Original Article

Binocular vision parameters and body mass index

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ABSTRACT

Background: Abnormal body mass Index (BMI) can adversely affect binocular vision. We aimed to assess the presence of possible differences in binocular vision parameters among the four BMI categories.

Methods: In this comparative cross-sectional study, we enrolled young adults and categorized them into underweight, normal weight, overweight, and obese groups based on their BMI. A complete orthoptic evaluation was performed to assess the mean values of binocular vision skills.

Results: We recruited 120 participants with a mean (standard deviation) age of 21.30 (1.80) years with best-corrected distance and near visual acuities of 6/6 and N6, respectively. The frequency of exophoria > 4 prism diopters was high in the obese group. The frequency of binocular vision dysfunction was higher in the obese and underweight groups, with vergence dysfunction being the most common. The mean values for near negative fusional vergence (NFV), distance positive fusional vergence (PFV), negative relative accommodation, positive relative accommodation, monocular accommodation facility (AF), and monocular estimation method were comparable among the groups (all $P > 0.05$). The obese group had significantly receded near point of convergence, and reduced accommodative convergence to accommodation ratio and binocular AF than the normal, overweight, and underweight groups (all $P < 0.05$). The distance and near vergence facilities were significantly lower in the obese group than in the overweight and normal groups, and the distance vergence facility was significantly lower than in the underweight group (all $P < 0.05$). The mean values of distance NFV and near PFV in the obese group were significantly lower compared to the normal and overweight groups, and the mean values of distance NFV were significantly lower compared to the underweight group (all $P < 0.05$). The mean values of near PFV were significantly lower in the underweight group than in the overweight group (both $P < 0.05$). Both the underweight and obese groups had a significantly lower amplitude of accommodation compared to the normal group (both $P < 0.05$).

Conclusions: The frequency of binocular vision dysfunction was higher in the obese and underweight groups. Most convergence and some accommodation parameters were adversely affected in individuals with obesity. Being underweight adversely affects certain binocular vision skills. Further studies are required to determine the relevance of BMI as a predictor of binocular vision abnormalities.

KEYWORDS

binocular vision, ocular accommodation, ocular convergence, frequency, obesity, overweight, underweight, body weights, quetelet index

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INTRODUCTION

The body mass index (BMI) is an anthropometric index used for obesity screening in adults [1] and calculated by dividing weight in kilograms (kg) by height in meters squared (kg/m^2) [2, 3]. It represents an index of individual fatness and can indicate several health issues [4]. It is categorized into underweight (< 18.5 kg/m^2), normal weight (18.5 – 24.9 kg/m^2), overweight (25.0 – 29.9 kg/m^2), and obese (30.0 – 34.9 kg/m^2) [5-7]. It has been linked to glaucoma, age-related cataracts, age-related maculopathy, and diabetic retinopathy [8]. It has a strong positive correlation with the anterior chamber depth and intraocular pressure. Overweight individuals have significantly higher intraocular pressure compared with normal-weight individuals [9]. A high BMI can increase the risk of age-related cataracts, particularly posterior subcapsular cataracts [10].

Binocular single vision is defined as simultaneous vision achieved through the coordinated use of both eyes [11, 12]. Binocular vision anomalies may be strabismic [13] and non-strabismic [14]. Strabismic binocular vision anomalies are associated with both congenital and acquired strabismus [13]. Non-strabismic binocular vision anomalies are more prevalent among young adults who perform extensive near work. This results in difficulty performing reading or other near tasks associated with binocular vision anomalies, such as accommodation and vergence dysfunction [14]. Binocular vision anomalies present with symptoms such as headache, asthenopia, eyestrain, occasional diplopia, intermittent blurred vision, and difficulty concentrating during reading [14].

The relationship between BMI and binocular vision skills has been investigated [15, 16]. Low BMI can adversely affect binocular vision. The near point of convergence (NPC) and vergence facility (VF) are affected by BMI, particularly among underweight and obese individuals, compared to their normal and overweight counterparts [15, 16].

We aimed to analyze the BMI and binocular vision status in young adults and investigate possible differences in binocular vision parameters among the four BMI categories.

METHODS

This comparative cross-sectional study was conducted following ethical approval from the Institutional Ethical Committee of the Faculty of Medicine (registration number CSP/19/JUN/78/220 on 17/07/2019) at the Sri Ramachandra Institute of Higher Education and Research, Porur, Chennai, Tamil Nadu, India. Study participants were recruited from volunteers attending the ophthalmic clinic and the Sri Ramachandra Institute of Higher Education and Research University after providing written informed consent for participation.

We included young adults with an age of 19 – 25 years and a best-corrected visual acuity of 6/9 or better in each eye at 6 meters (m) and 40 cm without manifested deviation for distance and near. Patients with strabismus, neurological deficits, nystagmus, amblyopia, ocular trauma, ocular pathology, previous ocular surgery, pregnancy, lactation, or a history of hospitalization within 3 months for any systemic illness were excluded.

The height (m) and weight (kg) of all participants were measured with a tape measure and weighing scale, respectively, and BMI was determined using the standard formula: weight in kg divided by height in meters squared (kg/m^2) [2, 3]. Based on the BMI, the participants were categorized into four groups; underweight, normal, overweight, and obese [5-7].

All participants underwent complete ophthalmological examination, including measurement of best-corrected distance visual acuity using a Snellen chart (care vision CV-060 Vision Test Chart, Karnataka, India); measurement of near visual acuity using the Jaeger near-vision card; intraocular pressure measurement using the non-contact tonometer (Shin-Nippon NCT 200, Rexxam Co. Ltd., Osaka, Japan); detailed anterior and undilated posterior segment examinations using slit-lamp microscopy (Appasamy Slit-lamp LED 3 step w/o stand AIA-12, India); and objective dry refraction using a streak retinoscope (Keeler; Halma UK, Windsor, UK).

A complete orthoptic evaluation was performed to assess the binocular vision skills. For sensory evaluation, stereopsis was measured using the Titmus fly test (Stereo Optical Co., Chicago, IL, USA) [17]. The worth four dot test was performed to check fusion and suppression of the eyes [18, 19]. A motor evaluation was performed as described below.

Initially, ocular alignment was assessed by evaluating the movement of the extraocular muscles [20]. Static alignment was evaluated using the cover/uncover test, and the amount of phoria was measured using a prism bar [21]. Near (40 cm) and distance (6 m) phoria were assessed using the flashed Maddox rod technique, and the accommodative convergence-to-accommodation ratio (AC/A) was calculated [22]. The NPC was determined using red and green filters or pen tip, and the value was recorded as the break and recovery point [23, 24]. VF was assessed using a VF flipper prism with 12 prism base-out and three prism base-in [15]. A vertical column of small "E" letters of approximately 6/9 size was used as an accommodative target at 40 cm [25].

Positive fusional vergence (PFV) and negative fusional vergence (NFV) were determined using a prism bar both near (40 cm) and distant (3 m) [26]. A vertical column was used as the target. For NFV and PFV, base-in and base-out prisms were placed before the eye, respectively. The blur, break, and recovery points were also noted [27]. The accommodation facility (AF) [28] was determined using the AF flippers of a +2.00 dioptric sphere (DS) and - 2.00 DS lens. Both monocular and binocular AFs were assessed at 40 cm.

The amplitude of accommodation (AoA) was determined by negative relative accommodation (NRA). NRA and positive relative accommodation (PRA) were measured at 40-cm intervals. For NRA and PRA, plus and minus lenses were used for assessment, respectively. The lead and lag of the accommodation were determined using the monocular estimation method [29]. The obtained values were compared with those of healthy individuals [30].

Data on binocular vision skills were collected for all BMI categories. Statistical analyses were performed using IBM SPSS Statistics software for Windows (version 23.0; IBM Corp., Armonk, NY, USA). The normality of data distribution was assessed. Quantitative and qualitative data are expressed as mean (standard deviation [SD]) and frequency (percentage), respectively. We compared quantitative data with parametric distribution among the four BMI categories using the one-way analysis of variance (ANOVA) and used Tukey's test as a post-hoc analysis for pairwise comparisons between groups when ANOVA revealed a significant difference ($P < 0.05$).

RESULTS

We recruited 120 participants, with a mean (SD) age of 21.30 (1.80) years and a male-to-female ratio of 22 (18.3%) / 98 (81.7%). The best-corrected distance and near visual acuities were 6/6 and N6, respectively. The participants were categorized into four groups based on the BMI, each with 30 participants. The mean (SD) BMI values were 21.25 (1.19), 16.8 (0.81), 27.08 (0.98), and 32.87 (3.40) kg/m^2 in normal, underweight, overweight, and obesity groups, respectively.

The mean (SD) near exophoria was higher in the obese and underweight groups (1.96 [2.05] prism diopters [PD] and 0.93 [1.59] PD, respectively) than in the normal weight and overweight groups (0.50 [1.35] and 0.36 [0.99] PD, respectively; $P < 0.001$). The frequency of exophoria > 4 PD was high in the obese group.

Table 1 shows the frequencies of normal and abnormal binocular vision in each BMI category. Overall, the frequency of vergence dysfunction (n = 23; 19.2%) was higher than that of accommodation dysfunction (n = 8; 6.7%). The frequency of binocular vision dysfunction was higher in the obese (n = 12, 40.0%) and underweight (n = 8, 26.7%) groups (Table 1).

Table 2 shows the mean (SD) values for various vergence parameters among the four BMI categories. The mean break and recovery values for near NFV and distance PFV were comparable among the groups (all $P > 0.05$) (Table 2). The mean NPC break and recovery values differed significantly among the study groups ($P < 0.001$). The mean (SD) NPC break and recovery values were receded in the obese (13.15 [3.90] and 15.45 [4.42] cm, respectively) and underweight (9.66 [3.80] and 11.83 [4.13] cm, respectively) groups (Table 2). Pairwise comparisons revealed that mean NPC break and recovery receded more significantly in the obese group than in the normal weight, overweight, and underweight groups (all $P < 0.05$; Table 4).

The mean distance and near VFs differed significantly among the study groups (both $P < 0.001$). The mean (SD) VFs in the distance and near assessments were lower in the obese group (9.28 [2.84] and 12.63 [2.73] cycle per minute [cpm], respectively) than in the other groups (Table 2). Pairwise comparisons revealed that mean distance and near VFs were significantly lower in the obese group than in the normal and overweight groups (all $P < 0.05$) and that mean distance VF was significantly lower in the obese group than in the underweight group ($P < 0.05$; Table 4).

The mean break and recovery values of the distant NFV (both $P < 0.05$) and near PFV (both $P < 0.001$) differed significantly among the study groups (Table 2). Pairwise comparisons revealed that the mean break and recovery values of distance NFV and near PFV were significantly lower in the obese group than in the normal and overweight groups and that the mean break and recovery values of distance NFV were significantly lower in the obese group than in the underweight group (all $P < 0.05$). Similarly, the mean break and recovery values of the near PFV were significantly lower in the underweight group than in the overweight group (both $P < 0.05$; Table 4).

The mean AC/A ratio differed significantly among the groups ($P < 0.001$; Table 2). Pairwise comparisons revealed that the mean AC/A ratio was significantly lower in the obese group than in the normal-weight, overweight, and underweight groups (all $P < 0.05$; Table 4).

Table 3 shows the mean values for the various accommodation parameters of the four BMI categories. The NRA, PRA, monocular AF, and monocular estimation method were normal in all groups, with no significant differences among the four BMI categories (all $P > 0.05$; Table 3).

Binocular AF was low in those with convergence insufficiency in all groups. As the frequency of participants with convergence insufficiency was high in the obese group (Table 1), the mean (SD) binocular AF in the obese group was low (7.80 [2.53] cpm; Table 3). This differed significantly among the groups ($P < 0.001$; Table 3). Pairwise comparisons revealed that mean binocular AF was significantly lower in the obese group than in the normal-weight, overweight, and underweight (all $P < 0.05$) groups (Table 4). Similarly, the mean AoA differed significantly among the groups ($P < 0.05$). Pairwise comparisons revealed a significantly lower mean AoA in both underweight and obese groups than in the normal group (both $P < 0.05$; Table 4).

The obese group had receded mean NPC, and lower mean VF, distance NFV, near PFV, AC/A ratio, binocular AF, and AoA compared to the other groups. The underweight group had lower AoA and near PFV compared to the normal-weight and overweight groups, respectively (Table 4).

Table 1. Frequency of binocular vision anomalies in each BMI group

BMI groups	Normal BV, n (%)	Abnormal BV, n (%)	Type of BV abnormality, n (%)	
Underweight (n = 30)	22 (73.3)	8 (26.7)	CI	6 (20.0)
			AIF	2 (6.7)
Normal (n = 30)	25 (83.3)	5 (16.7)	CI	3 (10.0)
			AIF	1 (3.3)
			Accommodative insufficiency	1 (3.3)
Overweight (n = 30)	24 (80.0)	6 (20.0)	Receded NPC and VF	4 (13.3)
			AIF	2 (6.7)
Obese (n = 30)	18 (60.0)	12 (40.0)	CI	10 (33.3)
			AIF	2 (6.7)

Abbreviations: BMI, body mass index; BV, binocular vision; n, number; %, percentage; CI, convergence insufficiency; AIF, accommodative infacility; NPC, near point of convergence; VF, vergence facility; kg/m², kilogram per square meter. Note: Underweight, with BMI < 18.5 kg/m²; Normal, with BMI 18.5 – 24.9 kg/m²; Overweight, with BMI 25.0 – 29.9 kg/m²; Obese, with BMI 30.0 – 34.9 kg/m².

Table 2. Values for various vergence parameters among four BMI groups

Parameters		Underweight	Normal	Overweight	Obese	*P*-value
NPC (cm), Mean ± SD	**Break**	9.66 ± 3.80	7.93 ± 2.54	8.06 ± 3.21	13.15 ± 3.90	**< 0.001**
	Recovery	11.83 ± 4.13	9.60 ± 3.04	9.76 ± 3.32	15.45 ± 4.42	**< 0.001**
VF (cpm), Mean ± SD	**Distance**	12.10 ± 3.37	13.88 ± 2.91	13.76 ± 2.90	9.28 ± 2.84	**< 0.001**
	Near	14.60 ± 2.76	15.26 ± 0.21	16.23 ± 2.86	12.63 ± 2.73	**0.001**
Distance NFV (PD), Mean ± SD	**Break**	8.40 ± 1.93	8.53 ± 2.02	8.26 ± 1.72	6.80 ± 1.93	**0.002**
	Recovery	6.13 ± 1.81	6.33 ± 1.97	6.06 ± 1.61	4.80 ± 1.93	**0.006**
Near NFV (PD), Mean ± SD	**Break**	14.93 ± 2.33	14.26 ± 2.27	14.93 ± 2.66	14.13 ± 1.96	0.389
	Recovery	12.00 ± 2.22	11.93 ± 1.99	12.46 ± 2.38	11.60 ± 1.61	0.451
Distance PFV (PD), Mean ± SD	**Break**	13.46 ± 2.62	13.26 ± 3.76	15.13 ± 3.09	14.13 ± 2.09	0.069
	Recovery	11.46 ± 2.62	11.20 ± 3.09	13.00 ± 3.00	12.06 ± 2.06	0.085
Near PFV (PD), Mean ± SD	**Break**	15.08 ± 3.53	17.90 ± 4.18	18.53 ± 3.61	14.33 ± 2.92	**< 0.001**
	Recovery	13.73 ± 3.51	15.53 ± 3.73	16.00 ± 3.01	12.13 ± 2.82	**< 0.001**
AC/A ratio, Mean ± SD		5.57 ± 0.76	5.88 ± 0.52	5.99 ± 0.37	4.98 ± 0.93	**< 0.001**

Abbreviations: BMI, body mass index; NPC, near point of convergence; cm, centimeter; SD, standard deviation; VF, vergence facility; cpm, cycle per minute; NFV, negative fusional vergence; PD, prism diopters; PFV, positive fusional vergence; AC/A ratio, accommodative convergence to accommodation ratio. Note: *P*-values < 0.05 are shown in bold; Underweight, with BMI < 18.5 kg/m²; Normal, with BMI 18.5 – 24.9 kg/m²; Overweight, with BMI 25.0 – 29.9 kg/m²; Obese, with BMI 30.0 – 34.9 kg/m².

Table 3. Values for accommodation parameters among four BMI groups

Parameters		Underweight	Normal	Overweight	Obese	*P*-value
NRA (D), Mean ± SD		3.35 ± 4.09	3.41 ± 4.09	2.62 ± 0.49	2.49 ± 0.41	0.484
PRA (D), Mean ± SD		- 2.94 ± 1.23	- 2.69 ± 1.23	- 2.75 ± 1.17	- 2.90 ± 0.46	0.809
AF (cpm), Mean ± SD	**OD**	10.03 ± 3.77	10.96 ± 3.91	9.83 ± 3.66	9.53 ± 2.71	0.438
	OS	9.88 ± 3.82	10.96 ± 3.77	9.88 ± 3.74	9.75 ± 2.06	0.494
	OU	9.90 ± 3.61	11.46 ± 2.95	10.46 ± 2.96	7.80 ± 2.53	**< 0.001**
AoA (D), Mean ± SD		10.89 ± 1.23	12.12 ± 2.40	11.60 ± 1.60	10.95 ± 1.28	**0.017**
MEM (D), Mean ± SD	**OD**	0.56 ± 0.13	0.58 ± 0.17	0.59 ± 1.3	0.57 ± 0.11	0.868
	OS	0.55 ± 0.16	0.55 ± 0.20	0.55 ± 0.18	0.60 ± 0.18	0.627

Abbreviations: BMI, body mass index; NRA, negative relative accommodation; D, diopters; SD, standard deviation; PRA, positive relative accommodation; AF, accommodative facility; cpm, cycle per minute; OD, right eye; OS, left eye; OU, both eyes; AoA, amplitude of accommodation; MEM, monocular estimation method. Note: *P*-values < 0.05 are shown in bold; Underweight, with BMI < 18.5 kg/m^2; Normal, with BMI 18.5 – 24.9 kg/m^2; Overweight, with BMI 25.0 – 29.9 kg/m^2; Obese, with BMI 30.0 – 34.9 kg/m^2.

Table 4. Pairwise comparisons of significant parameters among four BMI categories

Parameters	P_1	P_2	P_3	P_4	P_5	P_6
NPC, Break (cm)	0.999	**0.010**	0.220	**0.010**	0.286	**0.004**
NPC, Recovery (cm)	0.998	**0.010**	0.117	**0.010**	0.166	**0.009**
Distance VF (cpm)	0.999	**0.010**	0.102	**0.010**	0.141	**0.010**
Near VF (cpm)	0.650	**0.017**	0.853	**0.010**	0.206	0.127
Distance NFV, Break (PD)	0.950	**0.004**	0.993	**0.020**	0.993	**0.009**
Distance NFV, Recovery (PD)	0.943	**0.009**	0.975	**0.043**	0.999	**0.030**
Near PFV, Break (PD)	0.904	**0.001**	0.113	**0.010**	**0.020**	0.394
Near PFV, Recovery (PD)	0.947	**0.001**	0.154	**0.010**	**0.043**	0.242
AC/A ratio	0.925	**0.010**	0.295	**0.010**	0.085	**0.007**
Binocular AF (cpm)	0.582	**0.010**	0.196	**0.005**	0.888	**0.042**
AoA (D)	0.636	**0.042**	**0.030**	0.447	0.376	0.999

Abbreviations: BMI, body mass index; NPC, near point of convergence; cm, centimeter; VF, vergence facility; cpm, cycle per minute; NFV, negative fusional vergence; PD, prism diopters; PFV, positive fusional vergence; AC/A ratio, accommodative convergence to accommodation ratio; AF, accommodative facility; AoA, amplitude of accommodation. Note: *P*-values < 0.05 are shown in bold; P_1, *P*-value for the comparison between normal-weight versus overweight individuals; P_2, *P*-value for the comparison between normal-weight versus obese individuals; P_3, *P*-value for the comparison between normal-weight individuals versus underweight; P_4, *P*-value for the comparison between overweight versus obese individuals; P_5, *P*-value for the comparison between underweight versus overweight individuals; P_6, *P*-value for the comparison between underweight versus obese individuals; Underweight, with BMI < 18.5 kg/m^2; Normal, with BMI 18.5 – 24.9 kg/m^2; Overweight, with BMI 25.0 – 29.9 kg/m^2; Obese, with BMI 30.0 – 34.9 kg/m^2.

DISCUSSION

Both extremes of BMI adversely affected binocular vision skills, as evidenced by the significantly receded NPC, and reduced AC/A ratio, binocular AF, distance and near VFs, distance NFV, and near PFV in the obese group and a significantly low AoA in both underweight and obese groups. The prevalence of exophoria > 4 PD was high in the obese group. The frequency of binocular vision dysfunction was high in both obesity and underweight groups. The underweight group exhibited reduced near PFV.

Similar to Momeni-Moghaddam et al.'s study [15], we found that individuals in the normal or overweight BMI categories performed better in terms of binocular vision skills. They found significant differences in NPC and VF among different BMI groups [15], similar to the present study. The underweight group had significantly receded NPC and reduced VF compared to the normal, overweight, and obese groups [15]. In contrast, NPC receded more significantly in the obese group than in the normal, overweight, and underweight groups. Moreover, the distance and near VFs were significantly lower in the obese group than in the overweight and normal groups, and the distance VF was significantly lower in the obese group than in the underweight group.

Despite the observed differences between these two studies, the findings imply that both extremes of BMI can deteriorate binocular vision skills.

Vaishali et al. found no significant difference in convergence insufficiency among the four BMI groups. The results of various binocular vision tests, including NPC, near point of accommodation, base-in break, base-out break, abduction, adduction, and exophoria, were comparable among the four BMI groups [31]. However, we found high frequencies of abnormal binocular vision in the obese (40.0%) and underweight (26.7%) groups, followed by the overweight (20.0%) and normal (16.7%) groups. Convergence insufficiency was the most frequent binocular vision anomaly affecting 19 (15.8%) participants, with a higher frequency in the obese and underweight groups: 10 in the obese group, six in the underweight group, and three in the normal group.

The mean near exophoria was high in the obese and underweight groups. The frequency of exophoria > 4 PD was high in the obese group. Heterophoria could present because of anatomical factors such as abnormal strength of the extraocular muscle, volume of retrobulbar tissue, and size and shape of the globes [32]. A significantly higher retrobulbar adipose tissue volume in individuals with obesity than in normal-weight individuals [33] could affect the extraocular muscles, as evidenced by the presence of large amount of exophoria and deterioration of convergence parameters in the obese group in the present study. This possible causal relationship should be verified in future studies using magnetic resonance imaging of the head at the level of the optic nerve to measure the retrobulbar adipose tissue volume [33] and correlate it with the binocular vision skills of obese individuals.

Obesity adversely affected VF, as distance and near VFs were significantly lower in the obese group than in the normal and overweight groups, and distance VF was significantly lower in the obese group than in the underweight group. Facilitating rapid convergence and divergence movements was difficult with prisms for distant and near VFs. Distance NFV and near PFV were lower in the obesity group than in the normal and overweight groups. Wiegand et al. regarded the lack of proper vergence as a criterion for a high rate of drowsiness, which measures fatigue. Moreover, they reported a higher likelihood of fatigue in drivers with obesity (≥ 30 BMI) [34]. Considering the significance of unsafe driving behaviors [35], assessing binocular vision skills, particularly the vergence system, among individuals with an extreme BMI who engage in critical jobs such as drivers [36] could be recommended for occupational safety and health.

The accommodation parameters did not vary significantly among the groups, and we found comparable values for NRA, PRA, monocular AF, and monocular estimation method among all groups. However, the vergence system was affected more than the accommodation system in the obese group. Teasdale et al. [37] suggested that obese individuals have an abnormal gait because of mechanical stress, which affects the lower limb and consequently changes the gait pattern, and that ocular movements and the vergence system play a role in postural performance [38]. Plantar stimulation affects vergence eye movements and reduces sensitivity from the plantar to visual inputs in obese individuals, which may affect the vergence system [37]. Arphorn et al. found that the likelihood of occupational falls increased by 3.05 times in individuals with BMI ≥ 30 kg/m^2 compared to those with BMI < 25 kg/m^2 [39]. High BMI could cause strength deficits, as individuals with a BMI > 35.0 kg/m^2 had up to 63.1% lower joint strength compared to those in other BMI categories [40]. Therefore, we believe that investigating the effects of binocular vision skills, particularly vergence system performance, on postural performance among individuals at both extremes of BMI is a research question that scholars should address in the future.

In a cross-sectional study involving 1856 grade 1 students from primary schools, He et al. found that BMI was not a risk factor for strabismus using multiple logistic regression [41]. The first possibility is that, as participants had a mean (SD) BMI of 15.74 (1.80), fewer individuals may have had both extremes of BMI. The second possibility is that BMI could be less influential on strabismic [13] than on non-strabismic binocular vision anomalies [14], as they tested the effect of BMI in children with strabismus [41], whereas our participants had no manifest deviation for distance or near. The third possibility is that this outcome might be due to the difference in the age of participants between both studies, as He et al. [41] included children with a mean (SD) age of 6.83 (0.46), who were younger than our participants (age range: 19 – 25 years), as disparity in binocular vision parameters might be seen even between normal children and adults [42].

This study revealed that both BMI extremes could adversely affect binocular vision skills, predominantly the vergence system. Further studies on different BMI categories with a specific focus on obesity are necessary to determine the correlation between the vergence system and postural instability in obese individuals. A limitation of the present study is that it did not aim to determine the exact reason for the association between binocular parameters and BMI. Future studies are required to test the possible correlations among ocular movements, the vergence system, postural instability, and impaired vision in individuals with obesity. Moreover, future studies are required to find convincing evidence on the effects of weight change on improving binocular vision anomalies and vergence system dysfunction observed in both extremes of BMI and discover the relevance of BMI as a predictor of binocular vision abnormalities. Investigating the effects of other anthropometric characteristics on binocular vision skills is an exciting topic for future research.

CONCLUSIONS

The obese group had large amount of near exophoria. The frequency of binocular vision dysfunction was high in the obese and underweight groups, among which the obese group was more susceptible to binocular vision abnormalities. Individuals with obesity had receded NPC, and reduced AC/A ratio, binocular AF, distance and near VF, distance NFV, and near PFV. Both underweight and obese groups had significantly lower AoA, and the underweight group had reduced near PFV. A thorough binocular assessment of young adults should be assessed during eye examinations.

ETHICAL DECLARATIONS

Ethical approval: This comparative cross-sectional study was conducted following ethical approval from the Institutional Ethical Committee of the Faculty of Medicine (registration number CSP/19/JUN/78/220 on 17/07/2019) at the Sri Ramachandra Institute of Higher Education and Research, Porur, Chennai, Tamil Nadu, India. Study participants were recruited from volunteers attending the ophthalmic clinic and the Sri Ramachandra Institute of Higher Education and Research University after providing written informed consent for participation.
Conflict of interest: None.

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