Geraint Griffiths BSc Mech. Eng., MScOptom, MCOptom

The incidence of ametropia in elite sport

Recent research[1] has shown that visual and sporting performance, are directly related. The speed and size of the ball in cricket are likely to favour athletes with good visual skills, particularly batsmen. These players have to be able to aim accurately and judge depth to anticipate the arrival of the ball, having accurately predicted its mode of delivery. But perhaps the biggest potential for improvement could come from particular attention to the visual skills of the bowlers, who are also required to bat.

The visual assessments described in this article took place at Loughborough University on November 24 and December 1, 2004. The aim was to describe the visual profile of this elite group of players and identify deficiencies in visual performance, which might be amenable to correction.

Demographics

Eighteen players were screened, with an average age of 20.3 years and an average of nearly 12 years of playing experience for each player. Nearly all the subjects had played at county level and some had first class experience. Of the players who declared a speciality, there were five batsmen, three bowlers, four all-rounders and two wicket keepers

Difficulties

Table 1 illustrates the importance of vision with seven (40%) of the group already wearing contact lenses. Seven players (40%) were aware of problems (one of whom was not a contact lens wearer); 27.8% were directly related to vision.

Results of diagnostic tests and measures

Eye colour

Eye colour **(Table 2)** does not necessarily predict light sensitivity but may indicate a predisposition to either cataract (brown eyes) or macular degeneration (blue eyes)[2]. Both these conditions can be related to sunlight[3] and are, therefore, an important consideration in outdoor sport. Six players (33%) had brown eyes while 67% had light eyes (blue, green or hazel) **(Table 2)**.

Eye dominance

Eye dominance **(Figure 1)** gives a characteristic for each player. The importance of ocular correction may vary according to the individual's eye dominance[1]. A consideration of eye dominance has a bearing on the fundamental visual skills of aiming and anticipation (depth perception).

The incidence of right eye/right hand dominance (R/R) in the general population is about 68%[4] and this seems to predispose to hyper acuity. All the players with -0.1 LogMAR vision (~6/5 or better in one or both eyes as they presented with or without contact lenses) were right eye dominant and right-handed. Overall, the vision in the R/R players was significantly better (p = 0.05). Ten players (55%) were right dominant (R/R), two players (11%) were left dominant (L/L) and six (33%) were cross dominant (L/R or R/L) **(Table 2)**.

Figure 1
Eye dominance

Player	Correction	Difficulties
1	Distance soft CL	Used to be able to bowl. Left eye astigmatism
2	None	Right eye generally more blurry than left
3	None	
4	None	
5	Both soft	Some blurring sometimes during sport – patchy vision
6	Distance soft CL	Getting some bloodshot redness in eyes since Oct 04
7	None	
8	None	H/As if out in the sun all day
9	Distance soft CL	Not been able to bowl consistently since age of 15/16
10	Distance soft CL	
11	None	
12	None	Used to be a good leg spin bowler
13	None	
14	None	
15	None	
16	None	
17	Soft Monthly	
18	Soft monthly for astigmatism	

Difficulties 44% (visually related 27.8%)

Table 1
Difficulties and contact lens wear

Retinoscopy

Retinoscopy gives an indication of long or short sight, astigmatism or anisometropia **(Table 3)**. Small amounts of short sight are likely to create difficulties, seeing the bowler's hand for instance; astigmatism will cause general blur at distance and near. When vision is reduced (**Table 3**, red highlighted results), retinoscopy gives an indication why this might be. Blurred vision in the dominant eye will affect aiming (middling the ball on the bat or catching a high ball) and in the non-dominant eye, anticipation or depth perception (timing the strike of the ball or a catch).

Vision

Vision **(Figure 2)** was measured at high and low contrast using LogMAR charts, and reduced values are likely to confirm reported difficulties and results on retinoscopy.

Low contrast vision gives a clearer indication of deficiency than high contrast (**Table 3**, red highlighted results) and is a better representation of visual demand in real life, where contrast is reduced by mist, poor light and distracting backgrounds. It is measured as a decimal, where the norm would be zero (equivalent to 6/6 UK or 20/20 USA). Minus 0.2 is excellent (~6/4+) and +0.2 is likely to indicate blurred vision (~6/9).

Player	Eye colour	Dominance		
		Eye	Hand	Foot
1	Brown	RRRR	R	R
2	Green/blue	RLRL	R	R
3	Green	RRRR	R	R
4	Hazel	LLLL	R	R
5	Hazel	RRRR	R	R
6	Green	RRRR	L	R
7	Brown	RRRR	R	R
8	Brown	RRRR	R	L
9	Brown	LLLL	R	R
10	Brown	RRRR	R	R
11	Blue	RRRR	R	L
12	Hazel	LLLL	R	R
13	Dark brown	RRRR	R	R
14	Blue	LLLL	R	Both
15	Green/blue	RRRR	R	R
16	Blue	LLLL	L	R
17	Blue	LLLL	L	L
18	Dark Blue	RRRR	R	R

Incidence of eye dominance			
Eye	Hand	N=18	%
R	R	10	55.6
R	L	1	5.5
L	L	2	11.1
L	R	5	27.8

Table 2
Eye colour and eye hand dominance

	Retinoscopy		Vision			
			90%		10%	
Player	R	L	R	L	R	L
1	-0.5	... /-0.50x90	-0.02	-0.1	0.2	0.1
2	-0.5	-0.25	0.22	0.02	0.58	0.42
3	1.25	1.25	-0.1	-0.1	0.2	0.2
4	0.25	... /+0.75x100	0	0	0.22	0.2
5	0.25	... /+0.5x150	0.16	-0.02	0.42	0.2
6	... /+0.5x180	0.25	0.26	0.2	0.44	0.42
7	0.25	0.25	0	0	0.12	0.1
8	0	0.25	-0.06	-0.08	0.32	0.26
9	0.25	0.25	0.1	0.1	0.3	0.3
10	... /+0.75x90	0.25	0.22	0.1	0.54	0.32
11	0.25	1	-0.16	-0.2	0.02	0.02
12	0	-0.25	-0.04	-0.08	0.06	0.08
13	0.25	0.25	-0.1	-0.1	0.3	0.3
14	0	0	0.02	0.02	0.3	0.24
15	0.5	1	-0.1	0	0.22	0.22
16	0.25	0.75	0	0	0.22	0.24
17	... /0.50x10	0	0	-0.08	0.4	0.28
18	... /-3.00x180	... /-2.00x10	0.02	0.7	0.5	0.8
		Average	0.02	0.02	0.30	0.26
		Standard deviation	0.12	0.19	0.16	0.17
		Needs attention	>0.20		>0.4	

Table 3
Retinoscopy and vision

Six players (33%) had less than +0.4 vision in one or both eyes at low contrast, which is likely to cause problems playing[1].

Muscle balance

The Howell phoria chart **(Figure 3)** measures the underlying tendency for the eyes to diverge or converge. Excessive divergence or convergence can be related to prescription and can affect anticipation or depth judgment. Dissociation is achieved by putting a six base-down prism in front of the right eye and measuring how far apart the diplopic images are in prism dioptres, by asking the subject to say where the arrow is pointing. It is calibrated for three metres, but will give an indication at any distance. This is useful in the sporting situation and creates less distortion of free space than, say, the Maddox Rod.

Four players (22%) had muscle balance problems at distance or near (measured with a near Howell chart), which were likely to affect sporting performance directly or increase the rate of visual fatigue **(Table 4)**. Fixation disparity is used to confirm that muscle balance is leading to observable (to the player) effects on eye coordination **(Figure 4)**.

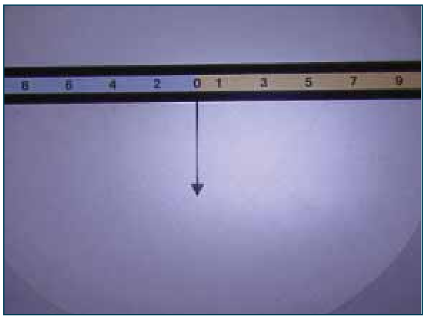


Figure 3
Howell phoria chart

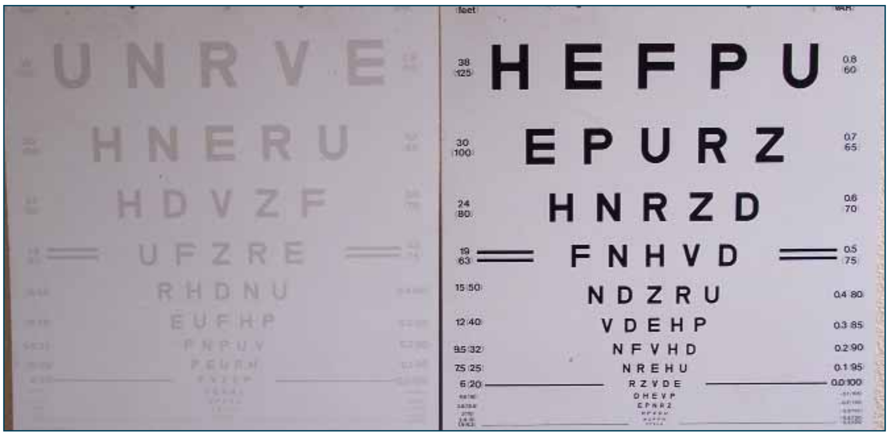


Figure 2
LogMAR vision charts

Figure 4
Testing fixation disparity

Geraint Griffiths BSc Mech. Eng., MScOptom, MCOptom

Fixation disparity

The Brock String (**Figure 4**) is a simple bead on a string, which the player looks at with both eyes. It demonstrates and measures the effect of muscle balance (Howell phoria) at a cortical level in the central nervous system, and is a powerful indicator of the need to prescribe a correction or exercises. It can also be used to measure the effect of therapy.

It measures fixation disparity in the same way that the Mallet test does, but is more useful in the field because it needs no electricity and the measuring distance is flexible. The bead is the equivalent of the 'X' in the oxo of the Mallet test, and the strings (as they are perceived when there is no suppression) are the equivalent of the nonius bars. The appearance of two strings going towards the bead confirms physiological diplopia. It is quite possible, for instance, for the bead to be seen as single because it is within Panum's fusional area when the strings apparently cross behind the bead. For instance, if the right string seems higher, it suggests a decompensated left hypophoria because one eye is higher than the other or there is a weak elevating muscle. Suppression shows an underlying weakness in the relationship between the eyes, which will affect binocular vision.

The power of the test is that the athletes can see exactly what is going on, which makes it easier to unravel some of the mysteries of visual perception, largely taken for granted by the sporting public.

Eight players (44%) described some anomaly of binocular vision, which ideally should be investigated with potentially useful results in terms of team performance (**Table** 4, red highlighted results).

Figure 5
Eye Bright Test

Colour preference and light sensitivity

Colour preference is affected by light sensitivity. For instance, a liking for blue tints and a strong dislike of yellow is diagnostic of clinically significant light sensitivity[5].

In outdoor sports, inadequate protection for light sensitive eyes will measurably degrade visual performance in the long and short term. Protection of the eyes needs to take into account eye colour (**Table 2**). Fifty-five percent of the squad did seem to have a measure of light sensitivity, which could affect their playing performance. Subjects favouring the quiet colours, like green, grey and blue, and showing a consistent dislike for yellow and orange, indicated this. Light sensitivity can cause watery eyes, blurred vision and headaches. Retinal bleaching will also reduce dark adaptation, which can cause a disproportionate loss of vision as light fades behind a cloud or into the late afternoon.

Player	Muscle balance Dist	Near	Fixation disparity	Colour preference Best	Worst
1	0	-2	0	Grey	Yellow/purple
2	1	2	0	Blue	Violet orange
3	1	-1	0, LE darker	Grey/yellow	Purple/green
4	-2	-5	Partial suppression, L exo ~30cm	Grey	Yellow orange
5	0	-2	0, R less clear	Grey	None
6	-2	0	L brighter, level alternating	Grey/green	Orange pink
7	0	0	0	Blue/green	Orange/yellow
8	-1	-5	Right string lower	Yellow/pink	Brown/blue
9	-1	-6	0	Grey/green	None
10	-2	-6	0, RE stronger	Orange	None
11	-4	-6	Anatomically R hyper XOP 30cm	Blue	Yellow
12	-3	-8	Left higher changing heights	Blue/pink	Yellow
13	0	-2	0	Yellow	Pink
14	1	3	Eso 3cm	Grey/blue	Orange
15	0	-2	Higher in R E	Green/grey	None
16	-2	-10	1cm Eso, intermittent L suppression	Grey blue	Orange pink
17	0	-2	L more prominent	Yellow	Green orange
18	0	0	R stronger eso 1 cm	Blue/grey	Yellow orange
Av	-0.78	-2.89	Dist< -2.00, near< -6.00 (needs attention)	Light sensitive 55.5%	
St dev	1.44	3.48	Dist > +2.00 (needs attention)	(likes blue/grey	
				dislikes orange/yellow)	

Table 4
Muscle balance, fixation disparity and colour preference

Figure 6
Bassin Anticipation Timer

Results (analytical test)

Anticipation timing

The Bassin Anticipation Timer (**Figure 6**) is an analytical test, which provides a laboratory simulation of one important and visually complex aspect of the game. One of the key skills in cricket is anticipating the arrival of the ball to time the shot or the catch.

The Bassin simulates this effect with a series of diodes, which emit light in sequence to give the appearance of an approaching object. Anticipation timing depends on the elements of visual performance as measured by the diagnostic tests above.

Using this instrument, deficiencies in timing can be related to these elemental visual skills and, therefore, become amenable to correction. A late response (measured to the nearest 100th of a second) is given a positive value, and an early response a negative value. Deficiencies in individual members of the squad compared to their peers may point to deficiencies in the elements of visual performance. As a group, slightly late timing seemed to be the norm (letting the ball come on the bat, avoiding getting under the ball is advantageous). Results show where timing is consistently much later than the average (more than a standard deviation), or much earlier. Two players had good average timings, but the spread of their results (standard deviation) suggested individual scores were inconsistent. Five players (28%) recorded results, which indicated a problem related to visual correction.

Table 5 shows a summary of key measures and individual reports.

Discussion

Vision correction

As a group, the players had a similar visual profile to many non athletic groups – with a fairly random scattering of convergence insufficiencies, uncorrected astigmatism, cloudy and under-corrected contact lenses, latent hyperopia and the residual problems and misunderstandings of cross

Player	Vision	Mus Bal	Bassin	Comment (needs attention ✓)
1				Aiming eye slightly under-corrected
2	✓		✓	Check for short sight R>L
3				Excellent all round visual performance. Routine eye exam to quantify long sight for future reference
4		✓		Correct astigmatism in left eye. Protect sensitive eyes in the sun consider convergence exercises
5	✓			Contact lens update. Consider silicone hydrogel
6	✓	✓	✓	Needs more oxygen permeable contact lenses and correction update
7				Excellent all-round vision. Blue grey tint for sun
8		✓		Consider routine eye examination to check right dominant eye
9		✓		Cross dominance could affect aiming if combined with convergence weakness. Consider convergence exercises
10	✓	✓	✓	Check right aiming eye (astigmatism). Consider convergence exercises as part of training
11		✓		Consider correction of left eye (long sight) could be affecting balance. Convergence exercise
12		✓		Consider convergence exercises, protect light sensitive eyes (blue/grey tint)
13				Excellent visual performance consider advantages of appropriate tints
14			✓	Excellent all round performance consider long-term protection from sun. Long sight/convergence excess may be affecting anticipation timing
15				Long sight in left eye may be affecting muscle balance at near. Routine eye exam indicated
16		✓		Check muscle balance convergence weakness and prescription
17	✓			Worth checking right prescription
18	✓			Check contacts toric lenses too tight and off axis

Table 5
A summary of key measures and individual reports

dominance and light sensitivity.

Even in athletes who are symptom free, an understanding of the visual process is critical to competitiveness, which in a team sport depends on the maximum number of athletes being available for selection at the peak of their form. Recognising problems related to sight early will prevent loss of form and ingrained faults, which can become difficult to eradicate. This can only be achieved by regular visual assessments. Loughborough University is a designated centre of sporting excellence and its commissioning of this report is important to the future of sport development in this country.

Eye dominance

One of the ironies of cricket is that fast bowling tends to predispose to left eye dominance, which in a right-handed player makes batting more difficult; and it is a fact of life that all bowlers have to bat. For batters and bowlers, it is important that the established relationship between the eyes is maintained, especially if this has been weakened by muscle balance problems or a difference in focusing between the two eyes.

The biggest single problem in aiming sports is a flip in eye dominance (very clearly demonstrated in shooting), of which the player is usually unaware. The result can be distressing, with an inexplicable loss of form and intense frustration on the part of the athlete. The usual remedy is to go out and practice more, which may compound the problem with increasing loss of confidence and over-training, which will eventually lead to chronic injury problems. One of the objects of visual correction is to restore natural eye dominance.

A radical solution to batting inconsistency in left eye dominant players (not susceptible to visual correction), who are right-handed, might be to try batting with their left-hand. It is easier to train the body to bat left handed than to change eye dominance, because there is no mechanism in the brain to control dominance (unlike holding the bat left-handed which controls the body). Players might be encouraged to try this in the nets out of season. Initially, the feeling might be of a lack of power, but confidence would build quickly as the ball begins to hit the middle of the bat.

Batting left handed might make it easier for the bowlers to appreciate that the skill of batting relies more on control and timing than brute force. This is a hard lesson for a naturally explosive athlete (the fast bowler) who finds cross dominance so frustrating when it comes to applying their particular strengths to the gentle art of batting.

Protection

There is great awareness in cricket for the need to protect against physical trauma but less about the danger of strong sunlight and UV radiation in an outdoor sport. Vision is measurably degraded by sunlight in the short and long term. In this highly visually dependant sport, everything should be done to maintain visual sensitivity and protect the eyes against the sun.

It is not clear why batters do not habitually wear sun filters, particularly when they are light sensitive and bating through the heat of the day. The correct level and colour of filter will enhance vision, not reduce it. When the light begins to fade the filter can be removed or changed to maximise sensitivity at low contrast. Modern appliances do not move easily under a helmet and can also be made to give added protection from trauma **(Table 6)**.

Contact lenses

Contact lenses are the correction of choice in sport for many reasons **(Table 7)** and can often be combined with the protective advantages of a plano polycarbonate or Trivex® filter in a sports appliance.

Forty percent of this group already wear contact lenses, which suffered from a range of problems like tight fitting, off axis toric

Table 6
Advantages of optical and non-optical sports appliances in yachting

Protection from: Blunt and penetrating trauma Hypertonic saline (sea water) Non-ionising radiation
Protection of the ocular adnexa
Complete range (hue and transmission) of contrast enhancing and protective tints available.
Hydrophobic materials
Ventilated appliances
Light weight
Low cost maintenance
Wide angle peripheral vision achievable up to ±4.00 up (to 2.00 cyl)
Important small and monocular corrections easily achievable
No adverse effects on corneal integrity
Plano or correction lenses can be worn over contact lenses
Easily applied in adverse conditions (if spare is washed overboard)
Cosmesis
Convenient

lenses, protein build up overwear and under-correction. Given that sporting and visual performance are directly linked big improvements are possible in team performance just through proper contact lens care, the use of appropriate materials, wearing regimes and solutions.

The number of light sensitive players highlights the need for clinically tinted contact lenses. The appropriate tint can improve contrast by UV and blue light absorption[6] and also reduce the pathological effect of short wavelength light on the crystalline lens and retina. For light sensitive athletes, the overall reduction in light levels would make concentration easier on very bright days; generally a green/ grey tint would be favoured by light sensitive players (see Eye Bright Test earlier) and a brown tint by less sensitive players although the demands of the sport may override this decision. A green tint in football, for example, would diminish the contrast of a white ball against green grass and decrease peripheral awareness (a key skill in soccer).

The psychological effects of each tint and their effects on the autonomic nervous system could also be significant. Red has an energising effect, which could be useful in aggressive fast moving sports[7] – the choice of tint would be based on the requirements of the sport and the physiological needs of the athlete.

Eye exercises

The term eye exercise is often misunderstood and may be subdivided into three separate areas – orthoptics, visual calisthenics and dynamic fixation.

Orthoptics

Orthoptics are established and

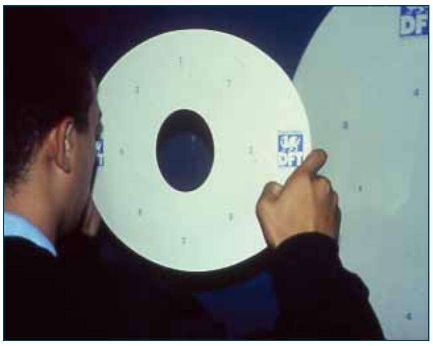


Figure 7
Dynamic Fixation Test

optometrically proven exercises to remedy muscle imbalance and visual deficiency.

Visual calisthenics

These are exercises designed to mobilise the extraocular muscles like dynamic fixation **(Figure 7)** and, to some extent, the intraocular muscles, in the same way that other major muscle groups may be trained.

Dynamic fixation

The Dynamic Fixation Test **(Figure 7)** is designed to measure eye speed[10] but is also a vigorous exercise, which encourages the discipline of control in skill learning. The physiological benefits are justified in terms of greater range of movement, thereby increasing muscle tone.

Hand/eye co-ordination

Eye movement is a powerful stimulant to a general warm up and could be used to prepare for competition using instruments like the Sport Vision Trainer (SVT) **(Figure 8)**. It is scientifically difficult to prove that this has any effect on sporting performance, but the Dynamic Fixation Test, for example, has shown a correlation of eye speed with athletic ability[8], and advanced instruments like the SVT have an important role to play in this area of research.

The SVT can also be classed as an analytical test when hand/eye coordination is a basic skill in a sport. It allows peer group comparison in the clinical situation and, like the Basin Anticipation Timer, visually complex results can be related to the diagnostic tests. These two major instruments are the most important in the advanced screening battery of sports vision tests

Therapy

Therapy might include visual calisthenics but embraces a much broader understanding of the visual process to include, for instance, visualisation and peripheral awareness, as well as the effects of behaviour on vision and vice versa. This could be considered as a panacea given to all athletes regardless of visual deficiency.

The scientifically supportable approach is to correct visual deficiencies and that the best form of eye exercise, is playing the game competitively. Behavioural colleagues are well supported by the public in their approach to vision therapy, which can show an improvement in visual performance even in the absence of (or despite) correction[9]. Scientific evidence is not always the final arbiter of value and sports vision may provide a scientific route to the true value of a behavioural or holistic approach to sporting performance.

Conclusion

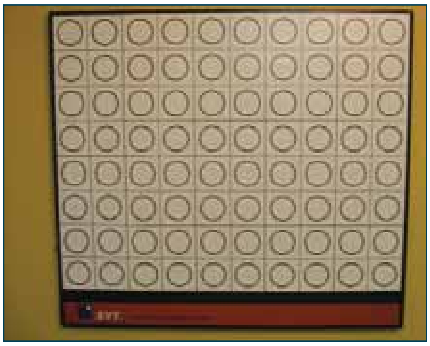
Vision changes throughout life and from hour to hour and day to day. It should be monitored on a regular basis with attention to:

- Monocular vision and acuity
- Muscle balance
- Eye dominance
- Colour preference and light sensitivity
- Where helpful, the use of vision therapy to enhance visual endurance, eye speed and peripheral awareness
- The retina, ocular media and field of vision

Table 7
Advantages of contact lenses in sport

Optometric	Dispensing
No differential prismatic effect in different positions of gaze	No differential prismatic effect in different positions of gaze
Correction of astigmatism and other eye aberrations	Correction of astigmatism and other eye aberrations
Correction of muscle balance problems, vertical and due to the prescription (e.g. decompensated esophoria related to hyperopia, affecting depth judgement and timing)	Correction of muscle balance problems, vertical and due to the prescription (e.g. decompensated esophoria related to hyperopia, affecting depth judgement and timing)
Correction of monocular problems which affect depth perception	Correction of monocular problems which affect depth perception
Correction of small amounts of astigmatism with aspherics, or GP lenses to improve contrast sensitivity	Correction of small amounts of astigmatism with aspherics, or GP lenses to improve contrast sensitivity
Correction of low levels of myopia down to -0.25 (equivalent to -0.75 under-correction based on the modal value for athletic groups[8]), which can be highly symptomatic	Correction of low levels of myopia down to -0.25 (equivalent to -0.75 under-correction based on the modal value for athletic groups[8]), which can be highly symptomatic
Correction of hyperopia in young athletes leading to decompensated esophoria	Correction of hyperopia in young athletes leading to decompensated esophoria
Lens looks where the eye looks	Lens looks where the eye looks

Figure 8
SVT hand/eye co-ordination



Given that visual sensitivity, aiming and anticipation are directly related to sporting performance, there may be significant gains to be made by maximising visual performance in the Loughborough squad.

Acknowledgements

The author would like to thank Andy Borrie, Head of Performance Support Services, Sports Development Centre, Loughborough University, and former international cricketer, Graham Dilley, for team liaison and invaluable cricketing insights.

Further information

For details of the equipment mentioned in this article and the Diploma in Sportvision Practice, visit www.sportvision.co.uk.

About the author

Geraint Griffiths is a founder member of the Sports Vision Association, editor of the SVA journal and Vice Chairman. He is a College of Optometrists Examiner and Assessor and Clinical Director of Sport Vision. A former British International high jumper and Welsh record holder, he currently holds the British veterans high jump record.

References

1. Griffiths GW (2003) Eye dominance in sport: a comparative study. *OT (Optometry Today/Optics Today)* 43: 16.
2. Billy R *et al* (2000) Iris colour and age related changes in lens optical density. *Ophthal. Physiol. Opt.* 20; 5: 381–386.
3. Bergmanson *et al* (1996) A sting in the rays. *Optician* 5560: 212.
4. Pointer JS (2001) Sighting dominance, handedness and visual acuity preference: three mutually exclusive modalities? *Ophthal. Physiol. Opt.* 21: 2.
5. Griffiths GW (2001) Colour preference: a comparative study. *OT (Optometry Today/Optics Today)* 41: 20.
6. Steen R *et al* (1993) Effect of filters on disability glare. *Ophthal. Physiol. Opt.* 13: 371-376.
7. Yapp R (2005) Why wearing red could turn you into a winner. Report of the work of Dr Russell Hill *et al* at University of Durham. *Daily Mail*, May 19.
8. Griffiths GW (2002) Eye speed motility and athletic potential. *OT (Optometry Today/Optics Today)* 42: 12.
9. Harris P (2005) Vision development and vision therapy. Two day British Association of Behavioural Optometrists (BABO) course, May 15-16, Scarman House Warwick University.