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The clinical application of sports vision appliances

An awareness of the importance of the eye examination has grown over the years and has led to the need for optometrists to be able to recognise and diagnose pathology. What seems to have been sidelined, however, is the importance of the optometric routine, including refraction, as a powerful diagnostic tool and a means of clinically justifying an optical appliance.

Photo 1 Confirmation of the dominant eye

Photo 2 Dynamic fixation

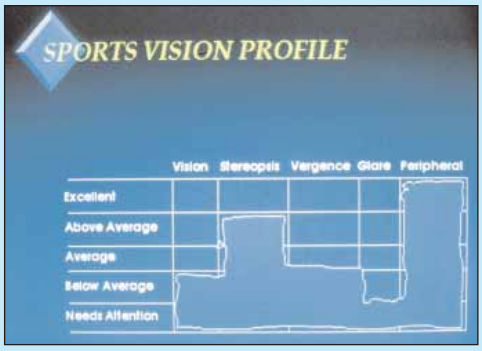

Photo 3 Sports vision profile

Photo 4 Manchester City Colts benefited from tinted Lunelle lenses and correction of hyperopic anisometropia

Photo 5 Hand-eye response

Optometry needs to be considered as a whole in which dispensing and clinical practice are inextricably linked and, ideally, carried out in the same place. It is uniquely different from ophthalmology. The study of visual performance in the healthy eye through the visual assessment (screening) of elite athletes illustrates this.

VISION SCREENING

Everything optometry teaches suggests that there is an inherent advantage in:

- seeing with two eyes;
- having both eyes appropriately corrected and orthoptically balanced;
- being protected against trauma and non-ionising radiation;
- maximising contrast sensitivity; *and*
- avoiding, recognising and treating pathology.

In addition, there is now an increasing body of data gathered by the Sports Vision Association (SVA) (**Table 1**) which is shedding new light on the clinical importance of basic optometric tests (**Table 2**).

ASSESSING VISUAL PERFORMANCE

Correlating visual performance with sporting achievement is scientifically very difficult; the result, i.e. the number of runs or goals scored, depends on too many variables (the coach, the weather, lighting, condition of the court, the opposition, diet, sleep and so on). Achievement in blind sport[8] suggests that, in any case, vision is not the overriding concern. Indeed, research from the Olympic Games[9] suggests that up to 20% of elite athletes compete with visual problems (there is also a parallel here with visual standards and driving).

Interestingly, an overall measure of vision performance (**Photos 3 and 4**) in U14 soccer players correlates very highly ($p=0.01$) with an independent subjective assessment of their playing skill by their professional coaches[10]. It could be hypothesised that this correlation will decrease in the senior players as the visually (as well as physically) disadvantaged youngsters are lost to the game.

It is safer to say that poor visual performance can be a barrier to high achievement in sport and that, in some sports, certain visual skills clearly contribute to success at the game (**Table 3**).

PHYSIOLOGICAL LIMITATIONS

To understand how a visual skill is used in sport, physiological limitations need to be appreciated. The findings for hand-eye response time (**Photo 5**) and peripheral awareness[1] have important implications. In cricket, for example, response time needs to be related to the speed of the ball and the length of the pitch. In first class cricket, the ball is likely to be delivered by a fast bowler at speeds of up to 90mph[11]. If the pitch is 22 yards long, it takes 0.5 seconds for the ball to travel from one end to the other. For a response time of 0.4 seconds (corresponds to the best response times on the peripheral awareness test and hand-eye co-ordination), there will be a zone of 52 feet in front of the batsman (**Figure 2**) where he will not be able to respond to any unexpected change of direction of the ball.

Table 1 Elite groups associated with SVA assessments

- British national archery squad
- British women's hockey team
- National and junior rifle teams at Bisley
- British Olympic yachting squad (Atlanta)
- Yorkshire cricket team
- Scottish cricket team
- Winter Olympics in Lillehammer and the British Olympic summer training camp Tallahassee (courtesy Bausch & Lomb)
- Ipswich Town youth team
- Lilleshall School of Soccer Excellence
- Leyton Orient FC senior squad
- Nottingham Forest U14 squad
- Manchester City FC football academy, U13 players
- All England Netball Association
- Panel umpires

Table 3 Important visual skills in different sports

CRICKET	Anticipation (batting) Hand-eye response (fielding)
FOOTBALL	Foot-eye co-ordination Peripheral awareness
ARCHERY	Visual acuity Glare
SAILING	Glare recovery Motility Peripheral awareness
TABLE TENNIS	Motility Hand-eye reaction time
SNOOKER	Stereopsis Vergence facility
NETBALL	Depth judgement including stereopsis Peripheral awareness
SKIING	Contrast sensitivity Dynamic visual acuity
HOCKEY	Dynamic visual acuity Hand-eye co-ordination
ATHLETICS TRACK AND FIELD	Visualisation, peripheral awareness

ANTICIPATION

By anticipating a course of action, such as which way the tennis ball will be hit, or the way the cricket ball will turn, response time is improved. Anticipation can make up for the physiological limitations of reaction time and will be affected by visual skills which are amenable to investigation, correction and therapy (**Table 4**).

MEASUREMENT

Anticipation timing is measured using the Basin Anticipation Timer and a sequenced row of light emitting diodes (**Photo 6**). Relatively low speeds are used (5, 10 and 15 mph) compared with the speed at which the ball is bowled, because the apparent speed of the ball moving straight to the batsman is governed by the rate at which it is falling vertically or swerving horizontally. The components of the speed in these directions are much slower than the actual speed of the ball towards the bat (**Figure 2**).

continued overleaf

Table 2 On-site diagnostic screening tests in the SVA battery

TEST	SIGNIFICANCE
Retinoscopy	Looking for gross errors, anisometropia, astigmatism
High and low contrast logMAR vision	Facilitates statistical analysis to give an accurate measure of changing and different performances
Dominant eye (**Photo 1**)	Ocular dominance can cause problems in aiming sports, where an arrow is aimed at a target or a foot is aimed at a ball[1]
Accommodation and vergence facility	The durability of these systems[2] is more important in sport than a one off measurement in the office of positive relative convergence
Brock string	Measures fixation disparity in the sporting context; raises underlying visual problems to a conscious level
Glare recovery	The ability to deal with glare from stadium lights or a low sun varies considerably in normal eyes; the differential effects of UV light on blue and brown eyes[3,4]
Colour vision and colour preference	Optical properties of tints need to be matched with underlying psychological preference; recent research in dyslexia, migraine[5] and colour deficiencies[6] needs consideration
Dynamic fixation (**Photo 2**) measures eye speed by a combination of vergence and motility	May give a measure of sporting preference and innate abiliy[7]
Stereopsis	For confirmation of basic ability time taken as well as level achieved

Table 4 Visual skills that facilitate anticipation

VISUAL SKILL	APPLICATION
Eye movements: pursuit, saccade, vergence and motility	Pursuit of the bowler's hand and following the ball
Visual acuity	Bowler's hand grip
Contrast sensitivity	Bowler's hand against the background
Hand-eye response time	Reaction to speed and direction of the ball
Accommodation facility	Speed of changing focus
Glare recovery	Dealing with different levels of illumination

Figure 2 Battling zone of no response

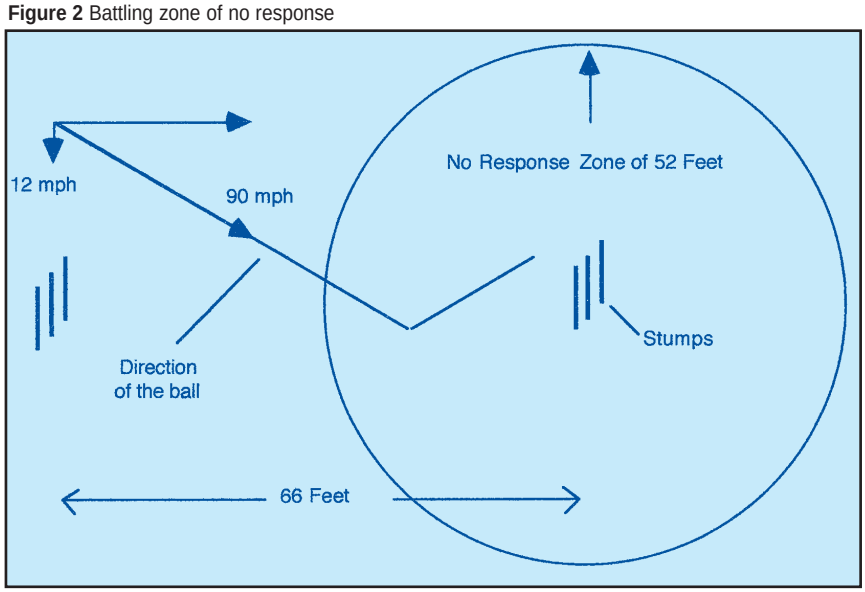

Table 5 The relevance of visual clues in competitive sport

VISUAL CLUE	SPORTING RELEVANCE
Ball spin	Cricket - swing of the ball in the air, direction off the ground Rugby - direction of bounce
Direction of gaze	Badminton - eye movement may signal the competitor's intention, or it may be a bluff
Speed and direction of bat	Table tennis - fast upward movement will impart top spin, fast forward movement a smash
Pattern of play off the ball	Football - fast movement on the wings would precede a pass from the centre
Body movement	Judo, football - may indicate nervousness, fluidity, being off balance
Wind direction	Archery, rifle shooting - direction of wind indicators, flags or trees are critical to the execution of the shot
Facial expression	Weight lifting - expressions of defeat or confidence can have a psychological effect on competitors
Skin colour	Athletics - excessive redness might be a sign of vulnerability or fatigue
Speed of approach	Cricket - bowling too fast, trying too hard. Too slow, has given up
Angle of racket head	Tennis - direction of the ball after being hit
Hand grip	Cricket - spin of the ball
Condition of the playing surface	Skiing - at 90mph, the quality of the snow and evenness of the surface are of critical importance

The forward movement of the bat may be more of a simple reaction to the release of the ball from the bowler's hand, but sideways and vertical movement in flight can, up to a point, be followed and anticipated.

STRATEGY

Physiologically, the human visual system is limited by the rate at which nerve impulses can be transmitted and, to a lesser extent, by the physical strength of the player. What marks the difference between the novice and the elite player, apart from physical development, is the ability to anticipate. Anticipation, it would seem, depends greatly on rapid interpretation of visual clues (**Table 5**).

TESTS

Given that visual performance is directly or indirectly important in sport, tests which measure it need to be broadly divided into two (**Table 6**) - those which represent an important visual aspect of the sport (analytical), and those which break down vision into its component parts (diagnostic). If members of the group do badly in the analytical (sport specific) tests compared with their peers, then this could be a reason for poor performance. The results in the diagnostic tests then give an indication of which aspect of visual performance may be at fault.

Using the Scottish Cricket Union as an example[12], anticipation (which seems important in batting) was taken as the main analytical test. The performance of individual players who did worst on this test (Mean Anticipation Timing $>\pm 10$ and/or Standard Deviation >5) are summarised on **Table 7**. Where the same players' results in the diagnostic test are below average, these are also shown. The blank spaces are results which are average or above.

Photo 6 Anticipation timing

TABLE 7 - TERMS AND MEASURES

Anticipation timing - Using the Basin Anticipation Timer (see page 37) a late response (measured to the nearest 100th of a second) is given a positive value and an early response, a negative value.

Stereopsis - Measured with the TNO.

Dominance - This gives the characteristic for each player. For instance, 'L Cross' means left eye dominant, but bats or bowls right handed. 'L' on its own means left eye dominant and left handed for batting and bowling.

Table 6 Screening strategy

TESTS	
ANALYTICAL	**DIAGNOSTIC**
Anticipation timing stereopsis	Retinoscopy Dynamic fixation Vergence facility Accommodation facility Contrast sensitivity Vision logMAR Glare recovery Eye-hand dominance Brock String

Table 7 Summary of significant data anticipation timing at 5mph

ANALYTICAL				DIAGNOSTIC								
SUBJECT	ANTICIPATION TIMING Mean (x100)	Stdev	STEREO	DOMIN	BROCK	RET	DYN FIX	VERG	FOCUS	CS Eye reduced	VISION	GLARE
M	10.16		120	L Cross	-0.33	+0.75				L	R	11
D		7.56		R Cross	-1			17	8			
B	-11.2			L	1							
G	29.38	21.39		L Cross	-0.11			18	10		R	
A	11.38	19.33		L Cross	-0.33	+1.5				R	R	
K	-22.6	23.53	120	L Cross	-0.22		25.76				R	

Table 8a Incidence of cross dominance with anticipation timing problems

ANTICIPATION PROBLEMS		NO PROBLEMS	
DOMINANCE	INCIDENCE	DOMINANCE	INCIDENCE
L Cross	4	R Dom	7
R Cross	1	L Cross	2
L Dom	1		
(Cross Dom 83%)		(Cross Dom 22%)	

Brock String - It is not possible to quantify individual observations on the Brock String, only whether the strings cross in front of, behind or at the bead. There were three beads on the string which was held in front of the player in three different positions, up, down and straight ahead. If the strings appeared to cross in front of the bead (esophoria) this was assigned a value of +1. If it was behind the bead, the response was given a value of -1 and at the bead, 0. For each player there were nine results and to give an indication of overall tendency, the average of the assigned values was taken. Someone who always saw the string in front of the bead would have nine assigned scores of +1 and an average of +1.

Retinoscopy - Estimate of refractive error.

Dynamic fixation[7] **-** A measure of eye speed and the average in seconds of three sets of three cycles on the instrument.

Vergence facility - The number of times the subject can converge on letters at 6m through a pair of 2 base out lenses, which are repeatedly placed in front of the eyes for a duration of one minute.

Focus or accommodation facility - This is the same as vergence facility except - 2.00 spheres are used instead of prisms.

Contrast sensitivity - Indicates where an eye is greater than two standard deviations worse than the average for the group in one of the four levels of spatial frequency (measured on the Vector Vision CVS 1000).

Vision - This is measured as the player presents, as he/she would be on the field of play. It shows where there is a difference between the eyes, the eye with the poorer vision at high or low contrast is recorded (all these eyes are within the defined range of average which is between + and - one standard deviation of the mean).

Glare - This is time in seconds to recover to a 6/9 line of letters, from disability glare caused by a camera flash held at 2/3 of a metre.

INTERPRETATION OF RESULTS

ANTICIPATION

Late anticipation (+) corresponds to exophoria on the Brock String (-) in all but one case. The exception was K whose poor eye speed and inconsistent results (SD 23.53 for anticipation) indicate poor muscle control. Reduced stereopsis and vision (R) may also be significant. Poor timing seems to be associated with reduced stereopsis in two subjects. In the group as a whole, 11 subjects (73%) had anticipation times at 5mph which corresponded to the opposite sign in Brock String. This suggests a trend, but is not statistically significant.

OCULAR DOMINANCE

All the players with poor anticipation were cross dominant (e.g. right eye, left hand or vice-versa) or totally left dominant (left eye, left hand). This compares with the remainder of the group (nine) with no problems, where only two (22 %) were cross dominant (**Table 8a**). The incidence of dominance is different in cricket compared with archery (**Table 8b**).

In the national squad of 15 players, all four of the specialist batsmen were right eye, right hand dominant (uncrossed) and favoured a full on stance and straight head (unlike the sideways stance favoured in baseball). It seems that binocular vision is important in batting and that the dominant right eye should not be hindered by facial features or head tilt[13] as it would be in a sideways stance. The incidence of cross dominant players (46.7%) compared with archery (18.7%) suggests that at least one aspect of the game favours this configuration (the side on delivery of the bowler?).

IMPLICATIONS

Using the cricketing example, the results suggest that binocular vision and eye dominance are important and that the diagnostic data will indicate which elements of visual function are defective. Poor vergence or focus facility, which could affect anticipation timing, might need exercises using stereo vectograms or prism and sphere flippers.

In two subjects, problems may be solved by correcting hyperopia with contact lenses to reduce esophoria, correct anisometropia and improve vision. Anisometropia and hyperopia can affect stereopsis.

Susceptibility to discomfort glare because of hypo-pigmentation in the iris and retina[14], aberrations from a large pupil, or fluorescence of blue and UV light in the ocular media, could be helped with an appropriate tint[15]. A course of action would be confirmed after a full eye examination. Poor recovery from disability glare may not be

Table 8b Incidence of hand dominance %

DOMINANCE		CRICKET	ARCHERY		MEETING DELEGATES	
EYE	HAND	SCOTTISH NATIONAL N=15	INTERNATIONALS N=16	COACHES N=17	NORTHERN OPTICAL SOC N=65	SVA MEMBERS N=25
Right	Right	46.7	62.5	84.3	78.5	48
Left	Left	6.6	18.75	10	1.5	12
Right	Left	6.6	6.25	2.85	0	8
Left	Right	40	12.5	2.85	20	32
		% CROSS DOM				
		46.6	18.75	5.70	20	40

continued overleaf

Table 9 Sport type

DYNAMIC	NON DYNAMIC
ATHLETICS	ARCHERY
SOCCER	BOWLS
YACHTING	SHOOTING
SQUASH	DARTS
HOCKEY	SNOOKER

Table 10 Visual components affected by spectacle Rx

Contrast sensitivity Binocular balance Accommodation vergency facility Depth perception Peripheral vision (lens size, material and design) Glare (inappropriate use or non use of tints, scratched lenses) Asenthopia	Dominant eye (e.g. when the non dominant eye takes over from a dominant eye, comprised by short sight or obstructions - the string of bow in archery) Speed of eye movement (differential prismatic effects caused by poor centration or anisometropia)

Table 11 Clinical reasons for lens specifications

Multi anti-reflection coat	Increases contrast sensitivity by improving lens transmission and reducing surface and internal reflections
Tint - Contrast - Visible light	Improves contrast sensitivity, reduces discomfort and possibly disability glare
Scratch resistance	Prolongs good light transmission
Peripheral distortion - Aspherics - Lens size	Maintains peripheral awareness
Water repellent	Maintains lens transmission in rain and spray
Cleaning	Keeps anti-reflection coat effective, maintains contrast sensitivity
Fit	Maintains effective power, keeps appliance stable, prevents vertical prismatic effects
Comfort	Prevents distractions
Weight	Helps to maintain fit and keeps comfortable in the active, hot sporting situation
Protection -Trauma - Non-ionising radiation	Built in protection with polycarbonate frames and lenses[16] Addresses possible hazards to ocular and surrounding tissue health[3,4]

Photo 7 Eye protection for squash
(Photo by courtesy of Loran MacEwan in 'Sports Vision')

Photo 8 Squash racket penetration of the orbit
(Photo by courtesy of Ed Zagelbaum, 'Sports Ophthalmology')

associated with eye colour. In fact, a blue eye which is used to dealing with light seems to recover more quickly than a brown eye in subdued light, which is suddenly surprised by a camera flash[1].

DISPENSING CONSIDERATIONS

Seeing as clearly as possible can make up for the physiological limitation of the human nervous system. This has important clinical implications in the dispensing of sports vision appliances.

TYPE OF SPORT

The type of appliance varies considerably with the sport for which it is needed. Sports can be divided roughly into two types (**Table 9**).

As the balance in a sport shifts from the dynamic to the non dynamic, from the physical to the cerebral, so dispensing considerations change. In sports like ice hockey and tennis, things happen very quickly and there is a great risk of trauma. In chess, there is very little movement and a lot of thought, so less risk of eye injuries. The intensity of competition in both these sports, however, should not be underestimated. In chess, for example, what are the effects of prolonged concentration at the near focal point, how does the light reflect off the board, what is the effect of the ambient light, is it harsh fluorescent or tungsten? What is the level of illumination? Information about muscle balance, individual ocular refraction, eye colour and age become very important. These considerations occur to varying degrees in all sports.

SPORTS VISION APPLIANCES

Safety is a primary concern in sport and although there is resistance from players to wearing eye protectors, most optometrists have no difficulty justifying them. The problems arise when practitioners are unaware of their patients' sporting interests and the potential hazards in specific sports. The new British Standard in squash and racket sports[16] makes an interest in sport and close questioning during history and symptoms even more important (**Photos 7 and 8**).

The ophthalmological significance of eye injuries is self-evident. Optometrically, it could be said that good vision and peripheral awareness help to avoid them. Seeing the cricket ball early gives time to take evasive action, seeing

Table 12 Contact lens considerations

SPECIFICATIONS	MAINTENANCE
Fit (reduce movement)	Wearing time
Aspherics (correct low cyls, Nissel)	Stability
Biocompatible (comfort)	Protein build-up
Water content (reduce dehydration)	Dehydration
Gas permeable or soft (What are the visual requirements?)	Replacement, disposable
UV protection (long-term health of the eye, compare with spectacles)	Adaptation (exclusions?)
Tinting (visual glare, protection - Lunelle)	• Archery (maximise acuity) • Swimming (keep clean, stick in fresh water *)

Table 13 Sports vision appliances[21]

SPORT	CONSIDERATIONS
Squash	Safety, weight, peripheral vision, acuity, glare
Archery/ shooting	Eye dominance, occlusion, acuity, safety (**Photo 9**)
Billiards snooker	Optical centres, refraction, binocular balance, reflections, frame
Clay pigeon	Contrast, safety, glare
Flying	Peripheral vision, UV filters, contrast enhancement
Skiing	UV protection, visible light reduction, safety, acuity
Cycling	Sun, optical centres, foreign bodies, wind protection (**Photo 10**)

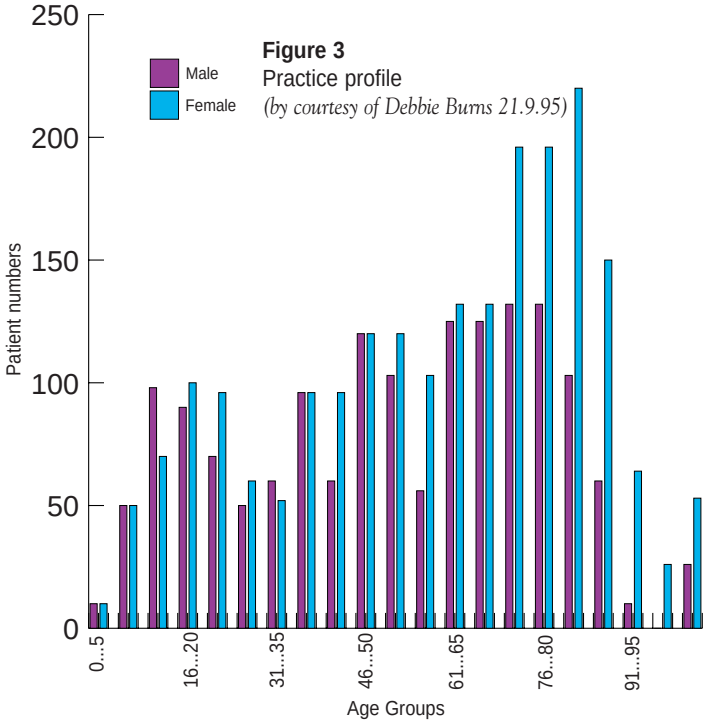

Figure 3
Practice profile
(by courtesy of Debbie Burns 21.9.95)

Photo 9 Clay pigeon and target spectacles
(Photo by courtesy of Norville Optical)

Photo 10 Cycling spectacles
(Photo by courtesy of Norville Optical)

the movement of a squash racquet in peripheral vision might help to avoid serious injury. It follows that a post injury reduction in visual performance will make subsequent injury more likely and diminish future enjoyment of the sport (poorer performance seems to encourage reduced participation in competitive sport).

Fifty percent of the population is involved in sports in some way or other[17] and the most active age group - 15 to 39[18] - is the least likely to attend for an eye examination (**Figure 3**).

CLINICAL CONSIDERATIONS

The shape, size and type of appliance may be governed by the overriding safety requirements and the risks should be emphasised to the player. Design and apperance also play an important part in peer approval. But, above all, vision in all its different ways needs to be maximised. Sport at all levels would logically seem to need sustained, clear and comfortable vision. Refractive findings become important and even small prescriptions may be significant in the sporting context (**Table 10**).

VISION IN SPECTACLES

Given the visual requirements of sport and the importance of the refraction, lens materials, coatings and filters are important considerations (**Table 11**).

continued overleaf

CONTACT LENSES

Contact lenses are usually the correction of choice in sport, but their effect on the tear layer and the cornea needs consideration (**Table 12**). In shooting and archery, small movements on blinking can be unacceptably distracting.

* Soft contact lenses stick to the cornea in fresh (hypotonic) water. This is probably an osmotic effect, not a marginal tightening of the lens. A lens that has been splashed is unsafe to remove for at least 20 minutes after leaving the pool. In salt water (hypertonic), soft lenses float as freely as they would in a tearing eye[19,20].

APPLIANCE EXAMPLES

Clinical, cosmetic and functional factors can now be translated into appliances for specific sports (**Table 13).**

CONCLUSION

Effective prescribing of sports vision appliances comes from an understanding of the clinical reasons for their use and matching this to the visual needs of sports men and women.

NEED FOR RESEARCH

Our understanding of the visual performance of the normal eye and the role of optometry in the prevention of eye disease through safe, healthy exercise and good nutrition, is in its infancy. Research in this area would be a natural progression for a mature profession.

ABOUT THE AUTHOR

Geraint Griffiths is a founder member of the committee of management of the Sports Vision Association and editor of the SVA journal. He is Clinical Manager with Rayner Opticians and a College examiner. He is an ex British International high jumper and Welsh record holder and currently holds the British veterans' high jump record.

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