• Investigation •

Visual efficiency among teenaged athletes and non-athletes

Rokiah Omar[1]*, Yau Meng Kuan*[1]*, Nurul Atikah Zuhairi*[1]*, Faudziah Abd Manan*[2]*, Victor Feizal Knight*[3]

[1]Optometry & Vision Science Program, School of Healthcare Sciences, Faculty of Health Sciences, University Kebangsaan Malaysia, Jalan Raja Muda Abdul Aziz, Kuala Lumpur 50300, Malaysia

[2]Department of Optometry & Vision Science, Kulliyyah of Allied Health Sciences, International Islamic University Malaysia, Bandar Indera Mahkota, Kuantan 25200, Pahang, Malaysia

[3]Faculty of Medicine and Defence Health, National Defence University of Malaysia, Sungai Besi Camp, Kuala Lumpur 57000, Malaysia

Correspondence to: Rokiah Omar. Optometry & Vision Science Program, School of Healthcare Sciences, Faculty of Health Sciences, University Kebangsaan Malaysia, Jalan Raja Muda Abdul Aziz, Kuala Lumpur 50300, Malaysia. r_omar@ukm.edu.my

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Abstract

● AIM: To compare visual efficiency, specifically accommodation, vergence, and oculomotor functions among athletes and non-athletes.

● METHODS: A cross-sectional study on sports vision screening was used to evaluate the visual skills of 214 elementary students (107 athletes, 107 non-athletes), aged between 13 and 16y. The visual screening assessed visual parameters such as ocular motor alignment, accommodation, and vergence functions.

● RESULTS: Mean visual parameters were compared between age-group matched athletes (mean age 14.82±0.98y) and non-athletes (mean age 15.00±1.04y). The refractive errors of all participants were corrected to maximal attainable best corrected visual acuity of logMAR 0.0. Accommodation function assessment evaluated amplitude of accommodation and accommodation facility. Vergence functions measured the near point of convergence, vergence facility, and distance fusional vergence at break and recovery point. Ocular motor alignment was not statistically significant between both groups. Athletes had a statistically significant amplitude of accommodation for both the right eye (t=2.30, P=0.02) and the left eye (t=1.99, P=0.05). Conversely, non-athletes had better accommodation facility (t=-2.54, P=0.01) and near point of convergence (t=4.39, P<0.001) when compared to athletes. Vergence facility was found to be better among athletes (t=2.47, P=0.01). Nevertheless, non-athletes were significantly better for both distance negative and positive fusional vergence.

● CONCLUSION: Although the findings are still inconclusive as to whether athletes had superior visual skills as compared to non-athletes, it remains important to identify and elucidate the key visual skills needed by athletes in order for them to achieve higher performance in their sports.

● KEYWORDS: accommodation; phoria; vergence; athletes; non-athletes; sports

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INTRODUCTION

Vision provides key sensory information that is required for athletes to perform in sports effectively. A high level of visual performance with good visual processing is vital in most competitive sports[1]. Over the years, many studies have postulated the possibility of athletes possessing significantly better visual skills as compared to non-athletes, thus leading to their superior on-field performance[2-5]. The basis of better visual skills includes ensuring optimal refractive error correction to achieve best visual acuity (VA) which is highly associated with visual efficiency. It is also known that both accommodation and vergence have a close relationship with and influence the binocular vision system[6]. Visual efficiency thus encompasses the basic visual physiological processes comprising of accommodation and vergence functions as well as ocular motility[7].

Visual skills have been found to be highly developed in athletes and similar patterns have been observed in athletes engaging in both competitive and non-competitive sports[8]. Nevertheless, the important link of visual skills to athletic performance is often not described completely or neglected. Researchers have found certain visual skills such as VA[9], accommodation facility[10], near point of convergence[2,10], vergence facility[2] and visual reaction time[4-5] to be significantly better in athletes.

Stine *et al*[11] also suggested that athletes with low phoria had better binocular vision and depth perception.

Nonetheless, contradictions over visual skill findings between athletes and non-athletes have been demonstrated in studies comparing the amplitude of accommodation and ocular motor alignment between athletes and non-athletes, where it was found that there were no significant differences between these two groups[2,10,12]. Some researchers did note differences between elite and novice players of particular sports, however, this only attributed to less than 5% of the population variance in that particular sports[12].

Athletes or coaches may not be aware that inadequacies in visual skills could be a barrier to or have an impact on peak sports performance, whence small improvements in visual skills may be critical enough to influence the sports outcome[13]. Hence, this study aimed to compare the visual efficiency of athletes and non-athletes.

SUBJECTS AND METHODS

Ethical Clearance Informed parental consent was obtained prior to the study's commencement. All consent was administered individually and the consent form was signed by the parents before the students were enrolled into the study. This study was approved by the National University of Malaysia Human Subject Ethics Committee (UKM 1.5.3.5/244/NN-081-2013) as well as by the Ministry of Education Malaysia [KP(BPPDP)603/5/JLD.10] and followed the tenets of the Declaration of Helsinki.

Participants This research was a cross-sectional study with its sample size determined using G*Power 3.0.10[14], with a power of 95% and an alpha level of 0.05 in a two-sided test construct. A total of 214 elementary students (107 athletes, 107 non-athletes) aged between 13 to 16 years of old, regardless of gender participated in this study. The mean age for the athletes was 14.82±0.98y while for non-athletes was 15.00±1.04y, with almost equal numbers of male and female participants enrolled. All participants were assessed using standard sports vision screening, conducted at Bukit Jalil Sports School, Bukit Jalil, Malaysian for athletes and Padang Tembak National Secondary School, Kuala Lumpur, Malaysia for non-athletes. Prospective subjects with a history of vision training, eye injury or ocular disease were excluded from this study.

Visual Parameters The battery of tests used in sports vision screening for this study included refraction, best corrected distance visual acuity, distance ocular motor alignment, accommodation and vergence functions. The accommodation functions assessed were amplitude of accommodation and accommodation facility. Vergence functions included near point of convergence, vergence facility, and fusional vergence which included both positive and negative fusional vergence.

Refraction Participants' refractive errors were determined using the retinoscopy technique without pupil dilation by qualified optometrists. Best corrected refractive errors were further refined through subjective refraction using the crossed-cylinder technique. The refractive errors were measured in diopters spheres (DS).

Best corrected visual acuity Once participants had completed refraction, the best corrected visual acuity was tested using an externally illuminated ETDRS logMAR chart at a distance of 4 m. Each letter in the chart scored 0.02 logMAR. Participants were encouraged to read the smallest identifiable letter. Three logMAR charts with differently arranged letters were used and presented to the participants in a randomized order to minimize the effect of learning and chart memorization.

Accommodation Functions

Amplitude of accommodation Amplitude of accommodation was tested using the best-corrected vision of each eye with an RAF rule. The target chosen for the test on the RAF rule was 6/9 and it was moved slowly towards the participant until they first reported a sustained blur. The test was then repeated two more times for each eye. The average reading for each eye was recorded in diopters (D).

Accommodation facility The dynamics and stamina of accommodative response were evaluated using an accommodation facility test. This test was conducted using a Word Rock card of text size 20/30 with a ±2.00 D lens flipper at a distance of 40 cm monocularly, and then binocularly for one minute. Participants were asked to clear out the letters as soon as possible once the lens flipper was placed in front of their eyes. The results for this test was based on the number of complete "flips" the participants were able to clear within one minute. Accommodation facility was measured in cycles per minute (cpm).

Vergence Functions

Ocular motor alignment This study measured distance ocular alignment using a Howell card with a 6 prism diopters (PD) base-down lens. The test was conducted at a distance of 3 m from the spectacle plane, leveled to the visual axis with the best refractive correction. A prism was placed in front of the left eye to create a doubling effect to the viewed Howell card. The magnitude of ocular misalignment was measured based on the participant's response to the arrow indicator of the number on the Howell card. An odd number denoted exophoria while an even number signified esophoria.

Near point of convergence Participants were asked to fixate on a single target and report to the examiner when the single target appeared as double when the target moved closer to their eyes. Any ocular deviation or misalignment noted during the measurement process signifies the near point of convergence objectively. The near point of convergence was measured three times and the average reading recorded in centimeters.

Vergence facility Vergence facility was tested at a distance of 40 cm using 12 base-out/3 base-in flippers placed on the left

Table 1 Accommodation and vergence functions among teenaged athlete and non-athlete groups

Category			Mean±SD	
			Athlete (n=107)	Non-athlete (n=107)
Accommodation functions	Amplitude of accommodation (D)	Right eye	12.47±1.76[a]	11.89±1.94
		Left eye	12.51±1.89[a]	12.01±1.81
		Both eyes	12.49±1.76[a]	11.95±1.83
	Accommodation facility (cpm)	Right eye	12.14±4.55	12.73±5.30
		Left eye	12.59±4.68	13.30±5.70
		Both eyes	12.02±4.61	13.65±4.81[c]
Vergence functions	Ocular motor alignment (PD)		0.13±1.37	-0.05±1.95
	Near point of convergence (cm)		5.93±3.60	3.81±3.44[c]
	Vergence facility (cpm)		13.61±2.67[c]	12.36±4.47
	Distance negative fusional vergence (PD)	Break	7.33±3.68	11.18±4.46[c]
		Recovery	4.59±2.89	6.38±3.28[c]
	Distance positive fusional vergence (PD)	Break	14.23±6.61	16.66±8.95[c]
		Recovery	11.1±5.50	10.49±6.37

[a]$P<0.05$ and [c]$P<0.001$ denote significant difference between athletes and non-athletes.

eye while fixating at a 0.18 logMAR target[15-16]. Participants were instructed to make the letters single and clear as quickly as possible. The duration of test was one minute. The number of "flips" were calculated in one minute and recorded as cpm by the examiner.

Fusional vergence Fusional vergence measures the amount of fusional strength reserve available to maintain fusion of a single target. Distance negative fusional vergence (NFV) was measured prior to distance positive fusional vergence (PFV) to avoid vergence adaptation. A base-in (BI) and a base-out (BO) prism was used for NFV and PFV measurement respectively. PFV and NFV break and recovery points were measured at 6 m with a horizontal prism bar using a vertical row of 0.02 logMAR letter targets. The break and recovery points were recorded in PD.

Statistical Analysis All data were analyzed using the IBM Statistical Package for Social Sciences (v22.0, SPSS Inc., Chicago, IL, USA). Descriptive data for all visual parameters were analyzed to show mean, standard deviation (SD), and range. The Kolmogorov-Smirnov test was used to determine the status of data normality and parametric tests were used when $P>0.05$. Independent t-test was used to examine the visual parameters between athletes and non-athletes with the level of significance at $P<0.05$.

RESULTS

All participants were required to undergo refractive assessment prior to the measurement of other visual parameters. The mean refractive error for athletes was found to be -0.85±1.47 DS while for non-athletes it was -0.87±1.72 DS with their binocular best corrected visual acuity being 0.01±0.03 logMAR and 0.00±0.01 logMAR respectively. The range of refractive errors for athletes was from -6.00 to +1.00 DS while for non-athletes it was from -8.00 to +1.00 DS. Analysis of the Kolmogorov-Smirnov test showed $P>0.05$, hence parametric tests were used to analyze the findings.

Accommodation Functions Table 1 shows the descriptive data of the accommodation parameters of athletes and non-athletes. Analyses showed that the athlete's amplitude of accommodation was significantly better than non-athletes for right, left and both eyes respectively (t=2.30, P=0.02; t=1.99, P=0.05; t=2.21, P=0.03). However, the accommodation facility was not statistically significant between the athletes and non-athletes where the analysis revealed (right eye, t= -0.87, P=0.38; left eye, t=-0.99, P=0.32 and for both eyes, t= -2.54, P=0.01).

Vergence Functions Table 1 describes the mean and standard deviation for vergence functions. Visual parameters on ocular motor alignment did not show any significance between athletes and non-athletes (t=0.77, P=0.44). Analyses showed that near point convergence was better in non-athletes compared to athletes (t=4.39, $P<0.001$). Vergence facility was statistically significant for athletes as compared to non-athletes (t=2.47, P=0.01). Nevertheless, it was statistically significant for both distance negative fusional vergence at break point (t=-6.89, P=0.001) and recovery point, (t=-4.25, P=0.001). Analyses were statistically significant (t=-2.26, P=0.03) for distance positive fusional vergence at break point, but not at recovery point (t=0.77, P=0.44).

DISCUSSION

The majority of participants in this study were myopes with mild to minimal astigmatism of 0.25 to 0.75 cylindrical diopter (DC). There were similar refractive errors and best corrected visual acuity between both the groups; probably because the research participants were entirely of an Asian population[17].

However, the best corrected VA for athletes was below normal as the standard recommended visual acuity for competitive athletes should be at least -0.1 logMAR monocularly and binocularly[18]. From our study, 63% of athletes had refractive errors at distance but were not wearing any form of optical correction for sharper and precise vision. Refractive error as low as 0.25 DS myope should be corrected as studies have found that even low refractive errors may possibly have a significant impact on sports performance[19] as athletes are required to differentiate fine details clearly in sports play prior to choosing the appropriate response. Stereopsis was also assessed between athletes and non-athletes but found to be insignificant (P=0.57), as most of the participants in this study consisted of junior athletes. Our results differ from previous studies[2,8-9] as most compared stereopsis between elite athletes and non-athletes.

Our findings were consistent with other studies with regards amplitude of accommodation for monocular and binocular conditions, showing superiority in athletes as compared to non-athletes and were within the normative values described by Hofstetter[20]. Stronger accommodation was postulated to be linked to an athlete's daily on-field training; where the training would emphasize on attaining and focusing on targets to achieve higher accuracy in sports play. Accommodation facility is crucial for athletes to facilitate them in adjusting their focus rapidly for stable and clear vision, especially when attempting to fixate from distance to near or vice versa. Although athletes were found to have a higher amplitude of accommodation than non-athletes, their accommodation facility was lower and these findings were consistent with the study by Christenson and Winkelstein[2]. In this study, accommodation facility was tested using ±2.00 DS lens flippers, in contrast to other studies which used ±1.50 DS or ±1.00 DS lens flippers. Subsequent studies have suggested using ±2.00 DS lens flippers for testing accommodation facility as it enables better differentiation of participants from symptomatic and non-symptomatic populations[16]. Due to the differences in the power of accommodation flippers used, the amount of relaxation and stimulation of accommodation system would be dissimilar. Higher power lenses would provide a lower range of relaxation and stimulation of the accommodation system[21].

Ocular motor alignment was found to be highly related to the spatial localization of an object in space, which is vital for sports performance in a dynamic environment such as in badminton, tennis, football and hockey[19]. This study noted that the athletic population studied were esophoric while the non-athletes were exophoric. Previous literatures have shown that athletes with esophoric eye posture tend to undershoot by seeing the object nearer to them than it actually is while exophoric eye posture tends to be vice versa[19], which could have a significant effect on athletes in dynamic sports requiring catching and/or hitting a ball. Another factor to take into consideration is the conduct of ocular motor alignment assessments in an uncorrected visual state. Though the amount of ocular motor alignment found in both populations was almost negligible and within the normative values as described by previous studies[7,22], this does not reflect the true scenario of ocular motor alignment in athletes as most participants were not wearing any refractive correction despite having refractive error.

There are contrasting views as to whether vergence functions should be better in athletes as compared to non-athletes[2,12,23]. However, in this study, it was found that athletes were better in near point of convergence than non-athletes, possibly because this test does not directly relate to the visual task requirements needed in many sports. There are not many studies conducted that include fusional vergence examination on athletes[12,24], hence direct comparison of these studies was not possible. Non-athletes had a higher fusional range as compared to athletes, indicating that athletes had lower compensation of their visual binocularity system. However, athletes did have a better ability to regain single vision after diplopia based on the analysis for distance PFV at recovery. Previous studies have speculated the possibility of athletes having narrower vergence ranges, which leads to a more precise spatial judgment ability[19,24]. More studies would be necessary to understand the relationship of vergence ranges in relation to better spatial judgement and sports performance. Nevertheless, vergence facility was reported to be superior in the athletes compared to the non-athletes in this study supporting the idea that athletes can adjust their vergence posture rapidly and accurately.

In contrast to previous literature, our study found non-athletes to have better accommodation facility, near point convergence, vergence facility, distance negative fusional vergence at break and recovery as well as distance positive fusional vergence at break parameters, indicating better accommodation and reserves than athletes. A direct comparison of data with the literature was not possible because most of these studies were conducted using different ethnic backgrounds, age groups, and sports background parameters.

In conclusion, only certain aspects of visual skills related to accommodation and vergence were noted superior in athletes compared to non-athletes while the other visual skills did not show that athletes were better than non-athletes. Although inconclusive, this study provides a baseline on the visual skills that need to be assessed and optimized in athletes to maximize their on-field visual potential through the use of an effective visual training program. All athletes should be advised to undergo regular eye examination annually with a visual performance evaluation to ensure that visual function would not be a limiting factor to their sports performance. Sports vision examination would enable an athlete to have better insight on their current level of visual efficiency which they can then use to compare with the standards which may have been determined for athletes in certain sports. Identification of these key visual skills have the potential to help athletes excel in their sports.

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