye pursuits for our subjects. This skill is important when tracking a moving object and shows that our subjects had a higher ability to follow a moving target at the end of our training than they began with.

Although we found significance in both stereopsis and EyeGuide measurements ($p<0.05$ and $p<0.001$ respectively), we did not see any improvement overall in batting average. Looking only at batting average, it would be easy to say that the SVT program did not have any effect on sports performance. If we were to take into consideration the amount of walks and hit-by-pitches that occurred as well and look at the team's on-base percentage each year, we are able to see improvement. The on-base percentage improved from 0.393 in 2017 to 0.418 in 2018. This is a 0.025 improvement in on-base percentage, and means that we got on base more often after performing visuomotor training. Our participants also had a higher slugging percentage after performing visuomotor training. They improved their slugging percentage of 0.393 in the 2017 season to 0.423 in the 2018 season. Slugging percentage takes into account the amount of multiple-base hits.

This is relevant because it demonstrates that our subjects were able to track the ball more efficiently, allowing them to make better contact with the baseball to get more extra-base hits. When compared to current literature, we see similar improvements in both slugging percentage and on-base percentage.[4] Conversely however, the same literature shows significant improvements in batting averages.[4] Both our study and the referenced studies utilized the same training parameters. A series of various exercises were used and rotated each training session, the exercises both targeted the same ocular motor parameters, and many of the same exercises were used in both our study and the referenced studies.[4,5] A major difference between our study protocol and that of Clark et al[4,5] is that our study only occurred during the competitive season, where their study design had vision training being done in both the fall and pre-season as well as during the competitive season. This may account for the difference we are seeing in batting averages.

For non-batting statistics, we recorded a decrease in errors after performing the SVT program. The subjects went from 38 errors in the 2017 season to 32 errors in the 2018 season. This may be attributable to improved visual motor coordination. Improved hand-eye coordination is a skill that may decrease the number of errors and dropped balls. The proficiency of the defensive player to track the ball off the bat and into the mitt may improve after performing visuomotor training. Again, we see very similar changes in the study by Clark et al[4] who also noted that their study cohort recorded less fielding errors and a higher fielding percentage after performing visuomotor training. They suggest that improved eye-hand coordination that comes with an SVT program may attribute to decreased numbers of dropped balls and fielding errors.[4]

Overall, the authors of this study believe that implementation of a low-budget SVT program is a viable option for improving the key skills necessary for enhancing sports performance in baseball. We were able to determine that our SVT program was able to improve DP, manual interception, and locomotion through tracking stereopsis and smooth-motor pursuit measurements. Further research must be done to determine a correlation between improved sports performance in the sport of baseball, and the use of a low-budget SVT program.

Delimitations/Limitations

The delimitation of this study is the amount of current literature supporting the exercises chosen to improve visuomotor ability

There are certain limitations that need to be addressed in this study. Certain changes in batting averages, slugging percentage, on-base percentage can occur season-to-season for a number of various reasons. Maturity and skill level of returning players tends to improve. Newly recruited players may also come from a stronger recruitment year. This being stated, we must assume that these reasons would not change more positively for our study group than for the other teams in the entire study group's conference.

Other variables that must be considered as limitations include the amount of road games the study group encountered compared to the other teams within the same conference. The study group played a total of sixteen home games in the 2017 season vs only playing six home games in the 2018 season. This is important to note because it led to sleep deprivation in a number of the subjects due to the amount of hours spent riding on the travel bus and trying to sleep in unfamiliar environments. A study by Tong et al[31] suggests that acute sleep deprivation induces instability in visuomotor prediction. This should be considered when determining the overall success of our SVT program. It may even be suggested that without the implementation of our SVT program, improvements in batting statistics may not have been seen at all, or even have gotten worse.

The weather conditions the study group played in during the 2018 season were worse than the 2017 season. Most games were played in weather that the subjects found to be cold. This may have mentally effected them as well as physically made them less able to perform to their optimal abilities.

We also must consider limitations with the equipment used. Clark et al[5] were able to adjust the height of their equipment to best achieve personalized training for each study participant. We had to use equipment fixed at an average height of all study participants which may have played a role in the study findings. Another limitation was with the EyeGuide Focus. We experienced technical difficulties with the EyeGuide equipment at the six-week follow-up measurement. Because of this, we were unable to have accurate readings for the EyeGuide at the mid-point of training, so we do not know whether there were any improvements to be seen at that time.

It must finally be noted that there may be some experimenter error involved in proctoring some of the visuomotor training exercises. The “laser board” was done by having a proctor point a laser at a dot on the wall, wait for the participant to touch the dot, and then quickly switch which dot the laser was pointing at. Although all proctors received the same training for this exercise, their individual speeds may have differed from training session to training session. Not only this, but their skill levels may have all progressed at different speeds as they proctored this exercise more and more as the study progressed. It should be taken into consideration that the Dynavision D2 was kept at a consistent speed as it was all automated and we may have encountered some user-error that resulted in uneven results across our subjects.

Future Research

Future research must focus on performing a low-budget SVT program over the course of several seasons. This will help to determine if the SVT exercises are helping to continue to improve athletes each year or if there is a plateau effect after a certain amount of time.

Research in the future should also continue to utilize EyeGuide Focus as an outcome measure. To our knowledge we are the first study to utilize it as a measure of visuomotor improvement and have no further support than our own to determine the efficacy of its use. We believe that it was a viable and useful outcome measure for this study, but further research must be done to confirm our findings.

Conclusion

The results of this study would imply that the implementation of a low-budget, SVT program is a viable option for improving the key visuomotor skills of depth judgement, visually-guided manual interception, and locomotion for enhancing sports performance in baseball. We were able to determine that our SVT program was able to improve DP, manual interception, and locomotion through tracking stereopsis and smooth-motor pursuit measurements. Although we did see slight improvements in slugging percentage, on-base percentage, and in defensive errors and fielding statistics between the 2017 and 2018 seasons, we cannot definitively state that our SVT program improved the performance of an NCAA division I collegiate baseball team. Further research should be done to determine if implementing an SVT program for more than one season helps to improve visuomotor ability and batting and defensive baseball statistics to a greater degree than what we have presented in this study.

CHAPTER 5

References

1. Krzepota J, Zwierko T, Puchalska-Niedbal L, Markiewicz M, Florkiewicz B, Lubinski W. The Efficiency of a Visual Skills Training Program on Visual Search Performance. *J Hum Kinet*. 2015;46:231-240.
2. Gao Y, Chen L, Yang SN, et al. Contributions of Visuo-oculomotor Abilities to Interceptive Skills in Sports. *Optom Vis Sci.* 2015;92(6):679-689.
3. Chang ST, Liu YH, Lee JS, See LC. Comparing sports vision among three groups of soft tennis adolescent athletes: Normal vision, refractive errors with and without correction. *Indian Journal of Ophthalmology*. 2015;63:716-721.
4. Clark JF, Ellis JK, Bench J, Khoury J, Graman P. High-performance vision training improves batting statistics for University of Cincinnati baseball players. *PLoS One.* 2012;7(1):e29109.
5. Clark JF, Graman P, Ellis J. Depth perception improvement in collegiate baseball players with vision training. *Optometry and Visual Performance.* 2015;3(2):106-115.
6. Uchida Y, Kudoh D, Higuchi T, Honda M, Kanosue K. Dynamic visual acuity in baseball players is due to superior tracking abilities. *Med Sci Sports Exerc.* 2013;45(2):319-325.
7. Kato T, Fukuda T. Visual search strategies of baseball batters: eye movements during the preparatory phase of batting. *Percept Mot Skills.* 2002;94(2):380-386.
8. De Lucia PR, Cochran EL. Perceptual information for batting can be extracted throughout a ball's trajectory. *Percept Mot Skills.* 1985;61:143-150.
9. Molia LM, Rubin SE, Kohn N. Assessment of stereopsis in college baseball pitchers and batters. *J AAPOS.* 1998;2(2):86-90.
10. Gray R. How do batters use visual, auditory, and tactile information about the success of a baseball swing? *Research Quarterly for Exercise and Sport.* 2009;80(3):491-501.
11. Reichow AW, Garchow KE, Baird RY. Do scores on a tachistoscope test correlate with baseball batting averages? *Eye Contact Lens.* 2011;37(3):123-126.
12. Alsharji KE, Wade MG. Perceptual training effects on anticipation of direct and deceptive 7-m throws in handball. *J Sports Sci.* 2016;34(2):155-162.
13. Wood G, Wilson MR. Quiet-eye training for soccer penalty kicks. *Cogn Process.* 2011;12(3):257-266.
14. Abernethy B, Wood JM. Do generalized visual training programmes for sport really work? An experimental investigation. *J Sports Sci.* 2001;19(3):203-222.
15. Klostermann A, Vater C, Kredel R, Hossner EJ. Perceptual Training in Beach Volleyball Defence: Different Effects of Gaze-Path Cueing on Gaze and Decision-Making. *Front Psychol.* 2015;6:1834.
16. Wood JM, Abernethy B. An assessment of the efficacy of sports vision training programs. *Optom Vis Sci.* 1997;74(8):646-659.
17. Zwierko T, Puchalska-Niedbal L, Krzepota J, Markiewicz M, Wozniak J, Lubinski W. The Effects of Sports Vision Training on Binocular Vision Function in Female University Athletes. *J Hum Kinet*. 2015;49:287-296.

18. Anderson L, Cross A, Wynthein D, Schmidt L, Grutz K. Effects of dynavision training as a preparatory intervention status postcerebrovascular accident: a case report. *Occup Ther Health Care.* 2011;25(4):270-282.
19. Appelbaum LG, Schroeder JE, Cain MS, Mitroff SR. Improved Visual Cognition through Stroboscopic Training. *Front Psychol.* 2011;2:276.
20. Laukkanen H, Rabin J. A prospective study of the EYEPORT vision training system. *Optometry.* 2006;77(10):508-514.
21. Schwab S, Memmert D. The impact of a sports vision training program in youth field hockey players. *J Sports Sci Med.* 2012;11(4):624-631.
22. Smith TQ, Mitroff SR. Stroboscopic Training Enhances Anticipatory Timing. *Int J Exerc Sci.* 2012;5(4):344-353.
23. Vesia M, Esposito J, Prime SL, Klavora P. Correlations of selected psychomotor and visuomotor tests with initial Dynavision performance. *Percept Mot Skills.* 2008;107(1):14-20.
24. Wells AJ, Hoffman JR, Beyer KS, et al. Reliability of the dynavision d2 for assessing reaction time performance. *J Sports Sci Med.* 2014;13(1):145-150.
25. Wilkins L, Gray R. Effects of Stroboscopic Visual Training on Visual Attention, Motion Perception, and Catching Performance. *Percept Mot Skills.* 2015;121(1):57-79.
26. Somers WW, Hamilton MJ. Estimation of the stereoscopic threshold utilizing perceived depth. *Ophthalmic Physiol Opt.* 1984;4(3):245-250.
27. Stine CD, Arterburn MR, Stern NS. Vision and sports: a review of the literature. *J Am Optom Assoc.* 1982;53(8):627-633.
28. Laby DM, Rosenbaum AL, Kirschen DG, et al. The visual function of professional baseball players. *Am J Ophthalmol.* 1996;122(4):476-485.
29. Heitger MH, Jones RD, Macleod AD, Snell DL, Frampton CM, Anderson TJ. Impaired eye movements in post-concussion syndrome indicate suboptimal brain function beyond the influence of depression, malingering or intellectual ability. *Brain.* 2009;132(Pt 10):2850-2870.
30. Muri RM, Nyffeler T. Neurophysiology and neuroanatomy of reflexive and volitional saccades as revealed by lesion studies with neurological patients and transcranial magnetic stimulation (TMS). *Brain Cogn.* 2008;68(3):284-292.
31. Tong J, Maruta J, Heaton KJ, Maule AL, Ghajar J. Adaptation of visual tracking synchronization after one night of sleep deprivation. *Exp Brain Res.* 2014;232(1):121-131.