A Survey of Sports Vision Practitioners

Thesis

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Abstract

The purpose of this study was to survey sports vision practitioners to gather information on sports vision practice. The goal was to learn where opportunities are being found within sports vision and the details of practitioners' preferred practice patterns. Sixty-one sports vision practitioners answered questions on an online survey after providing informed consent. For those who answered the question regarding their profession, 87% were optometrists. The survey included multiple choice questions, along with a table of sports vision related tools. For the multiple choice questions, survey takers were asked questions about practitioner and athletic population demographics, sports vision assessment and training, and optical tints and nutraceuticals. Survey respondents indicated how often they employed each of the tools in the table. The number of responses for the multiple choice questions ranged from 42 to 61 and the number of responses per device in the matrix table range from 47 to 50.

Devices in the matrix table were categorized three ways. Firstly, as analog and digital devices. Secondly, as devices that train the visual hardware versus visual software systems. Lastly, the devices were organized in a 4-tier system based on previously proposed hierarchical visual perceptual models.

The survey results indicate that sports vision practitioners have found a wide range of opportunities to work with athletes across several sports and age groups as

indicated by responses to questions about athletic patient population, characteristics of work with athletes, and about contracts with sports teams. The sports with athletes with whom the survey responders work (most commonly baseball, 71.15%) generally aligns with the published sports vision research, where baseball is the most studied population. There are discrepancies among the level of sport represented by the results of this survey (most commonly high schoolers, 75.4%) and the literature, where collegiate and professional are more commonly researched. Sports vision practitioners place significance in optimizing UV protection and contrast sensitivity by discussing or prescribing sun protection (30% characterize sun protection as very significant), tinted contact lenses (58% prescribe tinted contact lenses at least occasionally), and nutraceuticals for ocular health (Prescribed at least sometimes by 67% of respondents).

The survey questions related to device usage were analyzed using the percentage of respondents that indicated they use a device "most of the time" as opposed to "about half of the time" or "rarely/never". The results indicate preferences for analog devices more than digital ($p=0.027$; medians: analog= 29.79%, digital=10.2%), hardware training devices more than software (which targets higher order tasks such as attention) ($p=0.045$; medians: hardware= 29.79%, software=10.42%), and devices that target lower tier visual skills such as vergence, accommodation, and oculomotor skills as opposed to high level eye-hand and peripheral awareness ($p=0.078$; medians: Level 1: 61.42%; Level 2: 13.43%; Level 3: 31.25%; Level 4:18.37%). The literature suggests that training both hardware and software systems and high and low level visual skills is best for gains in visual and in-game performance measures.

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Chapter 1: General Introduction

Vision is critical for successful performance in sports. Executing tasks such as returning a tennis serve, batting a baseball, or intercepting a pass in football are very difficult in the absence of vision. Sports vision rests on the idea that vision is important in sports, and more specifically that optimized vision and visual function is a significant advantage over non-optimized vision[1–5]. Further, sports vision training is thought to improve visual function which in turn improves on-field improvements. Recently, research in sports vision has increased dramatically, and there are indicators that interest in clinical sports vision has similarly risen. The International Sports Vision Association (ISVA) is an organization of professionals interested in sports vision, and the Journal of Sports and Performance Vision now publishes papers on sports vision. The rising interest in research and clinical issues has been accompanied by the development of a number of digital devices for training and assessment.

Overview of sports related visual skills categories

There are a number of ways in which the visual skills associated with sports have been categorized. A general scheme for motor performance was proposed by Welford and subsequently elaborated on by Ciuffreda and Wang[6], Laby and Kirschen[7] and

Erickson[8] (Figure 1). This scheme consists of three mechanisms: the perceptual mechanism, the decision mechanism, and the effector mechanism. The perceptual mechanism “detects and selects the appropriate input”, the decision mechanism (referred to as the “translation mechanism” by Welford) involves “strategy formation and response selection”, and the effector mechanism (called the “central effector mechanism”) has responsibility for “response organization and control of ongoing movement”. Ciuffreda and Wang[6] developed a list of five categories of sports-related visual skills. These included visual resolution, depth perception, object tracking (with eye movements and accommodation), visuomotor integration (e.g. eye and hand coordination), and visual information processing (attention and other higher-level processes). Erickson fit some of the visual skills mentioned by Ciuffreda and Wang as well as other specific visual skills into the Welford scheme. For example, Erickson suggested that static visual acuity and peripheral vision would fall under the perceptual mechanism[8]. Information processing speed and multiple object tracking would fall under the decision mechanism, while visual-motor reaction time, peripheral eye-hand response, and coincidence anticipation timing would fall under the effector mechanism. As conceptualized by Welford, these mechanisms proceed sequentially (that is, the operation of the perceptual mechanism precedes the operation of the decision and effector mechanisms), although the output of the system feeds back on the perceptual and effector mechanisms. Thus, the Welford model is hierarchical, with performance of the higher-level mechanisms dependent on the functioning of the lower-level mechanisms. A different hierarchical model was developed by Kirschen and Laby[7]. This pyramid model is pictured in Figure 2. Similar to Welford’s model, higher-level visual skills rely on lower-level visual skills for proper execution. So, for example, reasonable static visual acuity is required to support the higher-level visual decision-making process. Of course, as pointed out by Laby and Kirschen[7], visuomotor actions are also guided by heuristics such as experience and expectation. For example, a baseball batter's expectations may be influenced by the pitch count or familiarity with a pitcher's tendencies.

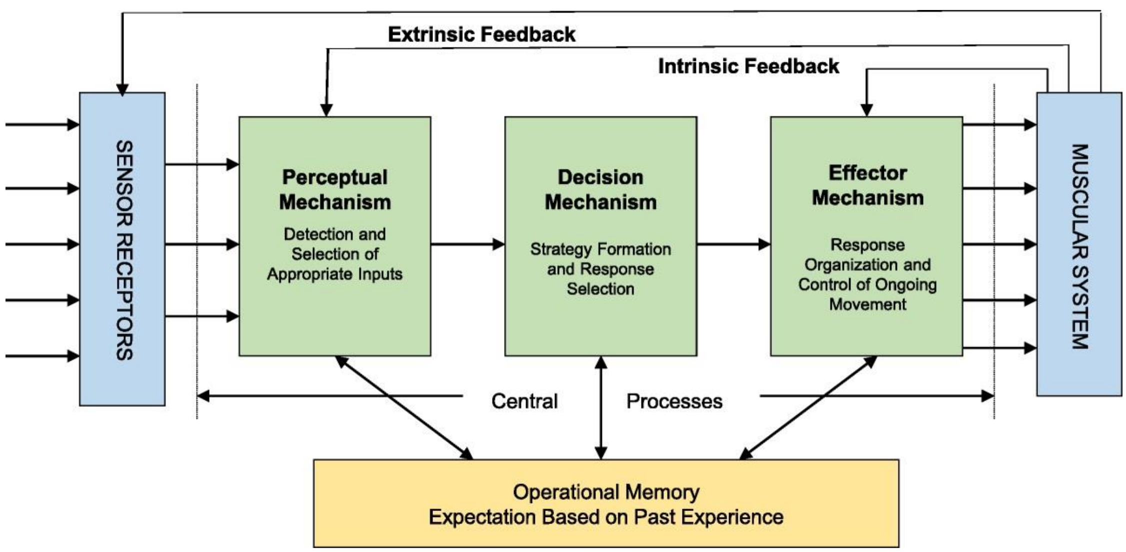

Figure 1. Welford information processing model used with permission: Erickson G. Review: Visual Performance Assessments for Sport. Optometry and Vision Science 2021; 98(7): p 672-680. https://journals.lww.com/optvissci.

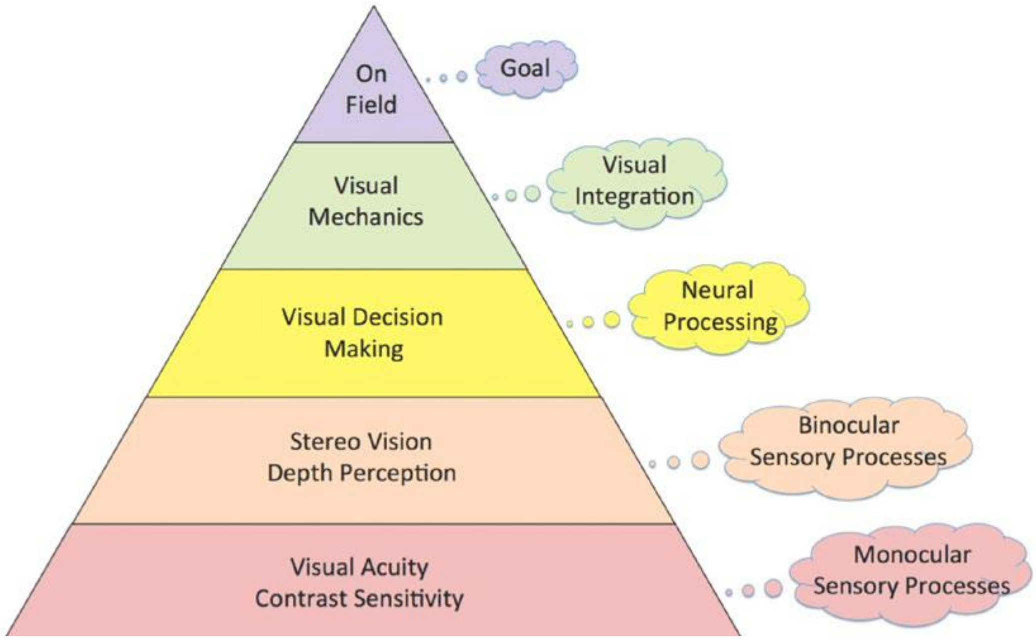

Figure 2. Sports Vision Pyramid visual information processing model proposed by Laby and Kirschen used with permission: Laby D, Kirschen D. Case Report: A new model for sports and performance vision. Vision Dev & Rehab 2018;4(2):85-91.

In a recent paper, Hodges and colleagues.[9] described a scheme to categorize the perceptual-cognitive skills that may be involved in sports performance. Hodges and colleagues placed these variables into four categories. The fundamental skills category included visual acuity (both static and dynamic) and visual fields, low-level visual skills included contrast sensitivity, stereoacuity, and motion perception, high-level visual skills and attentional skills included visual attention and eye movement control, and finally cognitive skills included anticipatory decisions, general decision making, memory, and situational knowledge.

The challenge for sports vision practitioners is to determine which of these visual skills influences on-field performance in a particular sport, and how to best test and train that particular skill. In some cases, the question of which visual skill is addressed by a particular test is obvious. For example, fundamental visual skills such as visual acuity or the visual field are tested using well accepted methods, and it is generally[7,10] (although not universally[11,12]) agreed that good visual acuity is a prerequisite for success in many sports. On the other hand, there are tests that require several component skills. For example, eye-hand coordination testing and training methods that require participants to push targets that appear in random locations on a wall-mounted board or computer screen involve peripheral stimulus detection, eye and head movements, and eye-hand (and perhaps eye-head-hand) coordination.

There are generally three ways by which investigators have attempted to determine whether visual skills are likely to contribute to on-field performance[13]. The first of these methods (hereafter referred to as Level 1 evidence), which provides the weakest evidence, is to compare expert and novice performance on a particular test. If experts perform better than novices, then the assumption is that the test assesses a visual skill that leads to better on-field performance. A second method by which to determine whether a visual skill (and the test associated with that skill) is associated with on-field performance is to correlate the results of that test with on-field performance metrics (Level 2 evidence). The evidence yielded by this latter method is intermediate in strength. Finally, the method that yields the strongest evidence is the placebo controlled clinical trial (Level 3 evidence).

While research in sports vision is increasing at a rapid rate, there has to date been no attempt to determine what tests and training methods and therefore which visual skills are emphasized by sports vision practitioners. Since a reasonable assumption could be that the most commonly used tests have been successfully applied by sports vision practitioners, then this would help in establishing best practices for sports vision. In addition, by determining how commonly the testing and training methods used by sports practitioners are applied, it may be possible to determine whether sports vision practitioners are testing and training visual skills within all of the levels or categories suggested by models such as those of Laby and Kirschen[7], Erickson[8], and Hodges and colleagues[9]. In addition, the answers to more general questions about sports vision practices including the competitive level of the sports vision patient population (e.g. high school, college, professional) that sports vision practitioners work with, the setting in which sports vision training occurs, and contractual relationships between sports vision practitioners and athletic teams can help in understanding the opportunities available in clinical sports vision.

The purpose of this thesis is to survey practitioners involved in sports vision to gather information on sports vision practice, including which testing and training methods are most commonly employed. The many devices proposed to test and train visual skills will be categorized based on the Welford model as modified by Erickson[8], the Laby and Kirschen[7] pyramid model, and the categorization proposed by Hodges and colleagues[9]. Then, similarities and differences between these scales will be described, a determination will be made as to which of the categories are most emphasized, and a determination will be made regarding whether there are categories of visual skills that tend not to be included as commonly in the sports vision practices.

Literature Review

Athletes' Vision Compared to Non-Athletes – Level 1 evidence

A number of studies have been done that suggest that athletes, especially those in tracking sports, possess superior low level and fundamental visual skills than non-athletes, although there is evidence to the contrary.

Laby et al.[14] conducted a study of 387 professional baseball players in the major and minor leagues and found the professionals to have better static visual acuity, distance stereo acuity, and contrast sensitivity than the average population. Over 80% of the players had a visual acuity of -0.125 logMAR or better. However, another study mostly found no significant difference between basic visual abilities including distance and near static visual acuity and color vision in published data for young non-sporting adults, compared to elite and near-elite cricket players[15]. Only stereoacuity in the elite players was better than those normative data from the general population. Fogt and colleagues looked at a number of fundamental and low-level skills in amateur esports players, and reported mostly insignificant differences in these skills between the esports players and the general population[16].

While there are a limited number of studies on athlete contrast sensitivity compared to non-athletes, one study demonstrated that athletes have greater contrast sensitivity[17] while another study found no difference between athlete contrast sensitivity and the general population[15]. One study showed an advantage among athletes compared to non-athletes when assessing visual field[18]. These data sometimes support the idea that athletes have better low-level visual abilities than the average population, but whether these abilities support on-field performance is unclear.

Another skill that is often assessed in studies on athletes is dynamic visual acuity. Dynamic visual acuity is a person's ability to resolve fine details of a target when either the target or observer is moving[19,20]. As the speed of motion increases, the ability to see details of the moving object decreases until resolution is no longer possible. The velocity at which resolution is no longer possible is taken to be the dynamic visual acuity. However, the results of the dynamic visual acuity studies cannot be easily compared or analyzed as a whole because the methods used to measure dynamic visual acuity vary greatly between studies. The majority of studies comparing the dynamic visual acuity of athletes to controls suggest a significantly better performance among athletes which may result from their practice of accurate tracking and catching of objects[19–22].

Relationship Between Vision Assessment and Sport Performance- Level 2 Evidence

A question that remains is whether differences exist in visual ability that are associated with sport performance within one level of sport. In other words, does vision play a role in separating the best of the best from other elite players? If there is no evidence that visual tasks have an impact on game performance among a group of athletes, the purpose of visual training for sports is called into question.

A critical review performed by Laby and Appelbaum[13] listed several non-interventional studies comparing visual assessments to sports performance. In non-interventional studies, tests of visual skills are conducted, and the results of these tests are compared to on-field performance measures. The cited studies utilized an array of vision assessment techniques, athletic populations, and analytical methods but suggest that different visual skills do in fact correlate with sport performance, even among higher and lower performing peers within the same level of sport. Among the 13 publications discussed in the review that compared results on visual assessments to sport performance, 9 yielded positive correlations, 3 found no significance, and one had mixed findings.

Two studies looked at the effect of quiet eye, or an athlete's ability to stabilize the eye in the moments before executing a sport skill, among basketball players and (gun) shooters respectively[23,24]. Athletes with more stable fixation and longer presence of a quiet eye prior to shooting had greater shooting accuracy. These studies demonstrate the importance of gaze stability in aiming sports.

Non-interventional studies conducted among baseball populations were by far the most common. Players' visual measures were compared to batting statistics from the season before or after the measurements. Some studies demonstrated favorable results between on-field measures and performance on visual training tools such as the tachistoscope[25], Sports Vision Trainer System(Australian Institute of Sports Vision, Sydney, Australia)[26], Nike SPARQ Sensory Station (now Senaptec) (Beaverton, OR) [27], Enhanced Vision Testing System[28], and RightEye (Bethesda, MD)[29]. These studies utilized a variety of the available systems for assessing sport-specific vision and serve as evidence that the most skilled athletes have superior visual skills even among other elite athletes. Stereoacuity, visual field size, and reaction time, while all found to be above average in elite athletic populations, did not yield significantly greater in-game performance[18,30,31].

Effect of Vision Training on Sport Performance- Level 3 Evidence

The ability of vision training to improve athletic performance is still widely debated. Much of the support comes from anecdotal sources or small case studies. Another barrier in drawing firm conclusions regarding the efficacy of vision training is the lack of consistency in vision training programs.

The critical review of sports vision by Laby and Appelbaum noted earlier also summarized 16 studies on the effects of sports vision training programs. Again, most of these studies were conducted with collegiate baseball teams, although other sports including cricket, badminton, golf, volleyball, and hockey were also included. The results of the studies were generally positive (only 2 of the 16 showed no positive training results). However, the variety of training methods and outcome measures make it difficult to draw conclusions regarding which training methods are most likely to result in positive effects on on-field performance[13].

Of the studies discussed in the review, two conducted generalized vision training programs using standard, well known vision therapy techniques to train vergence (ex. Brock String, tachistoscope), accommodation (Hart charts), and oculomotor skills (saccades). Both of these studies were implemented among Division I collegiate sports teams, one with baseball and one with hockey[32,33]. The baseball team who underwent training was found to have a higher mean batting average and slugging percentage compared to the rest of the conference, the latter group thereby serving as a control[32]. For the hockey players that underwent vision training, there was a reported positive impact on game performance with statistically significant increased number of goals, shots on goal, and shooting percentage[33].

Five of the studies, 4 of which were in baseball, utilized some form of occlusion training whether through stroboscopic methods or occlusion anticipation[34–38]. They all reported some gains from their training programs, three of which showed increased in-game statistics for the season following. One study observed a statistically significant increase in batting average[36]but another showed no increase [37]. Various in-game metrics were used in the five studies, which makes comparisons between studies difficult. Without standard protocols, it is unclear whether results from particular training methods are repeatable and generally applicable to sports. Laby and Appelbaum[13] concluded that more randomized clinical trials which were pre-registered and included both an adequate sample size and a (placebo) control group are necessary to draw firm conclusions regarding the impact of sports vision training procedures on performance in competition.

A recent study, published at the same time as the Laby and Appelbaum review paper, used a digital device to train visual skills including dynamic visual acuity and depth perception[39] The subject population included 32 college softball and baseball players. The study also incorporated a placebo training group. There was a trend toward improvement in visual skills in the training group, but overall, the training effects were relatively small. On the other hand, Liu and colleagues carried out a training study in 24 baseball batters using a digital training system[21]. The training included “stroboscopic drills”, “oculomotor and anticipatory timing drills”, and “dynamic vision training drills”.

This study was pre-registered in a clinical trial database and included a placebo control group. While in-game statistics did not improve, metrics on batting obtained during batting practice did improve.

Classification of Tools

With the number of devices and training techniques aimed at improving athlete vision constantly increasing, it is nearly impossible to compare each individually. It is more logical to compare groups of tools, however deciding how to classify the tools is challenging at least partially because some of these tools test and train a broad range of visual skills. The literature reveals at least three conceptions regarding visual skills for sports that can inform categorization of these tools.

The first, and perhaps most discussed method in sports vision is the Laby and Kirschen Pyramid[7]. This system was developed from the linear Welford/Erikson[8] model. As mentioned above, the Welford/Erikson model depicts a linear process proceeding from perception to action with steps including perceptual, decision, and effector mechanisms. The perceptual mechanism includes the detection and selection of relevant visual input which requires basic visual skills such as acuity, contrast, and stereopsis. Decision making occurs in the brain when strategies are formed and a response is selected, which requires adequate attention and anticipation. The effector mechanism organizes a response and provides constant control of the signals sent to the muscles for action, the result of which is evident in an individual's eye-hand/body coordination. As one progresses through the stages, the degree of neural activity and visuomotor integration increases.

The sports vision pyramid follows a similar pattern of increasing neurological demand. This model classifies sports vision skills into a hierarchy with each level of the pyramid providing a necessary foundation for the proceeding level. Using this system, training devices and techniques can be classified based on the visual skills they target and the corresponding levels of the pyramid. In this pyramid, the base comprises the monocular skills of visual acuity and contrast sensitivity. The next level consists of basic binocular skills including stereo vision and depth perception. An example demonstrating the hierarchical nature of the pyramid is that if each eye does not possess the monocular skills of the first level, a person cannot achieve the binocular skills in the second level. The following level begins to incorporate rudimentary visual decision making; a person must use visual information to make a go or no-go decision. Either a motor action is initiated to interact with the perceived event, or an inhibitory sequence begins. A “go” decision then requires a transition to the penultimate level of the pyramid in which visual input is integrated into accurate, coordinated motor movement. Only with success at all of the previous levels can one achieve optimal on-field sports performance, which is the tip of the pyramid.

The more recent Hodges and colleagues[9] classification divides sports related visual skills into four categories. Although not explicitly a hierarchical system in the sense that higher level functions were not necessarily described as dependent on lower level functions, this scheme resembles that of the Laby and Kirschen[7] pyramid model and the Ciuffreda and Wang[6] list of sports related visual skills, but with added specificity. The categories included in this model are fundamental skills (visual acuity, visual fields), low-level skills (contrast sensitivity, stereoacuity, motion perception), high-level visual skills and attentional skills (visual attention, eye movement control), and cognitive skills (anticipatory decision making, general decision making, memory, situational awareness).

Unlike the multiple classification schemes described above, a dichotomous system of classifying visual skills and subsequently the tools of sports vision practitioners into “hardware” and “software” has also been proposed. This system was first described by Abernethy[40] and more recently expanded upon by Poltavski and colleagues[41]. “Hardware” visual systems are responsible for gathering visual information while the “software” analyzes, interprets, and decides on a reaction to the information. Abernethy placed six skills in the hardware category: static and dynamic visual acuity, depth perception, accommodation, fusion (convergence), color vision and contrast sensitivity. Ferreira[42] (as referenced in Poltavski et al.) described the software system as including eye-hand coordination, eye-body coordination, visual adjustability (such as go-no go), visual concentration, central-peripheral awareness, visual reaction time and visualization (accurately imagining a game scenario without an associated movement). Poltavski et al.[41] suggested that traditional vision therapy techniques target the hardware system while tools such as the Senaptec Training System (Beaverton, OR), FITLIGHT (Miami, FL), and NeuroTracker (Quebec, Canada) target the software system. In their study 53 youth ice-hockey players underwent 5 weeks of hardware training and 5 weeks of software training (randomly assigned hardware first or software first). Both groups saw improvement on electroencephalography (EEG) and visual evoked potential (VEP) measures, indicating more efficient visual signal processing. The software first group demonstrated slightly greater gains.

Finally, Appelbaum and Erickson[43] discussed sports vision training tools in terms of whether they are analog or digital. The “analog” category includes any tool or device that does not require any power source. “Digital” devices, on the other hand, are ones that either need to be plugged in or that utilize battery power. Examining the extent to which digital tools are incorporated into clinical practice is interesting in that many of these digital tools have been developed relatively recently.

Chapter 2. Materials and Methods

A survey was created in Qualtrics (Qualtrics, Provo, UT). The questions on the survey were designed to address the trends of practice in the sports vision field and the methods of vision training most utilized. The entire survey is shown in Appendix A. The team that developed the survey consisted of the author of this thesis, an optometry and vision science graduate student whose interest in sports vision arose from being a certified athletic trainer and who worked with athletes who strongly desired to better all aspects of their skills. It also included the student's advisor, who is a sports vision researcher. In order to build a clinically relevant survey, the survey questions were reviewed by a leading sports vision clinician who works with professional sports teams. The overriding goals of the questions were to address sports vision practitioners' approaches in addressing the categories of visual skills suggested by Ciuffreda and Wang[6] and by Hodges[9]. That is, the questions were meant to address fundamental skills such as visual acuity which may require refractive correction, lower level skills such as contrast sensitivity which may benefit from tinted spectacles or contact lenses or perhaps even vision training[8], and high-level visual and attentional skills which may benefit from vision training.

The survey and study procedures were submitted to The Ohio State University Biomedical Sciences Institutional Review Board and the study was determined to be exempt. A consent form (Appendix B) was included at the beginning of the survey and participants were required to check a box indicating their informed consent in order to continue with the survey.

Recruitment

A recruitment script (Appendix C) was approved by The Ohio State University Biomedical Sciences Institutional Review Board. The script contained a brief description of the study and the link to the survey. For the purpose of this study, sports vision practitioners were defined as clinicians who regularly train competitive athletes to optimize their vision for improved performance. This definition largely determined those individuals to whom the survey was sent. Distribution of a link to the survey occurred through two email blasts to members of the International Sports Vision Association (ISVA) and one email blast to members of the College of Optometrists in Vision Development (COVD) between January and March of 2021. The survey link was also distributed on the social media platform Facebook in the private professional groups “Women in Athletic Training”, and “Athletic Training Professional Development” during the same time frame.

Question Development

The questions regarding the demographics of the survey takers included “how many years have you worked in the area of sports vision?”, and “what is your profession?”.

Another question asked practitioners to characterize their work in sports vision and to select all that applied. Potential answers included general eye examinations, sports vision therapy, binocular and accommodative orthoptic therapy, and neurovision rehabilitation. The aim of this question was to gain an understanding of how sports vision practitioners divide their time.

Practitioners were asked to estimate the percentage of their sports vision practice that is devoted to traumatic brain injury and concussion. Neurovision rehabilitation after concussion is a popular topic within sports vision research and it might be expected that the sports vision practitioners would spend significant time working in this area. There are estimated to be between 1.7 and 3 million sport related concussions each year[44]. A normal recovery period following a concussion is 10-14 days in adults and 2-4 weeks in children. However, about one out of every three patients will develop persistent pot-concussive syndrome with symptoms persisting beyond the normal recovery timeframe[45]. Having visual or vestibular symptoms within the post-concussive period increase the likelihood of prolonged recovery[46]. Following concussion, individuals can experience deficits in accommodation, vergence, oculomotor skills, and photosensitivity[47–49]. One retrospective study showed 82% of concussion patients had a binocular vision problem and that vision rehabilitation was successful in improving or resolving symptoms and clinical measures[50]. In a growing field like sports vision, new information is constantly becoming available and keeping up with it can be daunting. In order to inform new sports vision practitioners on the way that current clinicians obtain information regarding sports vision, respondents were asked to select the method in which they primarily obtain new information. Options included books, scientific journals, trade journals/magazines, sales representatives, and continuing education lectures.

Questions regarding the demographics of the athletic populations with whom the respondents work included “which sports do you perform sports vision with?”, and “which best describes the athletes you work with?”. This latter question was related to the level of play of the athletes that the practitioners worked with. These questions were asked to identify where practitioners are currently finding opportunities, to reveal opportunities that may not have yet been explored, and to compare the populations most worked with clinically to the populations most commonly involved in research.

Another question that was asked was “Do you use different assessment procedures for different sports?”. It was hypothesized that practitioners would answer yes to this question because each sport has a unique set of visual demands. For example, sports like basketball and football require greater degrees of divided attention compared to a sport such as golf.

An article by Farrow and Abernethy[51] in 2003 addressed the concept of coupled versus uncoupled training in sports. A number of subsequent studies have also examined this question. Coupled[52–54] training is training whereby the athlete is required to maintain the normal relationship between perception and action. It requires sport specific actions to be performed that are as similar as possible to the actions required on the field (*in situ*). In uncoupled training, the normal bond between perception and action is broken, as each component of an action is trained individually. It is unclear whether uncoupled training is as effective as coupled training. If uncoupled training is less effective than coupled training, then this raises an interesting question around the physical location where sports vision training occurs. This is because sports specific actions, which are by definition coupled tasks, may not be possible in offices with limited space. Therefore, a question was included that asked practitioners to indicate where they conducted assessments and training. Potential answers included "In the clinic/ office, at a team owned dedicated sporting facility, and/or a neutral dedicated sporting facility." Answers to this question to some extent reflect how much of sports vision training is coupled versus uncoupled. The answers to this question cannot be used to definitively determine whether coupled or uncoupled training is more common in sports vision, because for example virtual simulations requiring a coupled response similar to that in competition could be used in the office while uncoupled training could occur on the field of play.

Another question that was included in the survey was "Do you challenge balance in assessment or training?" Athletes must often perform under conditions where they are moving or where balance is disrupted[6] It has been shown that vision contributes to balance along with vestibular and proprioceptive control[55]. Balance and proprioceptive control are frequently trained in athletes as part of injury prevention or recovery[56,57]. Because of the connections between vision, proprioception, and the vestibular system, vision therapy often incorporates balance as a way of increasing the challenge of visual tasks. Challenging balance may increase the cognitive load of an activity.

An additional way that vision practitioners can care for athletes is through their prescribing practices. There are sunglasses, ANSI approved sport glasses frames, and contact lenses all marketed towards athletes. There are papers demonstrating that contrast sensitivity may be improved with amber and grey-green tinted contact lenses (the now discontinued Nike Maxsight lens (Bausch & Lomb, Laval, Canada)[58,59], although there is some evidence from one study that these changes may not be clinically significant[60]. In addition, there are papers suggesting that the use of lenses in sports is not detrimental to vision[61,62]. A new product by ALTIUS (Performance Vision Technologies, Inc., Lake Oswego, OR) utilizes the grey-green and amber lens colors in a daily disposable lens designed for athletes. Many outdoor athletes can be seen using sunglasses or visors during play in bright lighting, suggesting that protecting the eyes from the sun and mitigating effects of the sun such as glare are important to athletes. Therefore, the survey included questions about both the practitioners' views on the significance of sun protective eyewear for athletes, and questions about the frequency with which tinted contact lenses are prescribed.

Macular pigment filters short-wave energy as light passes through the eye to the photoreceptors[63]. In addition to providing ocular protection from short wavelength or ultraviolet (UV) light, macular pigment may reduce glare recovery times and increase color contrast and temporal processing speeds. Pigmented dietary carotenoids such as lutein and zeaxanthin are found in high concentrations in the brain and eye and are major contributors to macular pigment[63]. Nutraceuticals, defined here as antioxidant supplements, may result in visual advantages by increasing the macular pigment[64,65] . Therefore, a question regarding the frequency with which practitioners discuss or prescribe nutraceuticals was included.

Device Choice

A significant aspect of the survey was an assessment of the rate of usage of sports vision tools or devices. A list of 38 devices was developed and presented to the respondents in three matrix tables. For each device, the practitioner was asked to select the frequency with which they used that device in their sports vision practice. The answer choices were "most of the time", "about half of the time", or "rarely/never". The list of devices was developed by referring to published literature that referenced the devices[2,9,66] and by searching for devices using the Google search engine. While every attempt was made to develop the most comprehensive list of devices possible, it is acknowledged that the vast number of devices available for vision training make it difficult to ensure that all devices are listed. For this reason, an "other" choice in which respondents could write in devices not otherwise listed in the tables was included.

Analysis

Some of the questions in the survey were simple multiple-choice questions, most of which related to demographics of the survey respondents or their practice. These questions were analyzed using descriptive statistics. A few questions were multiple select whereby the users could "select all that apply". These questions mostly pertained to describing the populations with which the practitioners work and were also analyzed using simple descriptive statistics.

The matrix table asked respondents to indicate how often they use a variety of sports vision training and assessment tools. The tools were divided into categories in three ways. The first categorization method was based on the Welford/Erickson[8], Laby/Kirschen[7], Hodges and colleagues[9], and Ciuffreda and Wang[6] classifications. The second categorization was made based on the hardware/software visual skills dichotomy[40–42], and the third categorization was based on whether the device was analog or digital. Then nonparametric statistics were used to compare categories of tools to determine whether a particular category was used more commonly than another category.

Chapter 3. Results

A total of 68 individuals provided informed consent and began the survey, but 17 did not complete it. Seven of these latter 17 individuals did not complete any of the survey after providing informed consent and were deleted, while the remaining 10 individuals did complete the first half of the survey but terminated the survey at the beginning of the matrix table of devices (which followed the multiple choice questions). The number of responses for the multiple choice questions ranged from 42 to 61 and the number of responses per device in the matrix table ranged from 47 to 50.

Practitioner Demographics

Regarding the question of how long respondents had worked in sports vision, 27 of the 60 individuals (45.0%) who answered this question selected more than 15 years, 6 (10.0%) answered between 10-15 years, 5 (8.3%) answered between 6-10 years, 13 (21.7%) answered between 1-5 years, and 9 (15.0%) answered less than 1 year (Figure 3). Thus, 55% of those who answered this question answered either between 10-15 years or more than 15 years.

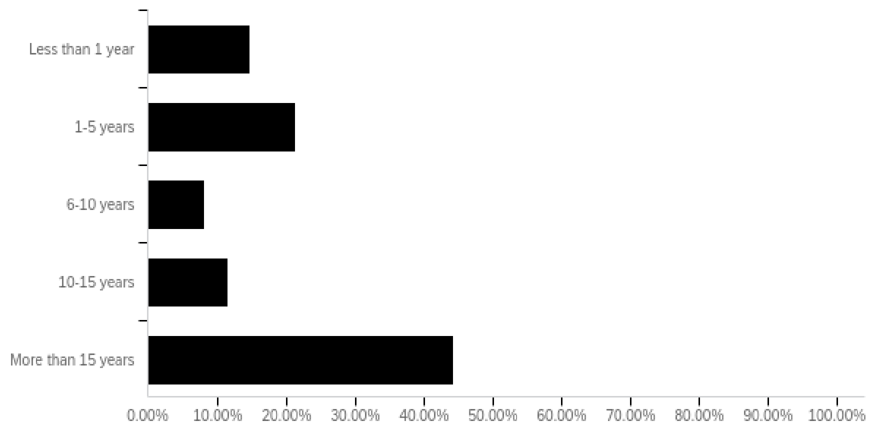

Figure 3. Results to the question "How many years have you worked in the area of sports vision?"

For the question regarding the respondent's profession, 45 individuals responded. 39 respondents were optometrists (ODs), one was a medical physician (MD), and one was an athletic trainer (AT). Four individuals selected "other" and indicated that they were vision therapists, chiropractors, or strength and conditioning coaches. Therefore, of the individuals who answered this question the majority (87%) were optometrists.

When asked whether or not the clinicians were contracted with specific sports teams, 35.00% (21 of 60 respondents) answered yes. Of these, 33.3% (7 of the 21 "yes" respondents) contracted with a single team or school and 66.6% (14 of the 21 "yes" respondents) were contracted with two or more teams or schools. Of the 60 respondents, 35 (65.00%) answered that they were not contracted with any teams. The results for this question are shown in Figure 4.

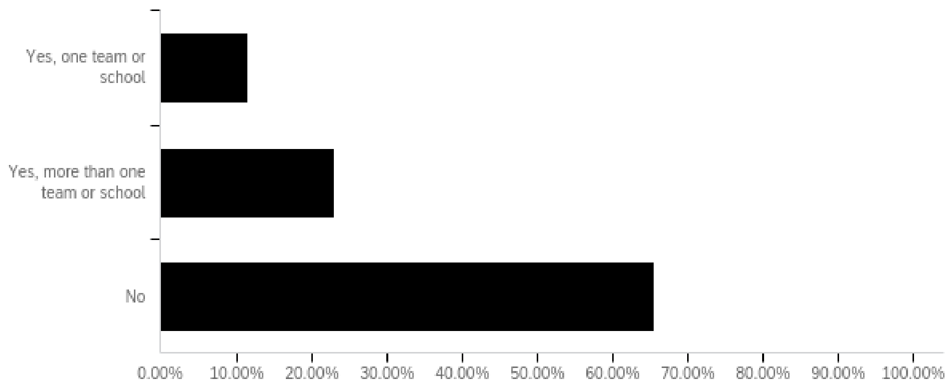

Figure 4. Results of the question "Are you contracted with one or more sports teams/schools?"

In another question, survey takers were asked to characterize their work with athletes. They could select all of the answers that applied (Figure 5). Among the respondents, 87.72% (48 of 55 respondents) indicated that their work with athletes included sports vision training. Forty-three of the 55 respondents (78.18%) include general eye exams in their practice and 43 of 55 respondents (78.18%) perform binocular and accommodative assessments. Forty-one of 55 respondents (74.55%) reported conducting neurovision rehabilitation. On average, a respondent selected 3.20 of the choices (SD = 1.043).

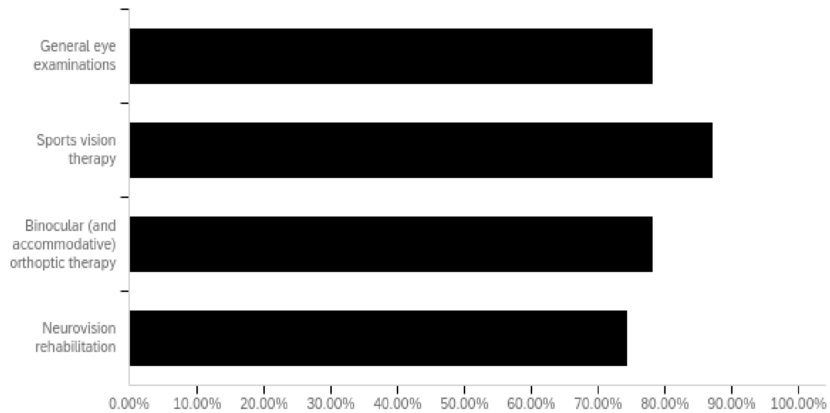

Figure 5. Results of the question, "Which of the following best characterizes your work with athletes in the context of sports vision? (Select all that apply)" expressed as percentage of responses.

Expanding on neurorehabilitation, a question was asked regarding the percentage of the practitioners' sports vision practice dedicated to issues related to traumatic brain injury (TBI). Results are shown in Figure 6. The response shows that 51.92% (27 of the 53 responses) of respondents manage TBI issues less than 20% of the time. The remaining responses indicate 18.87% (10 of 53 responses) dedicate less than 10% of their practice to TBI, and 32.08% (17 of 53 responses) dedicate between 10-20% of their practice to TBI. Of those who reported greater than 20%, 16.98% (9 of the total 53 responses) responded 21-30%, 11.32% (6 of the total 53 responses) responded 31-40% and 20.75% (11 of the total 53 responses) responded that over 40% of their practice is dedicated to TBI.

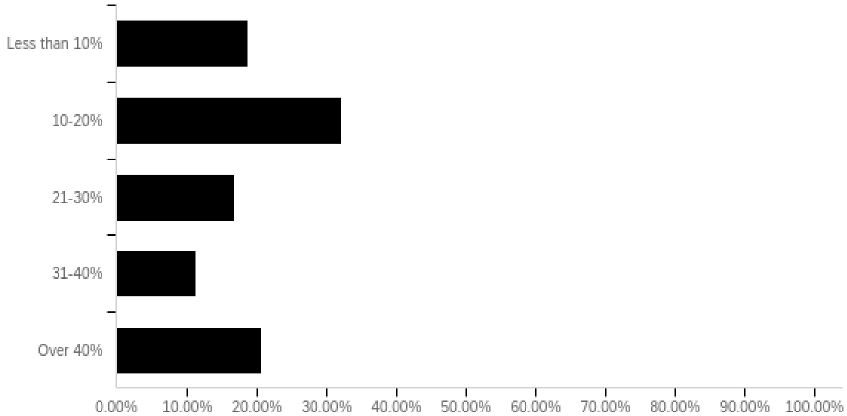

Figure 6. Results of the question "What percentage of your sports vision practice is devoted to issues related to traumatic brain injury and concussion?"

Of the choices regarding how practitioners primarily obtain information regarding sports vision (only one answer allowed), 66.04% (35 of 53 respondents) selected continuing education lectures. Scientific journals were identified as the primary source of information for 26.42% (14 of 53) of respondents. Books were chosen by 3.77% (2 of 53) of the respondents while trade journals and sales representatives each were chosen by 1.89% (1 of 53) of the respondents (Figure 7).

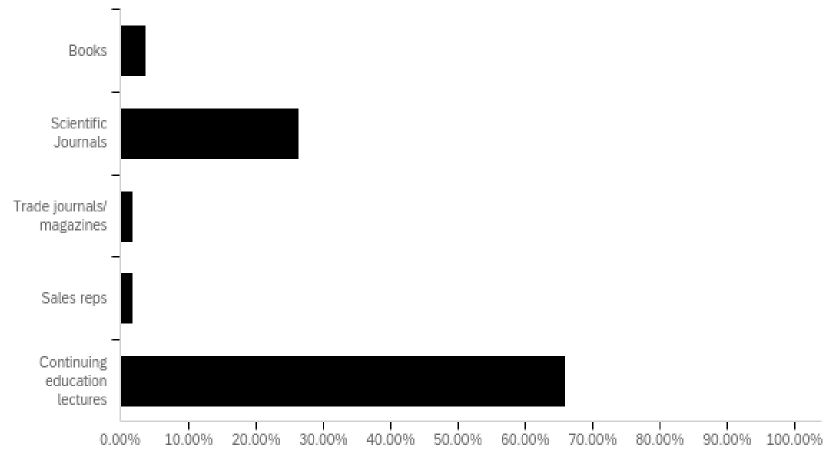

Figure 7.Results of the question “Where do you primarily obtain information regarding sports vision?”

Athletic Population Demographics

There were two questions designed to understand the populations with which the survey takers work. One question required the responder to select all age/ sport levels that they interact with in their practice (Figure 8). Among the respondents, 75.4% (43 of 57) of the respondents indicated they engage with high school athletes, 66.67% (38 of 57) with collegiate athletes, 52.63% (30 of 57) with professionals, and 50.88% (29 of 57) with athletes younger than high school age. Some of the respondents work within a single sport level, although many work across multiple levels (mean= 2.46 levels, SD= 1.13).

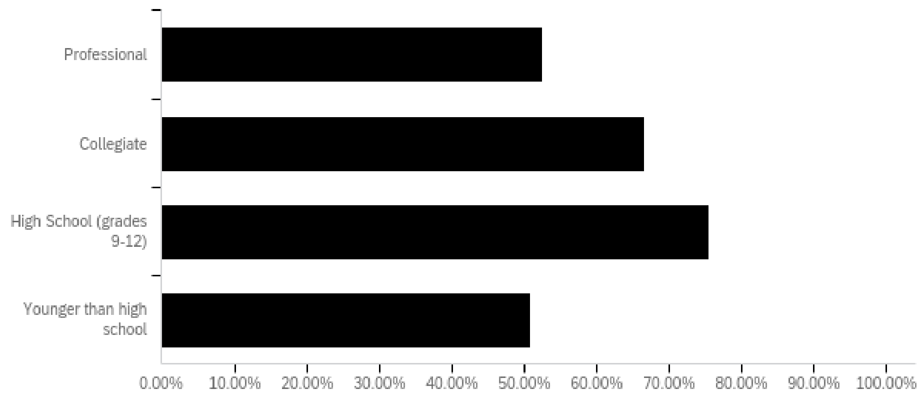

Figure 8. Results from the question "Which best describes the athletes you work with? (Select all that apply)" expressed as percentage of responses.

Another question was asked regarding the athletes that the practitioners work with. Specifically, the question addressed which sports these athletes play. The respondents could select all that applied, and in addition respondents were given the option to free type sports that were not listed. The results are shown in Figure 9. Among the respondents 71.15% (37 of 52) chose baseball/ softball, 51.92% (27) indicated basketball, 50.0% (26) indicated hockey, 48.08% (25) indicated football, 46.15% (24) selected soccer, 42.31% (22) selected golf, and 40.38% (21) answered shooting sports. The other responses included 5 individuals working with volleyball, 3 with automobile or motorcycle racing, 2 each for tennis, fencing, lacrosse, cricket, and in the military, and 1 each for water polo, e-sports, badminton, table tennis, skiing, archery, dance, gymnastics, and skating. The most common number of sports chosen by a respondent was 3, with a range of 1-10 sports.

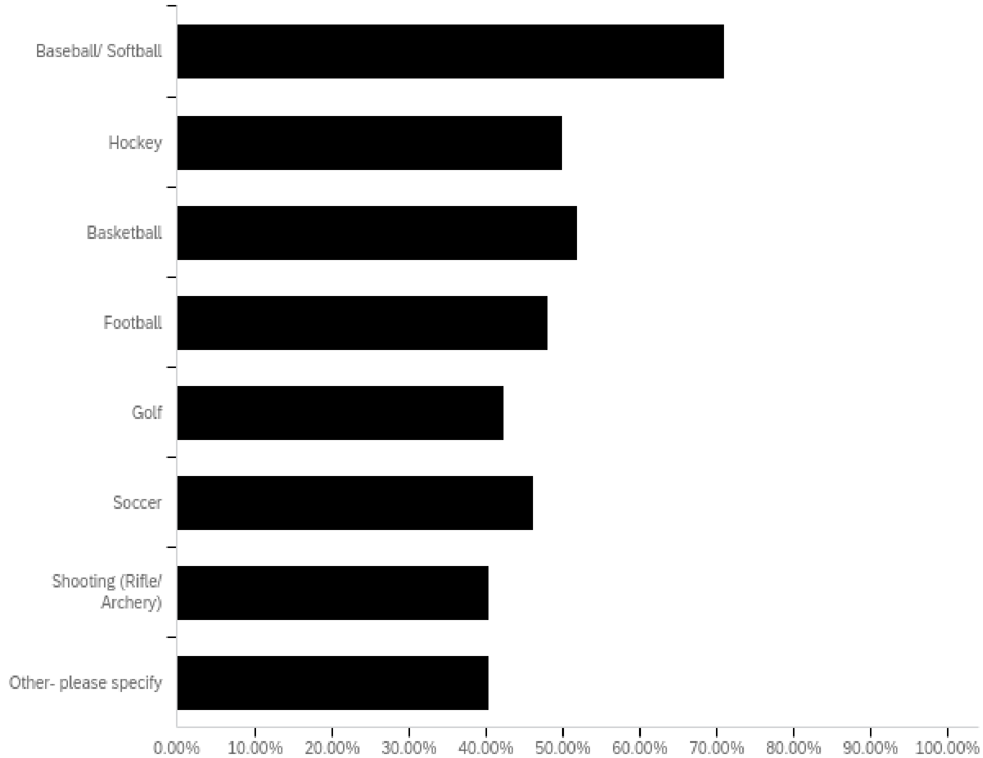

Figure 9. Results for the question “Which sports do you perform sports vision with? (Select all that apply)” expressed as percentage of responses.

Sports Vision Assessment and Training

Survey takers were asked if they use different assessment procedures for different sports. The results are shown in Figure 10. This question had a lower response rate with only 42 responses. Perhaps the question was accidentally skipped as it was the last of three questions on the page. Of those that responded, 66.67% (28) report sometimes utilizing different techniques, 21.43% (9) always use different techniques for different sports, and 11.90% (5) do not use different techniques.

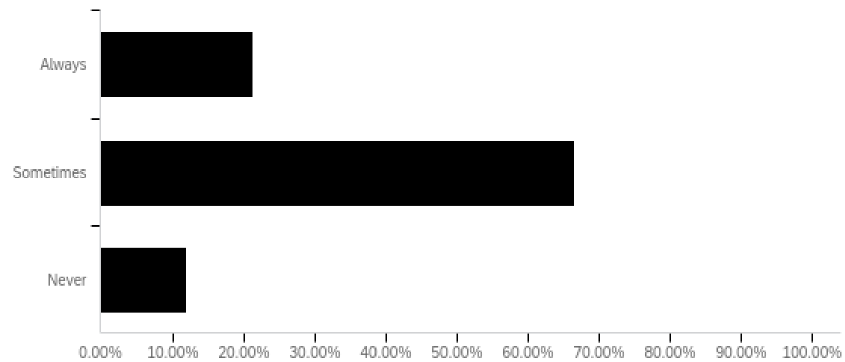

Figure 10. Results for the question "Do you use different assessment procedures for athletes in different sports?"

The respondents were also asked about the location in which they performed clinical sports vision assessments and training. Once again, respondents were able to select all of the choices that applied. Results are shown in Figure 11. Of the 53 respondents, 47 of the respondents (88.68%) indicated that they practice within their own clinic, 15 (28.30%) answered that they practice at team owned facilities, and 12 (22.64%) used neutral dedicated sports facilities.

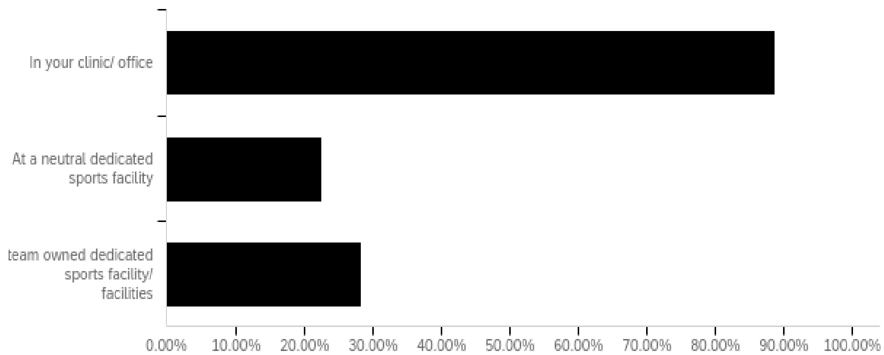

Figure 11. Results from the question "Where do you perform clinical sports vision assessments and training? (Select all that apply)” expressed as percentage of responses.

Another question that was asked was whether practitioners challenge the athlete’s balance during vision training. The responses are shown in Figure 12. Thirty-six of 51 (70.59%) individuals revealed that they “always” challenge athlete balance during assessment and training. Twelve respondents (23.53%) report “sometimes” challenging balance and only 3 respondents (5.88%) do not challenge balance in assessment and training.

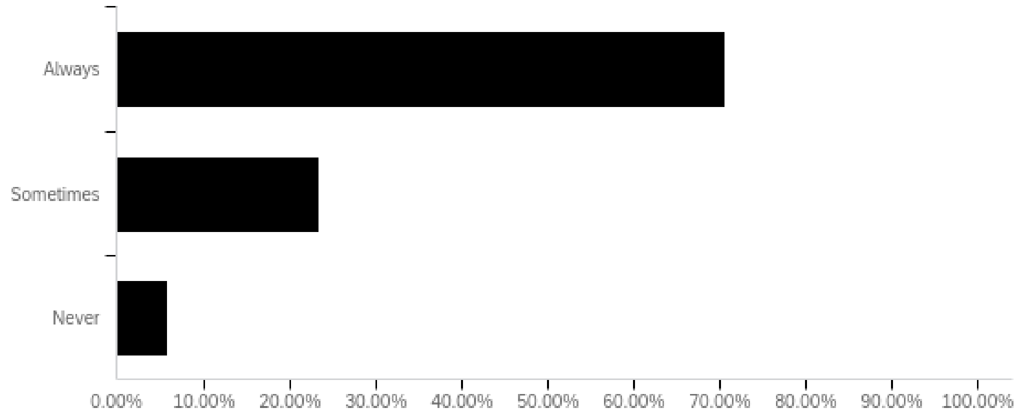

Figure 12. Results from the question “Do you challenge balance during assessment or training?”

Optical Tints and Nutraceuticals

There were three questions concerning optical tints and nutraceuticals. A question was posed about the significance of discussing sun protection with athletes. The results are shown in Figure 13. Twenty-four of the 53 respondents (45%) chose “moderately significant”, while 16 (30%) chose very significant and 13 (25%) chose insignificant.

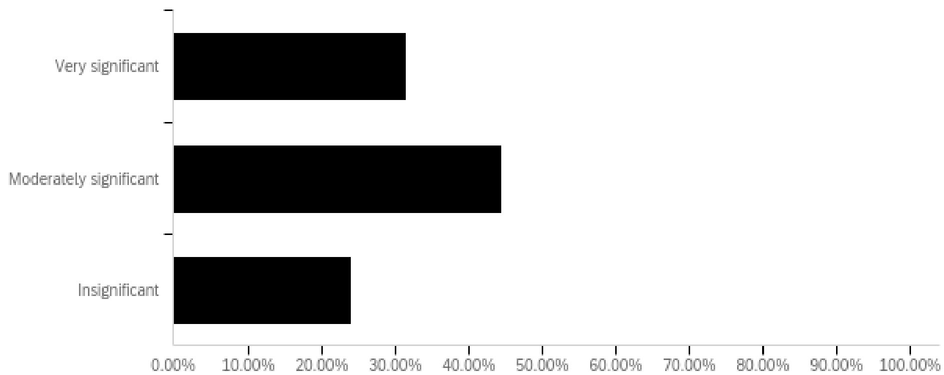

Figure 13. Results from the question "How would you characterize discussions of sun protective eyewear as a proportion of the athletes you work with?"

Another question was asked regarding how often practitioners prescribe tinted contact lenses. Results are shown in Figure 14. Of the 50 respondents, 21 (42%) of the respondents answered never or almost never, 12 (24%) answered very often, and 17 (34%) answered occasionally.

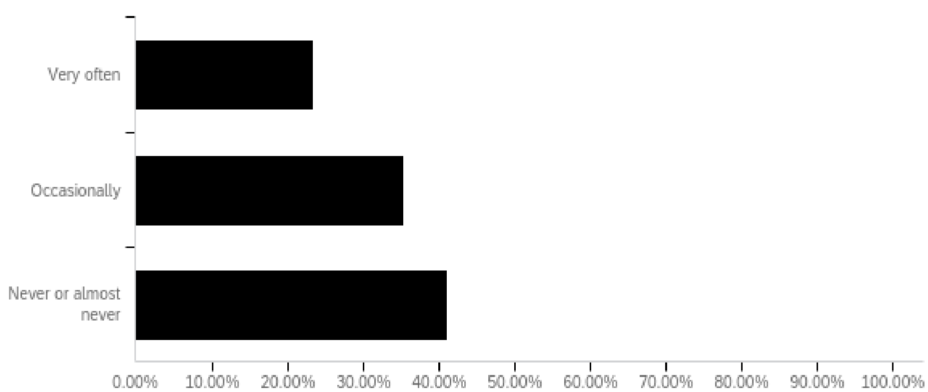

Figure 14. Results from the question "How often do you prescribe or recommend tints in contact lenses for athletes?"

Finally, survey takers were asked how often they prescribe or consider prescribing nutraceuticals to athletes. Results are shown in Figure 15. Of the 49 respondents, 11 (22%) selected always, 22 (45%) selected sometimes, 9 (18%) selected never, and 7 (14%) answered that prescribing nutraceuticals was outside of the scope of practice.

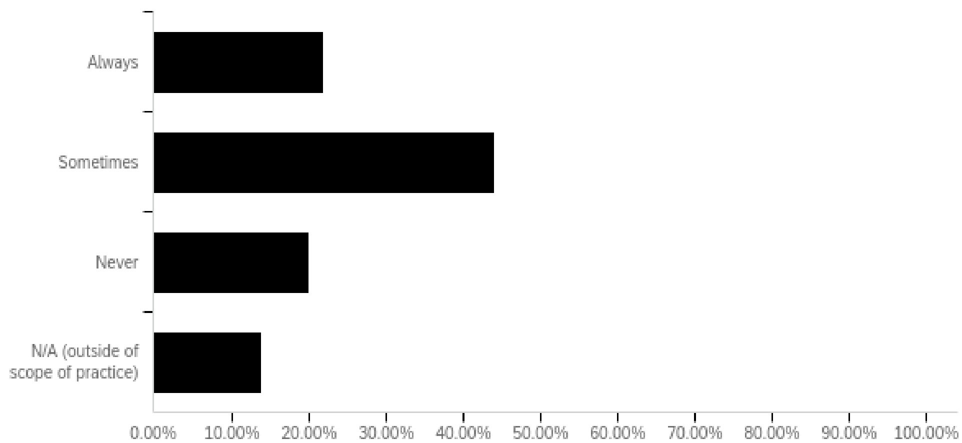

Figure 15. Results from the question "Have you discussed, considered prescribing, or prescribed nutraceuticals for vision or eye health for athletes? (e.g., Vitamins A, C, or E, Lutein, Zeaxanthin, etc.)"

Use of Tools in Sports Vision Assessment and Training

Respondents viewed a list of 38 devices and selected how often they use each device in their clinic practice. Potential choices were “most of the time”, “about half of the time”, and “rarely/never”. The results are listed in Table 1. The number of responses per device varied between 47 and 50 and are listed in the table below. The devices are presented in the order in which they appeared in the survey. It can be seen that a similar number of individuals responded for each question, so it was reasonable to compare responses for one device to the responses for all of the other devices.

Table 1. Survey responses for each device. Devices are classified by tier/level as described in the text, analog (A) or digital (D), and hardware (H) or software (S).

Device	Number of responses	% "Most of the Time"	% "About half of the time"	% "Rarely/ Never"	Tier	Hardware (H) or Software (S)	Analog (A) or Digital (D)
Snow Goggles	49	2.04%	2.04%	95.92%	2	S	A
Hart Charts	50	76.00%	10.00%	14.00%	1	H	A
Pegboard Rotator/Bernell Rotator disc	49	55.10%	24.49%	20.41%	1	H	D
Eyeport II	49	4.08%	12.24%	83.67%	1	H	D
Swivel Vision Goggles	49	6.12%	4.08%	89.80%	2	S	A
Lens Sorting	47	29.79%	29.79%	40.43%	1	H	A
Prism Sorting	49	24.49%	38.78%	36.73%	1	H	A
Lifesaver Card	50	60.00%	20.00%	20.00%	1	H	A
Brock String	50	88.00%	8.00%	4.00%	1	H	A
Ring toss with numbered or colored balls	49	44.90%	24.49%	30.61%	3	S	A
Howard Dolman Stereoacuity test	48	10.42%	16.67%	72.92%	1	H	A
Bucket Toss	49	44.90%	22.45%	32.65%	3	S	A
Juggling	48	29.17%	39.58%	31.25%	3	S	A
HECOstix	49	30.61%	12.24%	57.14%	3	S	A
SIBOASI reaction lights	48	10.42%	12.50%	77.08%	3	S	D

Continued.

Table 1. Continued

Vectorball	48	14.58%	16.67%	68.75%	3	S	A
Marsden ball	50	64.00%	24.00%	12.00%	3	S	A
Wayne saccadic fixator/ Binovi touch fixator	50	40.00%	20.00%	40.00%	3	S	D
Dynavision D2	49	14.29%	8.16%	77.55%	3	S	D
Sports Vision Trainer	50	18.00%	10.00%	72.00%	3	S	D
Batak Pro	48	2.08%	0.00%	97.92%	3	S	D
FITLIGHT trainer	49	32.65%	16.33%	51.02%	3	S	D
Reflexion Edge	49	10.20%	4.08%	85.71%	3	S	D
Vision Coach Light Board	48	2.08%	4.17%	93.75%	3	S	D
MOART	49	2.04%	2.04%	95.92%	3	S	D
Sanet Vision Integrator	50	42.00%	10.00%	48.00%	3	S	D
Reaction Plus	50	2.00%	6.00%	92.00%	3	S	D
Senaptec Sensory Station/ Nike SPARQ	49	40.82%	10.20%	48.98%	4	S	D
Vizual Edge Performance Trainer	49	4.08%	2.04%	93.88%	4	S	D
NeuroTracker	49	6.12%	12.24%	81.63%	2	S	D
ULTIMEYES	48	0.00%	8.33%	91.67%	1	H	D
EyeGym	49	2.04%	4.08%	93.88%	4	S	D
Axon sports occlusion/ anticipation technique	49	4.08%	6.12%	89.80%	2	S	D
Strobe glasses used without Senaptec	49	51.02%	18.37%	30.61%	2	S	D
Bassin Anticipation Timer	48	6.25%	10.42%	83.33%	2	S	D
Optics Trainer Virtual Reality System	49	10.20%	8.16%	81.63%	4	S	D
Vivid Vision Virtual Reality System	48	10.42%	12.50%	77.08%	1	H	D
RightEye	48	29.17%	10.42%	60.42%	4	S	D

Survey respondents were given the opportunity to free type devices used in sports vision assessment or training that were not listed in the matrix table. The responses acquired are presented in Table 2. The types of devices and training techniques are organized into categories. If a device was entered by more than one respondent, the number of responses is indicated next to the device.

Table 2. Responses to "If you use any other sports vision devices or techniques not listed previously, please list them." The responses were divided into categories.

Virtual Reality	Computerized/ Screen based	Balance	Eye Tracking	Anticipation
NeuroTrainer	HTS (Sports Vision Module)	Walking Rail	VMET	Senaptec Synchrony (5)
Visionary Virtual Reality	VTS4 (2)	Balance boards (2)	ReadAlyzer	
			Eye-SYNC	

Basic Devices	Techniques	Light boards or light pods	Other
Accommodative facility (2)	Just Noticeable Difference techniques	Makoto	Platform Test
Tachistoscope/ Stereoscope (2)	Dynamic Visual Acuity Test	Blaze Pods	Spaceboard
Vectograms (6)	Look hard, look soft	Light Trainer	Non-equipment activities
Aperture Rule	Slap/Tap (2)	Senaptec Swift Touch	HEART Software
Anaglyphs (2)	Tint Trials	Skillcourt	PATT
Yoked prism (2)	Infinity Walks	AcuVision 1000	Syntonic phototherapy (2)

Tiered Method

Using information from the Welford/Erikson[8], Ciuffreda/Wang[6], Laby/Kirschen[7], and Hodges et al[9] classification systems for visual skill, the devices in Table 1 (the devices that were free-typed were not included in this analysis) were arranged into four tiers or levels. The devices are shown by tier in Tables 3-6. Included in level 1 (lowest-level) were 10 devices to assess/train low-level or fundamental skills such as contrast sensitivity, accommodation, vergence, and other eye movements. In this level, higher levels of attention and visuomotor skills are not required. Level 2 included 6 tools that assessed/trained higher-level visual skills such as attention, anticipation, and decision-making. These devices were generally focused on one skill such as multiple object tracking (eg. NeuroTracker (NeuroTracker, Quebec, Canada)) or coincidence anticipation timing (eg. Bassin Anticipation Timer (Lafayette Instrument, Lafayette, IN)). Level 3 included 17 tools that required a (repeated) motor (eye-hand) response. Level 4 included 5 tools that could potentially assess/train multiple skills. The Kruskal-Wallis nonparametric test was used to compare the median percentage values for the frequency of use at each of the four visual skills levels. Within each level, the median number of tools selected from the category was found and compared. In all of the analyses that follow, $p<0.05$ was considered significant.

Table 3. Survey responses for each device in Tier 1, all of which train hardware.

Device	Number of responses	% "Most of the Time"	% "About half of the time"	% "Rarely/ Never"	Analog (A) or digital (D)
Hart Charts	50	76.00%	10.00%	14.00%	A
Lens Sorting	47	29.79%	29.79%	40.43%	A
Prism Sorting	49	24.49%	38.78%	36.73%	A
Lifesaver Card	50	60.00%	20.00%	20.00%	A
Brock String	50	88.00%	8.00%	4.00%	A
Howard Dolman Stereoacuity test	48	10.42%	16.67%	72.92%	A
ULTIMEYES	48	0.00%	8.33%	91.67%	D
Vivid Vision Virtual Reality System	48	10.42%	12.50%	77.08%	D
Pegboard Rotator/Bernell Rotator disc	49	55.10%	24.49%	20.41%	D
Eyeport II	49	4.08%	12.24%	83.67%	D

Table 4. Survey responses for each device in Tier 2, all of which train software.

Device	Number of responses	% "Most of the Time"	% "About half of the time"	% "Rarely/ Never"	Analog (A) or Digital (D)
Snow Goggles	49	2.04%	2.04%	95.92%	A
Swivel Vision Goggles	49	6.12%	4.08%	89.80%	A
NeuroTracker	49	6.12%	12.24%	81.63%	D
Axon sports occlusion/ anticipation technique	49	4.08%	6.12%	89.80%	D
Strobe glasses used without Senaptec	49	51.02%	18.37%	30.61%	D
Bassin Anticipation Timer	48	6.25%	10.42%	83.33%	D

Table 5. Survey responses for each device in Tier 3, all of which train software.

Device	Number of responses	% "Most of the Time"	% "About half of the time"	% "Rarely/ Never"	Analog (A) or Digital (D)
Ring toss with numbered or colored balls	49	44.90%	24.49%	30.61%	A
Bucket Toss	49	44.90%	22.45%	32.65%	A
Juggling	48	29.17%	39.58%	31.25%	A
HECOstix	49	30.61%	12.24%	57.14%	A
Vectorball	48	14.58%	16.67%	68.75%	A
Marsden ball	50	64.00%	24.00%	12.00%	A
Wayne saccadic fixator/ Binovi touch fixator	50	40.00%	20.00%	40.00%	D
Dynavision D2	49	14.29%	8.16%	77.55%	D
Sports Vision Trainer	50	18.00%	10.00%	72.00%	D
Batak Pro	48	2.08%	0.00%	97.92%	D
FITLIGHT trainer	49	32.65%	16.33%	51.02%	D
Reflexion Edge	49	10.20%	4.08%	85.71%	D
Vision Coach Light Board	48	2.08%	4.17%	93.75%	D
MOART	49	2.04%	2.04%	95.92%	D
Sanet Vision Integrator	50	42.00%	10.00%	48.00%	D
Reaction Plus	50	2.00%	6.00%	92.00%	D
SIBOASI reaction lights	48	10.42%	12.50%	77.08%	D

Table 6. Survey responses for each device in Tier 4, all of which train software.

Device	Number of responses	% "Most of the Time"	% "About half of the time"	% "Rarely/Never"	Analog (A) or Digital (D)
Senaptec Sensory Station/ Nike SPARQ	49	40.82%	10.20%	48.98%	D
Vizual Edge Performance Trainer	49	4.08%	2.04%	93.88%	D
EyeGym	49	2.04%	4.08%	93.88%	D
Optics Trainer Virtual Reality System	49	10.20%	8.16%	81.63%	D
RightEye	48	29.17%	10.42%	60.42%	D

The Kruskal-Wallis nonparametric test was used to compare the median values for the percentage of respondents who answered “most of the time” at each of the four visual skills levels. No significant difference was found (p=0.317; medians: Level 1=27.1%; Level 2=6.1%; Level 3=18%; Level 4=10.2%). The effect of adding the “about half of the time” to the “most of the time” responses was also examined. When the “about half of the time” responses were added to the “most of the time” responses, the differences between groups was still insignificant (p=0.078; medians: Level 1: 61.42%; Level 2: 13.43%; Level 3: 31.25%; Level 4:18.37%). While these analyses did not demonstrate significant differences overall between the groups, the median value for Level 1 was greater than that of the other levels both when only the “most of the time” responses were considered and when both the “most of the time” and “about half of the time” responses were included. The overall results for these comparisons are shown in Figure 16.

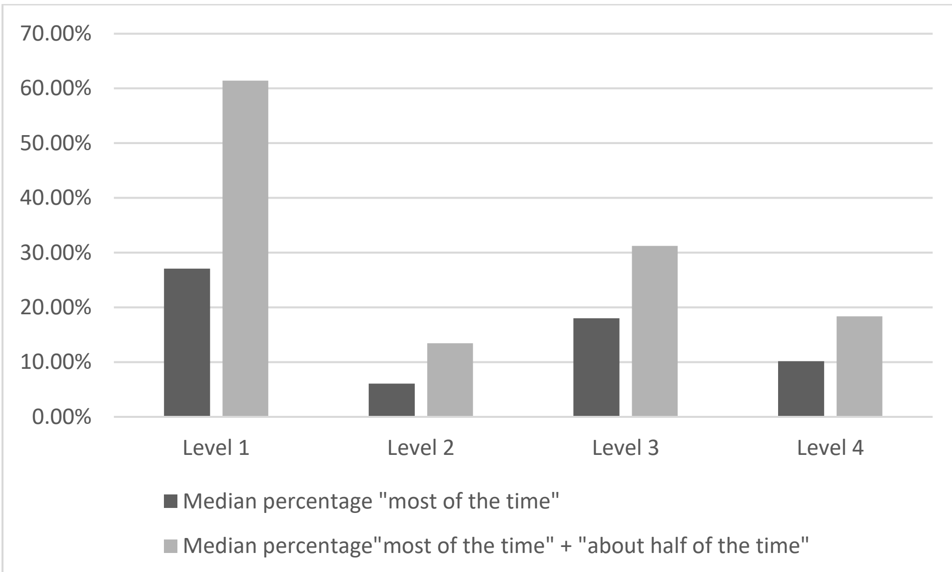

Figure 16. Plot of median percentage of “most of the time” responses and “most of the time” plus “about half of the time” responses at each device level.

The devices in the four levels were also examined to determine how many tools surpassed the 16% usage level based on the “most of the time” responses. The 16% threshold was used based on the following logic. In assessing the adoption of a product by the general public, Rogers[67] developed a model to describe the “diffusion” of a product into the population. In this model, of the total population who ultimately use or adopt a product, 16% is the proportion of people who adopt a product very early (termed innovators and accounting for 2.5% of product adopters) or early (termed early adopters and accounting for 13.5% of adopters). Individuals who adopt a product after the early adopters are termed the “early majority” (34%). The next group of product adopters in Rogers’ model is the “late majority” (34%), followed by the “laggards” (16%). A “chasm” exists between the early adopters and early majority and products that cross the chasm are predicted to have achieved mainstream success[68].

The percentage of devices at each level that exceeded the 16% threshold were as follows: Level 1=6/10 devices, Level 2=1/6 devices, Level 3=11/17 devices, Level 4=2/5 devices.

Hardware versus Software

The Mann-Whitney nonparametric test was used to compare the percentage for which respondents indicated that they used the tool “most of the time” for the tools in the hardware category (10) compared to tools in the software category (28). The medians of the percentages of “most of the time” responses were not significantly different between hardware and software (p=0.185; medians: hardware =27.14%, software=12.35%). The results became significant (hardware>software) with the addition of the “about half of the time” responses (p=0.045; medians: hardware=61.42%; software=22.68%).

Analog versus Digital

The Mann-Whitney nonparametric test was used to compare the percent of analog tools (14) to the percent of digital tools (24) for which respondents indicated that they used the tool “most of the time”. The medians were significantly different (p=0.027; medians: analog= 29.79%, digital=10.2%). When “about half the time” responses were added in, the results were highly significant ($p=0.003$; medians: analog=65.3%; digital=18.4%).

Chapter 4. Discussion

Practitioner Demographics

Regarding how long the survey takers had been working in sports vision, the respondents were relatively evenly divided between those who had been in the field for 10 or more years and those who had been in the field for 10 or fewer years. Individuals with a wide range of experience in sports vision were therefore amongst the respondents (See Figure 3).

The survey was overwhelmingly completed by optometrists (87% of the respondents who indicated their profession). While the results of the survey are driven primarily by optometrists, this cannot be taken as an indicator that most sports vision practitioners are optometrists. Although an attempt was made to distribute the survey to both optometrists and other professionals, it may be that optometrists simply had a higher response rate compared to individuals in other professions.

Of the respondents, 65% answered that they were not contracted with any teams (See Figure 4). However, the odds of being contracted with one or more sports teams was 2.76 times more likely if a practitioner had been in the sports vision field for greater than 10 years. This suggests that the longer a practitioner practices sports vision, the more likely it is that the practitioner will be contracted with a team.

There were 20 total respondents who indicated they were contracted with one or more teams. Among the 20 contracted individuals, 14 indicated working with professional athletes, 17 indicated working with collegiate athletes, 10 at the high school level, and 9 with athletes younger than high school. This may indicate that contracts occur more at the professional and collegiate levels.

Overall, the percentage of practitioners performing general eye examinations, sports vision therapy, or orthoptic therapy, or neurovision rehabilitation were similar (See Figure 5). The mean number of these potential practice modes selected by the respondents was 3.20, indicating that the practitioners were engaged in many different aspects of eye care.

On the other hand, given the high prevalence of TBI and concussion, it was surprising that over half of the respondents estimate less than 20% of their practice is dedicated to TBI (See Figure 6). Neurorehabilitation can apply in a wide range of conditions and injuries including spinal cord injuries, brain and spine disorders (e.g. stroke, TBI, multiple sclerosis), and muscle and nerve (e.g. muscular dystrophies) disorders. A multidisciplinary approach is often taken to neurorehabilitation with neurologists, physical and occupational therapists, social workers, psychologists, optometrists, and other care givers providing support to the patients[69].

Continuing education lectures was the primary source of information on sports vision for 66.04% of respondents (See Figure 7). This demonstrates the importance of sports vision conferences such as the International Sports Vision Association's annual meeting.

Athletic Population Demographics

Baseball was the most common sport associated with the athletes that practitioners worked with. In terms of age, high school athletes were the most common group that practitioners worked with. In an effort to identify whether clinical practices are aligned with research practices, the responses to the survey questions were compared to the International Sports Vision Association (ISVA) sports vision bibliography[70]. This bibliography is available to ISVA members and was compiled by Appelbaum, Liu, and Subramaniam. It contains 442 total documents, including papers that report on vision, attention, eye-tracking, visual-motor control, and visual neuroscience research Each sport that was included in the survey question regarding which sport or sports included athletes that practitioners worked with was searched in the ISVA bibliography and the number of results were recorded. The results of the survey and the results of the bibliography search are shown in Figure 17. Baseball yielded the most results in the bibliography search, correlating well with the survey findings where baseball was the most common sport that included athletes that practitioners worked with (See Figure 9). It appears as though more research could be dedicated to sports other than baseball.

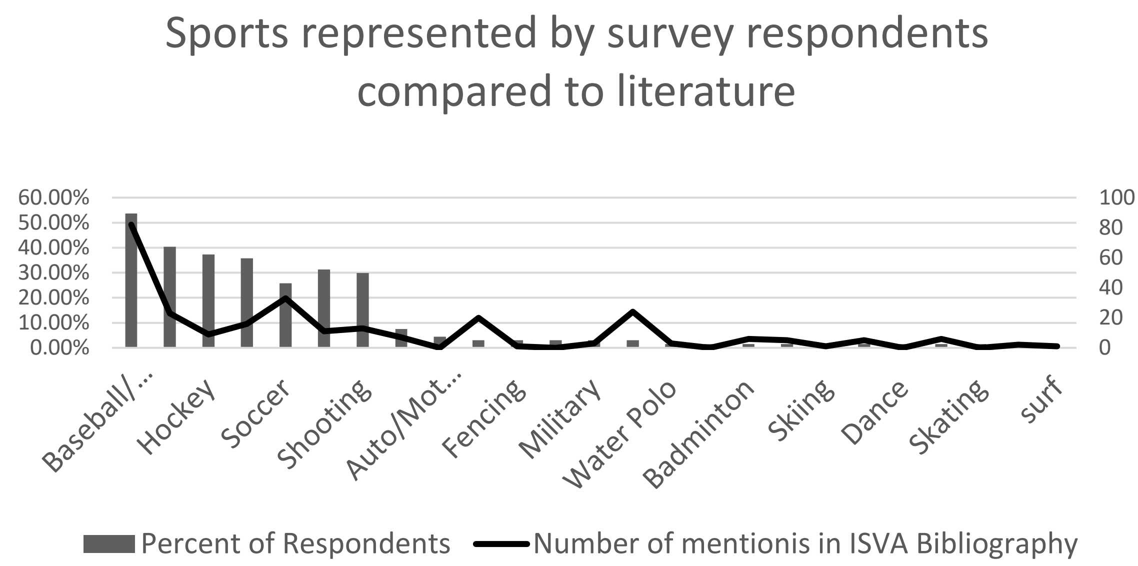

Figure 17. Comparison of sports with whom survey respondents work and prevalence of sports in the ISVA bibliography.

Each age group was also searched in the ISVA bibliography using the key words "professional" "elite" "college ""high school" "youth" and "young". The number of studies in the bibliography for which of these groups was included was determined. The survey results revealed high school as the most commonly worked with age group followed by college, professional, and then athletes younger than high school age (See Figure 8). The top result in the bibliography were studies in a professional population followed closely by collegiate athletes. There were very few studies in which the participant population was high school and youth athletes.

There may be multiple reasons for this discrepancy. It is well known that only a fraction of high school athletes progress to the collegiate level in a sport and even fewer enter into professional leagues. Thus, there are more athletes and more opportunities to participate in sports and to perhaps seek out sports vision practitioners at younger levels.

However, from the research perspective it may be easier to target the collegiate and professional demographics as these individuals have autonomy for consent and may be linked to organizations that are willing to fund research.

The lack of sports vision research that includes youth and high school athletes is concerning because the results of studies in higher level athletes may not be generalizable to athletes at lower levels. Further, it is important for sports vision studies to include younger athletes because greater visual and performance gains from sports vision training may be possible in this age group.

Sports Vision Assessment and Training

As hypothesized, as each sport has a unique set of visual demands[6], the majority of respondents report using different assessment procedures for different sports (See Figure 10).

Assessment and training most commonly occur within practitioners' offices/clinics as opposed to dedicated sporting facilities (See Figure 11). This could perhaps limit the degree of coupled training that can be done as many sporting tasks require more space than is available in an office space. However, as previously mentioned, the training location alone is not enough to draw strong conclusions on the topic. A practitioner may assign uncoupled exercises to an athlete at a team facility and conversely, some sport actions that do not require extensive space might be completed in an office in a coupled fashion. For example, a coupled action such as kicking a soccer ball might be possible in a hallway. There is also no standard size of a clinic or office space, so the extent of possible sport actions is likely unique to each individual practitioner. If practitioners are working in limited space, it is important to better understand the limitations of uncoupled vision training on sports performance and how the outcomes of uncoupled and coupled training compare. Virtual reality training has shown to have significant benefits on real world performance in table tennis players [71] and may be an important tool for practitioners to use in their offices[72]. Again, this is an opportunity for further research on the effects of virtual reality training on visual measures and in-game performance for various sports.

The difference between coupled and uncoupled sports vision training may not be straight forward. There may be a continuum from coupled conditions to uncoupled conditions. For example, a situation where training takes place on an actual field and requires the actual response required in the game (e.g. stroboscopic training while a baseball player bats balls thrown by an actual pitcher) could be considered highly coupled, while using a virtual reality simulator for training can be considered mostly coupled (same task as that in competition) but to some extent uncoupled (the setting is not exactly the same as that in a game).

When survey respondents were asked whether they challenged balance during training, the vast majority (94.12%) indicated that they do (See Figure 12). Because it may be necessary to execute tasks when athletes or moving or when balance is disrupted in competition, challenging balance results in a greater degree of coupled training.

Optical Tints and Nutraceuticals

Questions were asked about the significance of, or frequency of prescribing or discussing certain issues with athletes. One of the questions asked respondents about the significance of discussing sun protection with athletes. Among the respondents, 45% believed discussions about sun protection to be “moderately significant” while 30%

considered it to be very significant and 25% responded insignificant (See Figure 13). Likely, the response to this question varies based on the amount of work a practitioner does with athletes who participate in outdoor sports. In some sports, such as baseball, it is believed that sun protection is important to reduce the potential risks of UV damage and to maximize contrast sensitivity allowing players to more easily locate the ball in the sky.[63]

Prescribing or recommending tinted contact lenses to their athletes was reported by 58.8% of respondents (See Figure 14). The effect of tinted contact lenses on sports performance in competition is unproven, but there does seem to be reliable evidence for improvement in both contrast discrimination and subjective visual comfort. Altius (Performance Vision Technologies, Inc. Lake Oswego, OR), a brand of soft tinted contact lenses designed for sport, is said to "mitigate visual noise" and create "maximal visual comfort, clarity & quickness"[73]. The company has amber lenses designed for use in various outdoor lighting conditions that are recommended for baseball, tennis, soccer, lacrosse, football, and volleyball. On the other hand, this company has grey-green lenses advertised for open-air and recreational activities on water and land such as surfing, kayaking, golfing, fishing, running, and hiking. Both the amber and the grey green lenses claim to enhance contrast enabling greater clarity in object viewing. These claims are supported by studies using now discontinued amber and grey green NIKE Maxsight (Bausch & Lomb, Laval, Canada) contact lenses. These studies demonstrated that wearing the Maxsight lenses resulted in quicker glare recovery, quicker visual recognition, and better visual comfort and speed when looking between bright and shaded areas compared to clear lenses[58]. On the other hand, the amber lenses did not produce improvement in performance metrics[74] and there are no studies on the effect of grey green lenses on performance in competition. Another commercial tinted contact lenses that could be used for athletes is the Acuvue Oasys with Transitions (Johnson and Johnson, Jacksonville, FL) in which the soft contact lenses darken slightly when exposed to UV light similar to photochromic spectacle lenses. In summary, the respondents in this study commonly prescribed refractive correction with tints, and this practice is supported by published studies.

Lutein and Zeaxanthin are among the carotenoids found in macular pigment. While these carotenoids can be found in foods, westernized diets may not contain adequate amounts of these antioxidants. Macular pigment absorbs some of the ultraviolet light that does not get absorbed by the cornea or crystalline lens and is thought to be protective against oxidative damage. Outdoor athletes may be at higher risk for macular degenerative diseases with time due to their high amounts of UV exposure[63]. Individuals with denser macular pigment have also been shown to have faster glare recovery and improved contrast vision[63]. Of the respondents, 44% reported that they "sometimes" prescribe or consider prescribing nutraceuticals such as lutein and zeaxanthin, and an additional 22% report always prescribing nutraceuticals (See Figure 15). These results suggest that nutraceuticals are a part of sports vision care and practitioners believe in their benefits. The use of nutraceuticals is supported by the literature published thus far, although more evidence on the benefit of nutraceuticals for both eye health and sports performance is needed.

Analog versus Digital

The survey results indicate strong evidence that the median percentage of “most of the time” responses is higher for analog devices than for digital devices. This can be taken as evidence that when a device is used by a practitioner, it is more commonly used "most of the time" if it is an analog device compared to a digital device. The results of this analysis do not necessarily suggest that analog devices are more commonly used overall. However, on average, practitioners reported using 6.22 of the 24 digital devices (26%) at least half of the time, while they reported using 7.84 of the 14 analog devices (56%) at least half of the time. This latter result provides direct evidence that analog devices are more commonly used.

Hardware versus Software

In a similar way, there is moderate evidence that median percentage of “most of the time” responses is higher for devices that target “hardware” skills than for “software” skills. Further, the average number of devices reported to be used at least half of the time in the hardware category was 5.34, or 53.4% for these 10 devices. The average number of devices reported to be used at least half of the time in the software category was 7.8, or 27.9% of the 28 devices.

Tiered Analysis

Finally, the devices were divided into tiers or levels, thereby providing a higher degree of specificity for device type than that provided by the hardware/software dichotomy. Level 1 included devices to assess and train fundamental or low-level visual skills, level 2 included devices that assess and train things such as attention, anticipation, and decision-making, level 3 included devices that required a motor response, and level 4 included devices that can potentially assess and train multiple skills. While there was no statistical difference in the median percentages of “most of the time” responses for devices in the various tiers, the average number of devices reported to have been used at least half the time was 5.12 or 51.2% for the 10 devices in level 1, 1.30 or 21.7% for the 6 devices in level 2, 6.23 or 36.6% for the 17 devices in level 3, and 1.16 or 23.1% for the 5 devices in level 4.

Subgroup Usage of Devices

It is interesting to examine how various subgroups utilized the listed devices. Three groups were chosen to analyze: those who had practiced sports vision for greater than 10 years, those who work with professional sports, and those who dedicate at least 30% of their practice to TBI.

Overall, the top five devices used at least half the time by respondents were Brock string, Marsden ball, Hart charts, Lifesaver card, and the pegboard rotator/ Bernell rotator disc (Bernell Corp. Mishawaka, IN). By tier, the top devices were as follows: Level 1= Brock string, Level 2= Stroboscopic glasses, Level 3= Marsden ball, Level 4= Senaptec Sensory Station (Senaptec, Beaverton, OR).

Among the 33 respondents who had been in the field of sports vision for 10 years or longer, 32 reported using Brock string and Marsden ball at least half of the time. Twenty-nine of the 34 use Hart charts at least half of the time, and 28 use Lifesaver cards and the Pegboard rotator (Bernell Corp. Mishawaka, IN). By tier, the most commonly used devices were Brock String, stroboscopic glasses (26 of the 34 respondents with over 10 years of experience), Marsden ball, and Senaptec Sensory Station (Senaptec, Beaverton, OR) (17 of 34). This aligns well with the overall responses. There were 27 respondents who indicated working in sports vision for less than 10 years. Nine of these individuals did not complete the questions on devices. Of those that did indicate frequency of devices, the most commonly used ones were Brock string (17 of the 18 responses) and Hart charts (15 of 18 responses). Three devices were chosen to be used at least half of the time by 13 respondents: Lifesaver, Ring-toss, and Marsden ball. The device most frequently used in each tier were: Level 1= Brock String, Level 2= stroboscopic glasses (9 of 18 responses), Level 3= Marsden ball and Ring-toss, and Level 4= Senaptec Sensory Station (Senaptec, Beaverton, OR).

Thirty-two individuals reported working with professional athletes as part of their practice, although all but 3 of these work with other levels of sport as well. Two of these 32 terminated the survey prior to the matrix table of devices. Among those who work with professional athletes and completed the matrix table, the most commonly used devices were Brock string (25 of 30), Marsden ball (23 of 30), stroboscopic glasses and Hart charts (each with 21 of 30) and Lifesaver card (20 of 30). By tier, the most common devices among this demographic were: Level 1= Brock string, Level 2= stroboscopic glasses, Level 3= Marsden ball, Level 4= Senaptec Sensory Station (Senaptec, Beaverton, OR) (16 of 30).

Among the respondents that indicated dedicating more than 30% of their practice to TBI and concussion, of whom there were 17, the most common device was the Brock string (16 of 17 report using at least half of the time). Hart charts, Lifesaver card, and Marsden ball were all reported to be used at least half of the time by 15 of the 17 in this demographic. Bucket toss and the pegboard rotator both yielded 13 at least half of the time responses. By tier the most common devices were: Level 1= Brock string, Level 2= stroboscopic glasses (11 of 17), Level 3= Marsden ball, Level 4= Senaptec Sensory Station (Senaptec, Beaverton, OR). Thirty-six individuals reported dedicating 30% or less of their practice to TBI and concussion. One of those did not complete the matrix table of devices. The most common device used at least half of the time among this group was Brock string (33 of 35 responses). Next most common was Marsden ball with 30 responses, then Hart chart with 29, Pegboard rotator (Bernell Corp. Mishawaka, IN) with 27, and Lifesaver card with 26 responses. By tier, the most commonly used devices among this demographic were: Level 1= Brock string, Level 2= stroboscopic glasses (24 of 35 responded using at least half of the time), Level 3= Marsden ball, and Level 4= RightEye (RightEye, LLC Bethesda, MD) (16 of 35 responses).

Within these three subgroups, the most used device by tier remained the same with two exceptions. The first exception involved the subgroup who had been practicing less than 10 years, for whom the ring-toss tied the Marsden ball for the most frequently used eye-hand device in Tier 3. The second exception involved the practitioners who dedicate 30% or less of their practice to TBI, the RightEye (RightEye, LLC Bethesda, MD) was the most frequently used tier 4 device, with one more response than Senaptec Sensory Station. These groups are not discrete from one another as it is likely some respondents fell within all three categories of practicing sports vision for over 10 years, working with professional athletes, and dedicating at least 30% of their practice to TBI.

Regarding the overall most used devices in each category, there were some differences when comparing between subgroups and when comparing to the overall results. The results among those who have practiced more than 10 years align exactly with the overall results. Among those that work in professional sports, stroboscopic glasses were included in the most common devices. Those that work with TBI at least 30% of the time appear to use the bucket toss activity more frequently, but otherwise closely align with the overall results.

Summary of Device Usage

Many of the newer sports vision devices are digital. There are a number of possible factors that could contribute to the differences in usage rate between analog and digital devices. Digital devices are relatively new and perhaps less established in clinical care compared to analog devices, digital devices are generally more expensive than analog devices, there are digital devices that are unique but may share common features (e.g. push buttons or targets when they are illuminated), and digital devices may sometimes require more space to implement compared to analog devices. Some of these arguments can also be applied to the differences in usage rate between the tiers. Levels 1 and 3 had the highest usage rates and also the highest percentage of analog devices (Level 1: 6 of 10 devices (60%); Level 2: 2 of 6 devices (33.3%); Level 3: 6 of 17 devices (35.3%); Level 4: 0 of 5 devices (0%)).

The results for the hardware/software categorization as well as the 4-tier categorization suggest that lower level (hardware) skills are emphasized to a greater extent than higher level (software) skills. Because there is some evidence that both hardware and software skills may be improved by training, and because there is developing evidence that both of these sets of skills may potentially result in improved in-game performance, both sets of skills should be emphasized[23]. In fact, Poltavski and colleagues[41] demonstrated that software training preceding hardware training resulted in greater gains in sports-related cognitive efficiency. While this software first training seems to defy the models set forth by Welford and Laby and Kirschen[7] in which higher-level functions require efficient lower-level functions, Poltavski et al. explained their results by suggesting that software training improved visual hardware. Overall, the results of Poltavski et al.[41] suggest that software training is a potentially important aspect of sports vision training and that software training can affect both the software and hardware skills involved in sports.

Summary and Limitations

The major findings of this study are as follows. Sports vision practitioners have found a wide range of opportunities to work with athletes across several sports and age groups as indicated by responses to questions about athletic patient population, characteristics of work with athletes, and contracts with sports teams. The sports with athletes with whom the survey responders work generally aligns with the published research, although there are discrepancies among the level of sport represented by the results of this survey and the literature. Sports vision practitioners place significance in optimizing UV protection and contrast sensitivity by discussing or prescribing sun protection, tinted contact lenses, and nutraceuticals for ocular health.

The survey questions related to device usage indicate preference for analog devices, hardware training devices, and devices that target lower tier visual skills. However, the published research suggests the importance of training at both high and low levels. In these results, it is assumed that respondents intentionally choose devices based on the visual skill(s) each one trains, but there are other factors that may influence clinical decision making. Some of these factors might include cost, transportability, and awareness of the devices.

A limitation to this discussion of device usage is the difficulty in placing these devices in unique categories based on the visual skill or skills targeted by that device. Even though some devices may target low-level or hardware skills, it is possible that higher level skills such as attention are being recruited as well. For example, a small randomized, placebo-controlled study of individuals with symptomatic convergence insufficiency found evidence that after vision therapy the treatment group required less conscious effort, based on functional magnetic resonance imaging (fMRI), during convergence compared to control[75].

Overall, more research is required in sports vision, especially in regard to randomized clinical trials.

In the future, it will be interesting to assess these results with a larger study population and to perhaps expand the survey to a wider group of optometrists who may not necessarily spend significant time in sports vision. It will also be interesting to ask practitioners some of these questions in 5 to 10 years, as digital devices will presumably continue to become more common in sports vision training. The answers to questions regarding the perceived significance of assessing and training specific visual skills will be of significant interest in future surveys of sports vision practitioners.

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Appendix A. Survey Questions

1.Consent Form (See Appendix B)

2. Please indicate whether you are 18 years of age or more below.

- ○ Yes, I am at least 18 years old
- ○ No, I am less than 18 years old

3. How many years have you worked in the area of sports vision?

  - ○ Less than 1 year
  - ○ 1-5 years
  - ○ 6-10 years
  - ○ 10-15 years
  - ○ More than 15 year

4. What is your profession?

- ○ Optometrist (OD)
- ○ Physician (MD)
- ○ Physical Therapist
- ○ Occupational Therapist
- ○ Athletic Trainer (ATC)

Other- please specify: __________

5. Are you contracted with one or more sports teams/ schools?

- ○ Yes, one team or school
- ○ Yes, more than one team or school
- ○ No

6. Which best describes the athletes you work with? (Select all that apply)

- ☐ Professional
- ☐ Collegiate
- ☐ High School (grades 9-12)
- ☐ Younger than high school

7. Which sports do you perform sports vision with? (Select all that apply)

- ☐ Baseball/ Softball
- ☐ Hockey
- ☐ Basketball
- ☐ Football
- ☐ Golf
- ☐ Soccer
- ☐ Shooting (Rifle/ Archery)
- ☐ Other- please specify

____

8. Do you use different assessment procedures for athletes in different sports?

- ○ Always
- ○ Sometimes
- ○ Never

9. Which of the following best characterizes your work with athletes in the context of sports vision? (Select all that apply)

- ☐ General eye examinations
- ☐ Sports vision therapy
- ☐ Binocular (and accommodative) orthoptic therapy
- ☐ Neurovision rehabilitation

10. Where do you primarily obtain information regarding sports vision?

- ○ Books
- ○ Scientific Journals
- ○ Trade journals/ magazines
- ○ Sales reps
- ○ Continuing education lectures

11. Where do you perform clinical sports vision assessments and training? (Select all that apply)

- ☐ In your clinic/ office
- ☐ At a neutral dedicated sports facility
- ☐ At team owned dedicated sports facility/ facilities

12. How would you characterize discussions of sun protective eyewear as a proportion of the athletes you work with?

- ○ Very significant
- ○ Moderately significant
- ○ Insignificant

13. How often do you prescribe or recommend tints in contact lenses for athletes?

- ○ Very often
- ○ Occasionally
- ○ Never or almost never

14. What percentage of your sports vision practice is devoted to issues related to traumatic brain injury and concussion?

- ○ Less than 10%
- ○ 10-20%
- ○ 21-30%
- ○ 31-40%
- ○ Over 40%

15. Please indicate how often you utilize the following devices and techniques in your sports vision practice.

	Most of the time	About half of the time	Rarely/ Never
Snow goggles (1)	○	○	○
Hart Charts (2)	○	○	○
Pegboard rotator/ Bernell rotator disc (3)	○	○	○
Eyeport II (4)	○	○	○
Swivel Vision goggles (5)	○	○	○
Lens sorting (6)	○	○	○
Prism sorting (7)	○	○	○
Lifesaver card (8)	○	○	○
Brock string (9)	○	○	○

Ring toss with numbered or colored balls (10)	○	○	○
Howard- Dolman stereoacuity test (11)	○	○	○
Bucket toss (12)	○	○	○
Juggling (13)	○	○	○
HECOstix (14)	○	○	○
SIBOASI reaction lights (15)	○	○	○
Vectorball (16)	○	○	○
Marsden ball (17)	○	○	○

16. Please indicate how often you utilize the following eye-hand coordination and peripheral awareness devices and techniques in your sports vision practice

	Most of the time	About half the time	Rarely/ Never
Wayne saccadic fixator/ Binovi touch fixator (1)	○	○	○
Dynavision D2 (2)	○	○	○
Sports Vision Trainer (3)	○	○	○
Batak Pro (4)	○	○	○
FITLIGHT trainer (5)	○	○	○
Reflexion Edge (6)	○	○	○
Vision Coach light board (7)	○	○	○
MOART (8)	○	○	○
Sanet VIsion Integrator (9)	○	○	○
Reaction Plus (10)	○	○	○

17. Please indicate how often you utilize the following devices and techniques in your sports vision practice

	Most of the Time	About half the time	Rarely
Senaptec Sensory Station/ Nike SPARQ (1)	○	○	○
Vizual Edge Performance Trainer (2)	○	○	○
NeuroTracker (3)	○	○	○
Ultimeyes (4)	○	○	○
EyeGym (5)	○	○	○
Axon sports occlusion / anticipation technique (6)	○	○	○
Strobe glasses used without Senaptec (7)	○	○	○
Bassin anticipation timer (8)	○	○	○
OpticsTrainer Virtual Reality System (9)	○	○	○
Vivid Vision Virtual Reality System (10)	○	○	○
"Right Eye" (11)	○	○	○

18. If you use any other sports vision devices or techniques not listed previously, please list them below:

____

19. Do you challenge balance during assessment or training?

- ○ Always
- ○ Sometimes
- ○ Never

20. Have you discussed, considered prescribing, or prescribed nutraceuticals for vision or eye health for athletes? (eg. Vitamins A, C, or E, Lutein, Zeaxanthin, etc.)

- ○ Always
- ○ Sometimes
- ○ Never
- ○ N/A (outside of scope of practice)

Appendix B. Informed Consent

Please read the following consent form and then indicate whether you wish you to provide consent. The Ohio State University Consent to Participate in Research **Study Title:** Survey of Sports Vision Practitioners **Protocol Number:** 2021E0025 **Researcher**: Nick Fogt, OD, PhD **Sponsor:** None This is a consent form for research participation. It contains important information about this study and what to expect if you decide to participate. Your participation is voluntary. Please consider the information carefully. Feel free to ask questions before making your decision whether or not to participate. **Purpose:** The purpose of this survey is to identify the current sports vision assessments are thought to predict athletic success, determine whether practitioners are prioritizing these procedures, and to identify the types of medical personnel administering sports vision assessment and training and the categories of athletes receiving sports vision assessment and training. Procedures/Tasks: You will be asked to confirm that you have read this consent form and agree to provide informed consent to complete the survey. The survey has 20 questions after you provide your consent. **Duration:** This survey will require about 20 minutes to complete.

You may leave the study at any time. If you decide to stop participating in the study, there will be no penalty to you, and you will not lose any benefits to which you are otherwise entitled. Your decision will not affect your future relationship with The Ohio State University.

Risks and Benefits: There is a risk (described below) that someone could access your responses and possibly identify you. The results may help optometrists and sports medicine doctors and athletic trainers understand the most used techniques being used in sports vision assessment and training. **Confidentiality:** We will work to make sure that no one sees your online responses without approval. But, because we are using the Internet, there is a chance that someone could access your online responses without permission. In some cases, this information could be used to identify you. Also, there may be circumstances where this information must be released. For example, personal information regarding your participation in this study may be disclosed if required by state law. Also, your records may be reviewed by the following groups (as applicable to the research): Office for Human Research Protections or other federal, state, or international regulatory agencies; The Ohio State University Institutional Review Board or Office of Responsible Research Practices; The sponsor, if any, or agency (including the Food and Drug Administration for FDA-regulated research) supporting the study. **Future Research:** Your de-identified information may be used or shared with other

researchers without your additional informed consent. **Incentives:** None **Participant Rights:** You may refuse to participate in this study without penalty or loss of benefits to which you are otherwise entitled. If you are a student or employee at Ohio State, your decision will not affect your grades or employment status. If you choose to participate in the study, you may discontinue participation at any time without penalty or loss of benefits. By agreeing to participate, you do not give up any personal legal rights you may have as a participant in this study. This study has been determined Exempt from IRB review. **Contacts and Questions:** For questions, concerns, or complaints about the study you may contact Nick Fogt, OD, PhD at 614-688-4594 or fogt.4@osu.edu. For questions about your rights as a participant in this study or to discuss other study-related concerns or complaints with someone who is not part of the research team, you may contact the Office of Responsible Research Practices at 1-800-678-6251 or hsconcerns@osu.edu. **Providing consent** I have read (or someone has read to me) this page and I am aware that I am being asked to participate in a research study. I have had the opportunity to ask questions and have had them answered to my satisfaction. I voluntarily agree to participate in this study. I am not giving up any legal rights by agreeing to participate. To print or save a copy of this consent form, please click on the link below.
NF_Consent_Template_Online__Exempt.pdf Please indicate whether you wish to participate by answering the following question. If you do not wish to participate, please answer no or close your browser window.

- ☐ Yes, I consent to participate in the study
- ☐ No, I do not wish to participate

Appendix C. Recruitment Script

E-mail/text subject line: Survey on sports vision assessment and training practices

This survey is for a research project on sports vision practices being conducted by the Ohio State University. We are conducting this survey to better understand current assessment and training techniques being utilized in sports vision. The survey is expected to take 20 minutes or less. Optometrists and individuals that work within sports medicine and include sports vision as a part of their practice are eligible to participate. You may forward this e-mail/text to optometrists, sports medicine doctors, physical therapists, occupational therapists and/or athletic trainers that you think may be interested in completing the survey or who may be interested in forwarding it on to others. If you are interested in participating in this survey, please go to [link].

If you have questions regarding this survey please contact Nick Fogt, OD, PhD at 614-688-4594 (phone) or fogt.4@osu.edu. (e-mail). No names or other identifiable information of the individuals completing the survey will be collected.

Appendix D. Device Manufacturers

Bernell Rotator Disc……………………………………Bernell Corp. Mishawaka, IN
Eyeport II……………………………………………....Bernell Corp. Mishawaka, IN
Swivel Vision Goggles……………………………………..Swivel Vision, Norco, CA
HECOStix…………………………………………………..Hecostix, Boca Raton, FL
SIBOASI Reaction Lights…………………………………..SIBOASI, Dongguan, China
Binovi Touch Fixator………………………Binovi Technologies Corp. Ontario, Canada
Dynavision D2………………………Dynavision Global Holdings LLC, Cincinnati, OH
Sports Vision Trainer…………..Australian Institute of Sports Vision, Sydney, Australia
Batak Pro……………………………………………………Quotronics Ltd. Surrey, UK
FITLIGHT trainer……...…………………………………...FITLIGHT Corp. Miami, FL
Reflexion Edge…………………Reflexion Interactive Technologies, Inc. Lancaster, PA
Vision Coach Light Board…………………Perceptual Testing, Inc. Cascade Locks, OR
MOART…………………………………………..Lafayette Instrument, Lafayette, IN
Sanet Vision Integrator……………………………………...HTS, Inc. Gold Canyon, AZ
Senaptec Sensory Station……………………………………Senaptec, Beaverton, OR
Vizual Edge Performance Trainer………………...Phoenix Sports Partners, Phoenix, AZ
Vector Ball……………………………………....……..Eye on Ball Inc. Oviedo, FL
NeuroTracker……………………………………………NeuroTracker, Quebec, Canada
ULTIMEYES……………………………Carrot Neurotechnology, Inc. Calabasas CA
EyeGym…………………………………………EyeGym Stellenbosch, South Africa
Axon Sports Occlusion………………….………………Axon Sports, LLC Portland, OR
Bassin Anticipation Timer…………………………..Lafayette Instrument, Lafayette, IN
Optics Trainer Virtual Reality System…...…………Optics Trainer, LLC San Diego, CA
Vivid vision Virtual Reality System………………Vivid Vision, Inc. San Francisco, CA
RightEye…………………………………………………..RightEye, LLC Bethesda, MD