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# The influence of high additions in multifocal contact lenses for myopia control on binocular vision

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## HIGHLIGHTS

High-addition multifocal contact lenses designed for myopia control can change phoria at distance and vergence ranges at near.

## ABSTRACT

**Objectives:** This study aimed to investigate the influence of soft multifocal contact lenses with high additions designed for myopia control on binocular vision in young adults.

**Methods:** A prospective randomized, double-blind study including 24 subjects aged between 18 and 36 years. Subjects were divided into two groups. The first group wore multifocal soft contact lenses (MFSCLs) with a 3.0 mm central zone diameter, while the second group wore contact lenses with 4.5 mm central zones. Each subject was fitted with two MFSCLs: one with +2.00 D and the other with +4.00 D peripheral addition power and, additionally, with plano single vision contact lenses (SVCLs). Phoria at a distance and near, distance and near vergence ranges, vergence facility at near, stereopsis at near, and fixation disparity at near were measured in each study lens type.

**Results:** No significant influence of addition on distance phoria was found in either group ($p = 0.446$ and $p = 0.317$, for 3 mm and 4.5 mm central zone diameter, respectively). Additionally, no significant difference was observed for any MFSCLs and SVCLs in near phoria ($p = 0.320$), near vergence facility ($p = 0.197$), or near fixation disparity ($p = 0.203$). A decline in fusional vergence ranges at a distance in the base-out direction was noted in subjects wearing +4.00 D addition compared to +2.00 D addition ($p = 0.002$) and plano lenses ($p = 0.014$). Both additions reduced fusional vergence ranges at near the base out ($p = 0.020$) and shifted vergence ranges more in the exophoria base in directions ($p = 0.014$).

**Conclusions:** The study showed that MFSCLs with high additional power in the periphery have only a marginal impact on the binocular functions.

**Key words:** multifocal contact lenses, myopia, myopia control, binocular vision, phoria

## INTRODUCTION

Binocular vision may play an essential role in everyday activities, such as reading, watching TV, reaching, grasping, and sports activities [1, 2]. Therefore, binocular vision testing is a core element of vision examination necessary to prescribe optical devices and improve the quality of vision [3]. Eye care professionals have a large selection of optical products to correct refractive errors, which may be recommended for children. Owing to the observed increase in the global incidence of myopia [4], significantly more attention is given to correcting the error and, even more importantly, to control its progression [5], which has onset and significantly increases at school age [6]. To control myopia progression, practitioners can use several optical correction methods [7–9]. One is correction with multifocal soft contact lenses (MFSCLs) [10–13]. In some designs of these lenses, the central part of MFSCLs corrects the central myopic defocus, while the additional power placed in the paracentral part of the lens is designed to evoke a myopic defocus in the peripheral part of the retina, which should reduce myopia progression [14, 15]. Currently, there are different designs of MFSCLs for myopia control, including alternating bifocal design, center-distance progressive multifocal design, and aspheric single-vision design [16]. Although recent studies have shown that a higher addition power at the peripheral part of the MFSCL could boost the effect of myopia control [15, 17], there is still no consensus on which MFSCL design parameters perform best in slowing down myopia progression and facilitating the optimum visual performance during everyday activities [18].

However, assuming that the goal of myopia control is to create a wide area of myopic defocus on the peripheral retina using MFSCLs with high addition power, it is crucial to assess the impact of the lenses on essential visual functions and binocular performance since high prescription power located in the periphery may interrupt both the peripheral and central vision [19, 20].

In most of the studies on MFSCL application for myopia control, researchers used small or medium addition powers (ADD from +1.5 D to +2.5 D) with constant central distance zone diameter (CZ, usually from 2.7 mm to 3.5 mm) [21, 22]. However, both ADD, and CZ can affect monocular and binocular vision. In the previous studies performed by our group on MFSCLs designed for myopia control (RELAX, SwissLens), it was found that high ADD (+4.00 D) reduced central and peripheral contrast sensitivity [19, 23], similar to medium ADD (+2.00 D) and partially decreased distance visual acuity (VA), mainly when a small CZ (3 mm) was used. Additionally, MFSCLs with high and medium ADDs increased the lag of accommodation and decreased accommodative response [23]. Accommodation is strongly coupled with vergence [24–26] so the weakening of accommodative response may also impair vergence, leading to higher near exophoria or decreased stereovision [22, 27]. It was also shown that the changes in the peripheral vision observed when high ADD power was used did not influence simple visuomotor behavior such as reaching or saccadic eye movements [28]. However, little is known about the influence of high ADDs in MFSCLs on binocular vision functions [29].

Since MFSCLs with high ADDs might be intended mainly for pediatric applications, it is necessary to examine the effect of such lenses on binocular functions before recommending them for commercial use in cases of myopia. Moreover, specific lens parameters such as ADD power and CZ size might be recommended individually in each case based on the patient's binocular vision status.

The results presented in this study are part of a larger project focused on the impact of MFSCLs with high ADDs on visual functions. In the first part of the project, basic monocular parameters (visual acuity, contrast sensitivity, and accommodative skills) were investigated [23]. The results presented in the current study were focused on binocular function in the same group of participants. The aim was to investigate the influence of medium (+2.00 D) and high (+4.00 D) ADDs with different CZ sizes (3 mm and 4.5 mm) in MFSCLs dedicated to myopia control on short-term binocular functions.

## METHOD

### Subjects and inclusion criteria

The inclusion criteria were: refractive error between +0.50 D and -6.00 D and regular astigmatism no greater than -1.00 D, the best-corrected visual acuity at a distance and near at least 0.0 log MAR, good accommodative skills (measured with a spherical flipper and dynamic retinoscopy), and no binocular vision disorders (assessed by the cover test, stereo acuity test and prismatic vergence ranges test). Moreover, subjects with ocular pathologies (assessed by direct ophthalmoscopy and slit-lamp examination) were excluded from the study. The study protocol followed the tenets of the Declaration of Helsinki and was approved by the Ethical Committee of Poznan University of Medical Sciences. All subjects received an explanation of the nature of the study, signed an informed consent form, and had the option to discontinue their participation in the study at any time.

The exclusion criteria included accommodation deficits, binocular vision dysfunctions, history of ocular and/or systemic diseases, and any medication intake that may be considered a contraindication for contact lens wear or that might impact visual function measurement results. Contact lens wearing experience in the past was not required.

### Contact lenses

Custom-made MFSCLs or single-vision spherical (SVS) contact lenses (CLs) from SwissLens (Relax/Orbis) were used. MFSCLs were designed with two different central distance zone diameters (3.0 mm and 4.5 mm) and two different ADD powers in the peripheral part (+2.00 D and +4.00 D, further referred to as ADD2 and ADD4, respectively). SVS plano lenses with zero addition (ADD0) were used as control lenses. The design of the MFSCLs includes a polynomial progression zone. All the parameters and design details of the lenses used in this study are presented in table 1.

TABLE 1

Parameters of the lenses used in the study.

| Parameter | MF lenses |
|---|---|
| Commercial name | Orbis (SVS), Relax (MFSCLs) |
| Material | Contaflex GS3 58% (Acofilcon A) |
| Water content | 59% |
| Base curve | 8.6 mm |
| Diameter | 14.2 mm |
| Distance power | Plano |
| Distance zone diameter (MFSCLs only) | 3.0 mm and 4.5 mm |
| Near ADD power (MFSCLs only) | +2.00 D and +4.00 D |

## Study design

The study was prospective, randomized, and double-blinded. Three follow-up visits were scheduled for all the subjects. The same researcher performed all measurements in the same room under the same illumination conditions using the same methods and equipment. Numbers and symbols were used to hide the subject's identity, and neither the researchers nor the subjects had any information on what ADD power was used during the measurements. The subjects were randomly divided into two groups, wearing MFSCLs with different central zone diameters (3.0 mm – CZ3 group or 4.5 mm – CZ4.5 group).

Each subject was fitted with three designs of contact lenses (ADD0, ADD2, and ADD4) used in a counterbalanced order and on a different visit. The contact lenses were evaluated during the slit-lamp examination and topography (with and without lenses) with additional pupil size measurements under photopic conditions using Keratograph®4 (OCULUS Optikgeräte GmbH, Germany). The study measurements were taken after one hour of adaptation to the CLs.

## Procedure

Each subject underwent a series of monocular and binocular tests. The procedure applied by the researchers and the results concerning basic visual functions, such as visual acuity, accommodative abilities, and contrast sensitivity with the study lenses, are discussed in another paper [23]. In the present study, the researchers focused on binocular visual functions; therefore, a series of binocular tests were performed, including distance and near phorias, distance and near fusional vergence ranges, vergence facility at near, near fixation disparity, and near stereo acuity. All the tests were performed with three types of contact lenses (ADD4, ADD2, and ADD0) and, if necessary, with spectacles providing refractive error correction.

### Phoria

Distance phoria tests were performed at 5 m using the Frey CP-600P chart panel, and near tests were administered at 0.4 m using a fixation stick and a column of letters (font size corresponded to 20/30 vision acuity). Phoria was measured at distance and near (three times each) with a prismatic cover test, and the results were recorded with a minus sign for exophoria and a plus sign for esophoria. Subsequently, the results were averaged.

### Vergence ranges

Distance and near-horizontal fusional vergence ranges were measured behind a phoropter using Risley prisms. The target for distance vergence ranges was a vertical column of letters (size corresponded to 20/30 vision acuity) displayed on a Frey CP-600P chart panel (distance test) or a near card attached to the phoropter (near vergence ranges). The subjects were asked to report blur, break (see a double column), and recover (see a single column again). At least three measurements were taken for each distance using BI and BO prisms.

### Vergence facility

The vergence facility was measured at 0.40 m using a flipper with 3Δ base-in and 12Δ base-out prisms while the subjects were looking at the column of letters (20/30 VA). The subjects were instructed to report seeing a single clear image after the prism flipper was flipped. The number of prism flips over 30 s were counted and recorded as cycles per minute (CPM).

### Horizontal fixation disparity at near

Horizontal fixation disparity (FD) was measured directly using the Wesson Fixation Disparity Card at 0.40 m. The subjects wore polarized filters (over their habitual prescription) and were asked to judge the position of an arrow presented above a graduation scale. FD was measured three times, recorded in minutes of arc, and then averaged.

### Stereopsis at near

At near (0.4 m), stereopsis was measured using the Paul Harris Randot Test (Bernell, Stereo Optical Co, Chicago, IL, Special Edition). This test consists of circles, ranging from 400 to 20 s of arc, and measures global stereopsis. Therefore, it is more sensitive than the standard contour stereo vision test [30]. The subjects wore polarized filters (over their habitual prescription) and were asked to assess which circle on the stereograms was seen with depth. The test was performed three times, and the results were averaged.

### Statistical analysis

Statistical data analysis was performed using STATISTICA v.13.1. (Statsoft). The Shapiro-Wilk test was used to assess the normality of data distribution, and the non-parametric Friedman ANOVA (for distance phoria, FD, vergence, and stereopsis) or ANOVA with repeated measurements (for the remaining parameters) was used. Two factors were included in the analysis: group (CZ3 and CZ4.5) and ADD (ADD4, ADD2, ADD0), while for vergence, three factors were employed: group, ADD, and response (blur, break, and recovery). Tukey's test was used for post hoc analyses. Differences were considered significant when the p-value did not exceed 0.05.

## RESULTS

### Subjects

Twenty-four subjects (mainly students at Adam Mickiewicz University in Poznan) who met the inclusion criteria (mean age 23.9, range 18–36 years) participated in the study. Thirteen of the subjects were myopes (mean spherical equivalent: -2.08 D, SD: 2.01, range: from -0.25 to -6.12 D), two were small hyperopes (mean spherical equivalent: +0.50 D, SD: 0.35, range: from +0.25 to +0.75 D) and nine were emmetropes (mean spherical equivalent: between -0,25 D and +0,25 D). All subjects exhibited normal binocular vision (no suppression, stereo acuity of at least 40 s of arc, orthophoria, or compensated heterophoria), normal accommodative functions (amplitude of accommodation and accommodative facility), and no history of strabismus.

### Phoria

The median distance phoria (shown in fig. 1A) was almost equal for all ADDs in the CZ3 group (p = 0.446). Similarly, there was no significant difference in the median value of distance phoria in the CZ4.5 group for all ADDs (p = 0.317). Additionally, no statistically significant difference was found for median values of distance phoria between the CZ3 and CZ4.5 groups for ADD0 (p = 0.102) and ADD2 (p = 0.206). However, in the case of ADD4, median exophoria at a distance when using CZ3 was higher than with CZ4.5 (-2.7 vs. -0,5 PD), and this difference has reached the level of statistical significance (p = 0.035).

The results for mean phoria at near (fig. 1B) showed an insignificant difference between the ADDs (p = 0.320). This parameter was also independent of the group, which was confirmed by the non-significance of the main effect of the group (p = 0.272) and the ADD × group interaction (p = 0.995).

### Fusional vergence ranges

The mean values of the blur, break, and recovery for vergence ranges measured at a distance and near for all ADDs and in both CZ groups were presented in table 2.

Mean BI vergence ranges at distance were almost equal for all the study ADDs (p = 0.784). The values were not affected by the central zone diameter, which was indicated by the non-significant group × ADD interaction (p = 0.161). The mean BO vergence ranges at distance were partially affected by ADDs (p = 0.004). Namely, the vergence ranges for ADD4 were narrower than those for ADD0 and ADD2 (post-hoc: ADD0 vs. ADD4, p = 0.014 and ADD2 vs. ADD4, p = 0.002). Significant ADD × group × response interaction (p = 0.006) and further post-hoc tests showed that ADD4 caused a decline in the recovery value in the CZ3 group when ADD2 was compared with ADD4 (post-hoc: ADD2 vs. ADD4, p < 0.001) and the blur value in the CZ4.5 group (post-hoc: ADD2 vs. ADD4, p = 0.026).

The mean BI near vergence ranges depended on the ADD and group (p = 0.014). As table 2 shows, near vergence ranges in the CZ3 group with ADD2 took more negative values than ADD0 (p = 0.050) and when ADD2 was compared to ADD4 (p = 0.019). There was no significant difference between ADD0 and ADD4 in the CZ3 group (p = 0.998), and no significant differences between the ADDs were found in the CZ4.5 group (post-hoc: p > 0.999). A shift towards more negative values was observed for blur, break, and recovery results, which was confirmed by the insignificant response × ADD × group interaction (p = 0.481).

The mean BO vergence at near decreased with increased ADD powers (p = 0.022). However, a significant difference was found only between ADD0 and ADD4, which was confirmed by the post-hoc test (p = 0.020). This effect occurred for all the study responses (blur, break, recovery) and in both groups (CZ3 and CZ4.5), which was confirmed by the insignificant ADD × group interactions (p = 0.760) and ADD × group × response (p = 0.869).

### Vergence facility

Vergence facility results are presented in figure 2. The mean near vergence facility was 20.1 CPM for ADD0 and ADD2, and 21.8 CPM for ADD4. The difference was statistically insignificant (p = 0.197). Additionally, the interaction between the ADD power and group was not statistically significant (p = 0.980).

### Horizontal fixation disparity at near

Horizontal fixation disparity results at near are presented in figure 3. In the CZ3 group, the median value of fixation disparity was lower for ADD0 and ADD2 than for ADD4

FIGURE 1

A. Median phoria at distance in two groups (CZ3 and CZ4.5) for ADD0, ADD2, and ADD4. The error bars represent the 25% and 75% percentiles, and the whiskers represent the non-sticking range. B. Mean near phoria in two groups (CZ3 and CZ4.5) for ADD0, ADD2, and ADD4. The rectangles represent the standard error, and the whiskers represent the standard deviation.

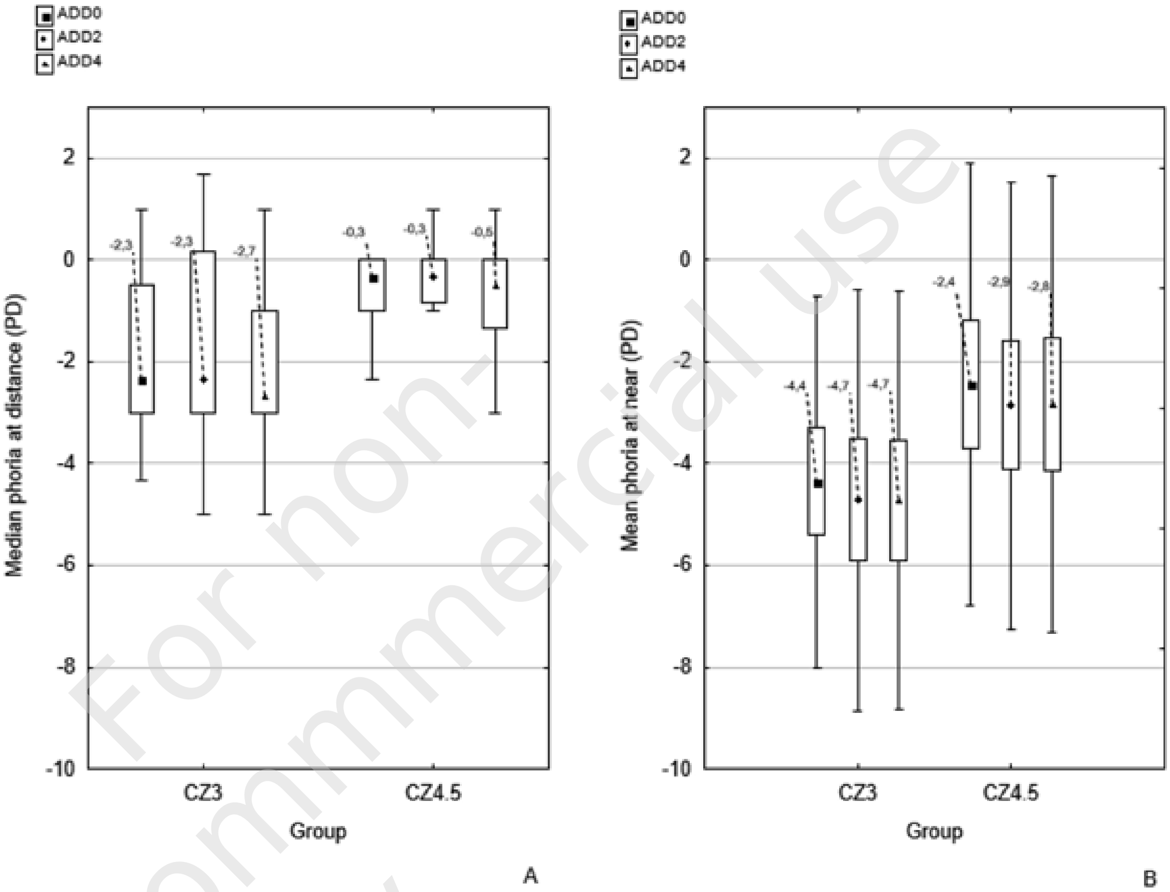





TABLE 2

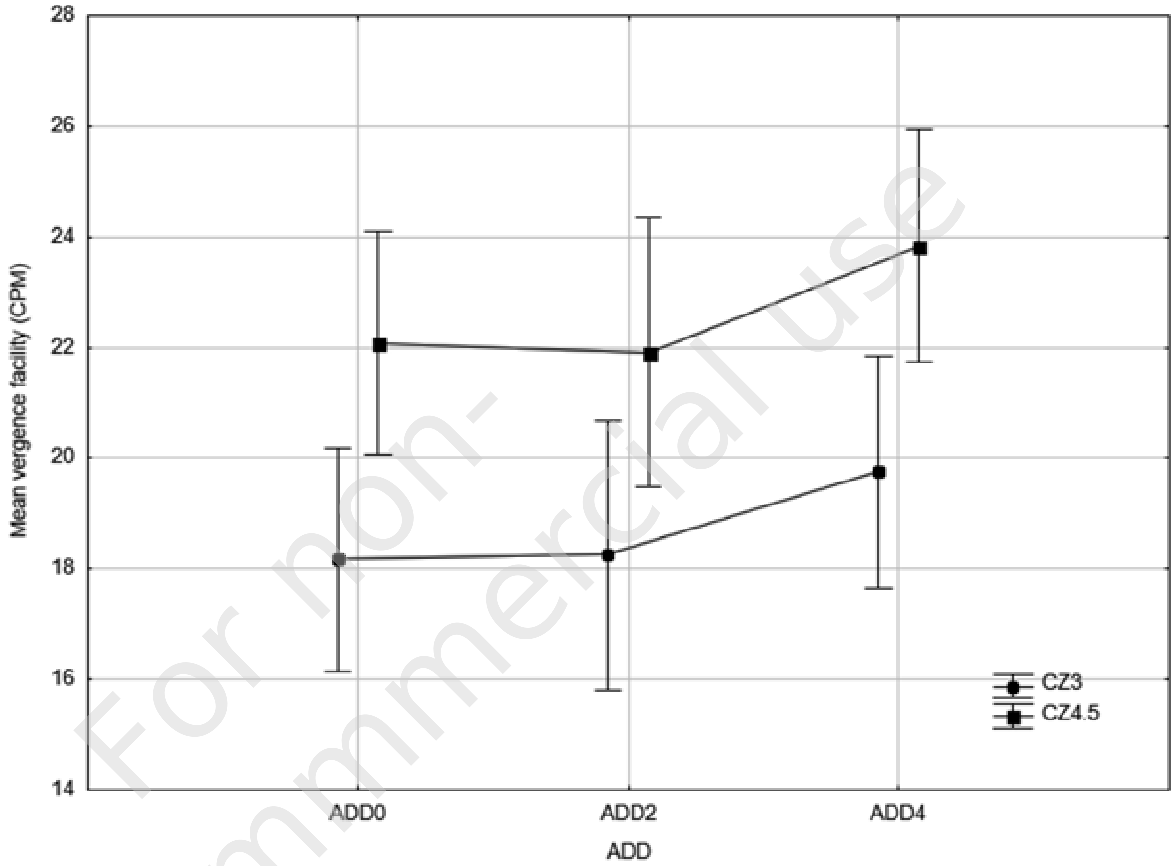
Mean values of blur, break, and recovery for the vergence ranges measured at 5 m and 0.4 m for ADD0, ADD2, and ADD4 in the CZ3 and CZ4.5 groups.

| Distance | Group, ADD | BI Blur (SE) [PD] | BI Break (SE) [PD] | BI Recovery (SE) [PD] | BO Blur (SE) [PD] | BO Break (SE) [PD] | BO Recovery (SE) [PD] |
|---|---|---|---|---|---|---|---|
| 5 m | CZ3, ADD0 | -11.9 (1.0) | -12.7 (1.4) | -5.8 (0.6) | 18.8 (2.5) | 24.6 (2.6) | 16.0 (3.1) |
| | CZ3, ADD2 | -8.2 (0.8) | -10.7 (1.1) | -5.7 (0.7) | 15.6 (2.4) | 26.9 (3.1) | 20.8 (3.9) |
| | CZ3, ADD4 | -10.1 (0.9) | -11.5 (1.0) | -6.0 (0.8) | 15.6 (1.8) | 21.7 (2.0) | 11.5 (1.9) |
| | CZ4.5, ADD0 | -10.8 (1.1) | -11.3 (1.0) | -5.7 (0.9) | 19.8 (2.4) | 24.8 (2.9) | 14.3 (3.1) |
| | CZ4.5, ADD2 | -11.3 (0.9) | -11.9 (0.8) | -6.5 (0.8) | 19.9 (2.3) | 25.3 (3.1) | 14.2 (3.0) |
| | CZ4.5, ADD4 | -10.5 (1.0) | -11.0 (0.9) | -6.3 (0.7) | 16.5 (2.0) | 19.4 (2.1) | 13.5 (3.5) |
| 0.4 m | CZ3, ADD0 | -16.5 (1.4) | -19.6 (1.5) | -11.8 (1.0) | 26.3 (2.2) | 30.0 (2.0) | 18.8 (3.4) |
| | CZ3, ADD2 | -19.0 (1.8) | -21.6 (1.6) | -15.2 (1.7) | 22.5 (3.2) | 27.8 (2.1) | 16.1 (3.0) |
| | CZ3, ADD4 | -16.5 (1.2) | -19.4 (1.5) | -11.0 (1.2) | 22.2 (2.6) | 26.2 (3.4) | 16.2 (3.7) |
| | CZ4.5, ADD0 | -17.3 (2.0) | -20.8 (1.7) | -11.4 (1.6) | 29.6 (2.9) | 30.7 (3.1) | 21.9 (3.5) |
| | CZ4.5, ADD2 | -16.7 (2.1) | -19.8 (1.7) | -11.7 (1.6) | 26.9 (3.1) | 29.5 (3.2) | 21.7 (3.8) |
| | CZ4.5, ADD4 | -18.0 (2.1) | -19.7 (1.6) | -12.3 (1.8) | 26.2 (2.6) | 29.1 (2.9) | 19.5 (4.0) |

BI – base-in prisms; BO – base-out prisms; SE – standard error; PD – prism diopters.

FIGURE 2

Mean vergence facility (CPM) for ADD0, ADD2, and ADD4 in both groups (CZ3 and CZ4.5). The rectangles represent the standard error, and the whiskers represent the standard deviation.






(-1.43 min of arc for ADD0 and ADD2, and -4.30 min of arc for ADD4) but the difference was statistically insignificant (p = 0.203). In the CZ4.5 group, the median value of this parameter was -1.4 min of arc for ADD0 and ADD4, and -2.1 min of arc for ADD2 (p = 0.678). No significant difference was found between the groups for any of the study ADDs (p > 0.050).

### Stereopsis at near

No significant median difference in the stereo acuity between the ADDs was found in the CZ3 group (p = 0.097) and CZ4.5 group (p = 0.254). Similarly, no significant difference was found between the CZ3 and CZ4.5 groups for ADD0, ADD2, and ADD4 (p > 0.05).

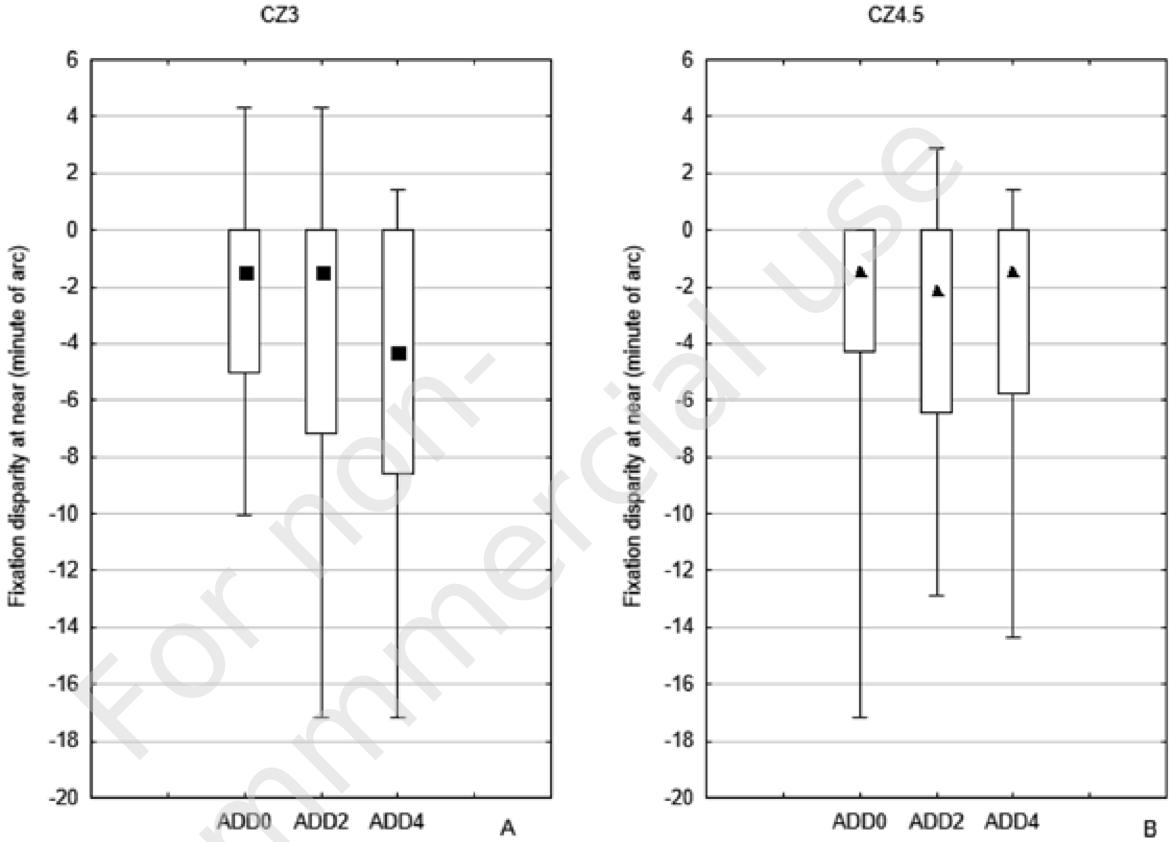
## DISCUSSION

The primary purpose of this study was to assess the effect of MFSCLs dedicated to myopia control with medium (ADD2) and high (ADD4) addition powers on binocular vision functions. The second aim was to compare the influence of different CZ diameters on visual skills. The number of MFSCL designs available on the market and prescribed by eye care practitioners to control myopia progression constantly increases. Numerous MFSCL designs allow the clinician to choose lens parameters, such as the addition power. The concept of inducing peripheral myopic defocus to slow down myopia progression [31] provides reasonable grounds to assume that MFCLs with high ADDs could induce a more substantial inhibitory effect than those with low ADDs. This assumption was confirmed by Walline et al. [15] in a study where lenses with +2.50 D ADD were compared against designs with +1.50 ADD. However, many practitioners are reluctant to prescribe high ADDs (above +3.00 D) because their influence on essential visual functions and binocular vision remains unknown. Therefore, we decided to investigate the effects of the most prescribed [21, 22] power of peripheral ADD (+2.00 D) and compare it with a high peripheral power (+4.00 D).

A previous study by this research team, [23], showed that MFSCLs with medium ADD decreased the distance VA, which was more significant in the CZ3 group than in the

FIGURE 3

A. Median fixation disparity at near (minutes of arc) for ADD0, ADD2, and ADD4 in the CZ3 group. B. Fixation disparity at near (minutes of arc) for ADD0, ADD2, and ADD4 in the CZ4.5 group. The error bars represent 25% and 75% percentiles, and the whiskers represent the non-sticking range.






CZ4.5 group. The authors have also observed an increased lag of accommodation in the case of lenses with ADD2 and ADD4 and decreased peripheral contrast sensitivity in the CZ3 group with ADD2 and ADD4. The present study focused on binocular and vergence skills in high-ADD lenses. The results showed that subjects wearing MFSCLs were slightly more exophoric at distance with CZ3 than CZ4.5. However, the difference was only 2 PD. This value, although statistically significant, did not seem clinically relevant. However, more substantial differences were observed in the vergence ranges measured at different distances. High addition power (ADD4) in both subject groups resulted in decreased BO ranges. For CZ4.5 with ADD4, the blur values diminished slightly compared to ADD2, while for CZ3, the fusion recovery values nearly doubled. These results show that introducing high additions may affect vergence abilities and make it more difficult to obtain a single clear image for individuals with high exophoric values. In previous studies, no significant influence of MFSCLs (+2.50 ADD, central zone size 2.3 mm) and MFSCLs (+1.50 and +3.00 ADD, central zone size 3.36 mm) [27, 32] or concentric design lenses (+2.00 ADD, central zone size 3.36 mm) [33] on distance lateral phoria was reported. However, the lenses used in the present study have a different design in which full ADD power is located closer to the central zone than in standard progressive contact lenses. The distorted image in the periphery of the lens might have influenced the change in phoria and the narrowing of the vergence ranges.

Surprisingly, no significant influence on near phoria was found for any ADDs or CZ applied in this study. Most previous studies had shown significant changes in near phoria when subjects were fitted with center-distance MFSCLs and other myopia control contact lens designs (concentric) compared to single-vision spherical lenses [27, 33, 34]. The difference in the amount of exophoric shift between the studies could be due to different lens designs, central zone sizes, phoria measurement methods, and protocols used by the researchers. Our study showed that near phoria remained intact in each of the study ADDs, but vergence ranges were significantly affected. ADD2 in the CZ3 group caused a slight shift in the BI ranges in the Exo direction but did not affect the ranges in the BO direction.

In contrast, ADD4 induced an overall decrease in all the components of the BO ranges in both groups. The decrease in near-vergence ranges might have been due to a reduced accommodative response in the study of MFSCLs reported in the authors' previous paper [23]. The influence of the tested lenses on vergence ranges was insignificant, as it did not exceed 3 PD. However, it might be relevant for an individual with substantial exophoria as it could cause the phoria to decompose and lead to problems during prolonged close work. Therefore, the patient's initial phoria should be considered before fitting high-addition lenses. Moreover, in the case of patients with significant exophoria, vergence ranges should also be measured to ensure that the applied correction will not cause asthenopia complaints. The shift of the near vergence ranges in the Exo direction might be important, as myopic children show a more divergent shift during sustained near activity than emmetropic children [35].

In addition to the standard phoria and vergence range measurements, the authors also performed additional tests using procedures that, due to their sensitivity, could detect even small changes in binocular vision. The researchers tested vergence ability in a vergence performance test with a prism flipper, and even minute changes in eye alignment were tested with a fixation disparity test. None of the tests showed any significant effect of the tested contact lenses on the subjects' binocular vision.

The lack of significant change in FD was in agreement with the results of previous studies concerning center distance MFSCLs with +1.50 and +3.00 ADD power [34] and concentric-design central distance contact lenses for myopia control [33].

The stereopsis remained unaffected by any of the tested lenses, and this result was also consistent with previous studies on center distance MFSCLs [32, 34] and concentric design contact lenses for myopia control [33]. Nevertheless, the authors know that near stereopsis may be slightly decreased by various centers near MFSCL designs [36, 37].

Subjective tests have shown that, despite some adverse effects of high-addition lenses on vergence ranges (narrowing of BO ranges) and shifting of ranges towards more Exo direction at near (mainly due to weakened accommodative responses, as shown in our earlier study [23], these lenses did not significantly affect the quality of binocular vision.

The presented study had some limitations, such as a short time of adaptation (1 h), and two groups of subjects for small (CZ3) and large (CZ4.5) MFSCL central zone sizes. Other studies performed on low and medium-addition MFSCLs show that longer (2 and 4 weeks) adaptation to contact lens wear might alter binocular vision parameters over time [29]. Therefore, it is essential to test the effect of adaptation in future studies and assess whether the vergence system adapts to high addition powers. Otherwise, care should be taken with exophoric patients when considering MFSCLs with high additions. Additionally, the results could be different when measured in a pediatric population with progressive myopia, as children (especially myopes) can present different binocular vision status [38] and altered responses to prescription [39]. With the increasing interest of practitioners in MFSCLs for myopia control, it seems necessary to further investigate the influence of lens design parameters such as ADD and CZ size on vision performance. Since the authors have shown that introducing additional power on the lens mid-periphery can affect binocular vision, especially near vergence ranges, it is important to consider patients' binocular vision status when fitting MFSCLs for myopia control.

## CONCLUSION

Based on the results discussed above, we have shown that MFSCL parameters, including the amount of ADD power and CZ size, only marginally influence binocular vision in the non-presbyopia adult population. A high ADD (+4.00) may increase exophoria at a distance with small central zone size designs (CZ3), as compared to large central zone size designs (CZ4.5) and reduce base-out vergence ranges. However, vergence facility, stereovision, and fixation disparity remained unaffected by low (ADD2) and high (ADD4) additions. MFSCLs with high ADDs and small central zones should be prescribed with caution to subjects with high exophoria, as the lens might evoke decompensation.

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Sylwia Kropacz-Sobkowiak: design and conduct of the experiment, contact lens fitting, statistical analysis, and preparation of the manuscript; Anna Przekoracka-Krawczyk: design and coordination of the study, statistical analysis, proofreading of the manuscript; Andrzej Michalski: conducting ophthalmological examinations of the participants of the experiment, proofreading the final version of the publication; Jan Olszewski: supervision of the project, proofreading of the manuscript; Klaudia Wasilewska: conducting part of the optometric examination of the participants of the experiment.

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The content presented in the article complies with the principles of the Helsinki Declaration, EU directives and harmonized requirements for biomedical journals.