



Original Article

Improving interpupillary distance accuracy in the plusoptix A12R: A distance-dependent correction

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ABSTRACT

Purpose: Handheld photorefractors are increasingly used in paediatric populations, where patient cooperation and examination time are often limited. Given this widespread use, it is essential to characterise potential sources of measurement error. This study aimed to investigate the dependence between interpupillary distance (IPD) measurements and measurement distance (MD) when using Plusoptix A12R.

Methods: Variability in interpupillary distance (IPD) measurements with the Plusoptix were observed during a paediatric vision screening programme ($n = 67$). A theoretical model predicting a linear IPD - MD relationship was developed, including a correction factor. The model was validated under controlled conditions ($n = 3$) using a bench testing. Then, a pilot study ($n = 8$) was carried out under habitual clinical conditions to assess the applicability of the correction factor. IPD measurements obtained with the Plusoptix before and after correction were compared with those obtained using a pupilometer. Agreement between methods was assessed using Bland–Altman analysis and Cohen's effect size.

Results: In 42% of children, IPD measurements were relatively stable ($SD \leq 1$ mm), whereas 9% showed fluctuations exceeding 4 mm. Bench testing data confirmed a strong linear dependence of IPD on MD (slope = 0.99), with larger IPD values obtained at shorter MDs. The pilot study showed that applying the proposed correction factor reduced IPD variability and improved agreement with pupilometer measurements.

Conclusions: IPD measurements obtained with the Plusoptix A12R are affected by MD, introducing a systematic and predictable error. The application of a correction factor effectively compensates for this effect improving its clinical reliability.

Introduction

Vision screening based on handheld devices are widely used in paediatric populations due their speed, objectivity and minimal requirement for patient cooperation.^{1–4} Among these instruments, photoscreeners such as the Plusoptix A12R have become increasingly popular in children clinical practice and large-scale screening programmes, where time plays a critical role.^{3,5–8}

The Plusoptix A12R is a handheld photorefractor designed to obtain non-invasive measurements under natural viewing conditions. This device allows obtaining refractive error, sight asymmetry, pupil size and interpupillary distance (IPD) values in just a few seconds. Numerous studies have validated the Plusoptix for refractive assessment, reporting a high level of precision determining ocular refraction compared to retinoscopy, cycloplegia, and other highly effective techniques.^{3,8–10} However, parameters obtained from facial images like IPD remain underexplored. IPD deserves particular attention due to its optical, functional and anatomical relevance. It represents the distance between the

centres of the pupils, and it can be measured using different techniques including manual rulers, pupilometers, autorefractors and even mobile phone applications.^{11–13}

Accurate IPD measurements are essential for the correct centration of ophthalmic lenses.¹⁴ When IPD measurement is incorrectly measured or applied, lens decentration occurs, leading to the induction of unwanted prismatic effects.¹⁵ According to Prentice's rule ($P^A = x \cdot F$), the magnitude of the induced prism is directly proportional to both, the amount of decentration and the power of the lens. Consequently, even small errors in IPD may result in clinically relevant prism, particularly in prescriptions with moderate to high refractive power.¹⁵ This issue is especially critical in paediatric patients, who may be less able to compensate for induced prism and may experience visual discomfort, asthenopia, reduced visual acuity or compromise binocular vision.^{15,16} For example, a 3 mm IPD error in a child with $a + 5.00$ D prescription induces unwanted 1.5 prism dioptres.

Beyond its importance in spectacle dispensing, IPD is also important to binocular vision and ocular alignment.¹⁷ Accurate IPD measurement

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contribute to the correct interpretation of binocular function and stereopsis, which are essential for visual development during childhood. Even more, IPD may serve as an early indicator of certain genetic syndromes, such as those associated with craniofacial abnormalities, in which IPD values are abnormally small or large.¹⁸

In general, IPD values obtained using automated instruments are usually assumed to be a stable parameter, independently of testing conditions and therefore suitable for direct clinical use. The Plusoptix A12R is calibrated to take measurements at a nominal working distance of 100 cm (± 5 cm); however, valid readings can still be acquired over a large range of distances. In clinical use, the examiner and patient move naturally, so the actual measurement distance (MD) often varies. Despite the widespread clinical use of handheld photorefractors, the potential influence of MD on geometrically derived parameters such as IPD has not been systematically evaluated. Although previous studies have focused mainly on refractive accuracy and repeatability, the possibility of a systematic bias associated with deviations from the nominal working distance remains largely unquantified. Given that these devices rely on image scaling principles, variations in MD may introduce proportional errors in IPD estimation. The absence of a defined correction model for this effect represents a relevant gap in the literature and justifies further investigation. It was within this clinical framework that the present study originated.

During a routine visual screening programme conducted prior to this investigation, inconsistencies were observed in the IPD values obtained with the Plusoptix A12R. These observations led to the hypothesis that the variability in IPD measurements obtained with the Plusoptix A12R was not random but instead related to the MD at which the device is used. The aim of this study was to investigate this dependence both, theoretically and experimentally, and to derive a correction factor that allows IPD values to be adjusted when measurements are performed at different working distances. To address this objective, the study was designed as a sequence of complementary stages, which are described in detail in the following section.

Material and methods

The study combined clinical data obtained from a paediatric population with theoretical modelling and experimental validation. Specifically, the methodology comprised four consecutive stages: (1) analysis of IPD measurements obtained during a paediatric vision screening programme; (2) theoretical modelling of the relationship between IPD and MD; (3) experimental validation of this relationship under controlled conditions; and (4) a pilot study evaluating the proposed correction factor. Each stage was designed to build upon the results of the previous one.

Paediatric participants

Data for the first stage of the study was obtained during a paediatric vision screening programme conducted prior to the present investigation. Children participating in the screening were recruited from different schools in Spain, and measurements were collected in accordance with the manufacturer's recommendations for use of the Plusoptix A12R. IPD was measured in 67 children aged 10 years old (52% females). Subjects were instructed to look at the nose of the smiling face of the Plusoptix (fixation target), while the photorefractor was handheld by the examiner in front of the child's face. The device was gradually moved until the lateral bars turn into green, indicating an acceptable measurement position. For each subject, three consecutive measurements were obtained using the automatic mode of the device, and the mean of the three measurements was calculated. Measurements were performed under standard room illumination without head stabilization, replicating typical clinical conditions. All examinations were performed by the same experimenter/examiner to minimize inter-examiner variability. The data collected in this stage were used to describe the

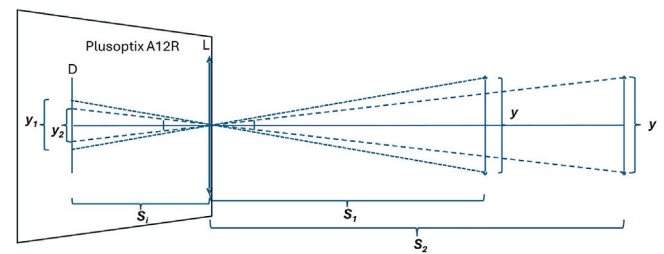


Fig. 1. Schematic illustration of similar triangle geometry showing how changes in measurement distance alters image scale and lead to systematic over-estimation or under-estimation of IPD value.

fluctuations of IPD measurement under routine screening conditions and to explore their relationship with MD.

Theoretical IPD–MD relationship and a correction factor proposal

The Plusoptix A12R calculates IPD values from the analysis of the relative positions of the pupils in the facial image captured by the device. As the optical configuration of the instrument is fixed, changes in the distance between the instrument and the subject directly affect the size of the facial image. When the MD changes, the scale of the facial image changes accordingly. Consequently, if the device assumes a fixed or nominal MD, any deviation from this distance leads to a systematic error in the estimated IPD. This means that measurements obtained at shorter distances result in larger facial images and higher IPD values, whereas measurements obtained at longer distances result in smaller facial images and lower IPD values. This effect can be explained using simple geometric relationship illustrated in Fig. 1.

Based on this relationship, a **correction factor** can be defined to compensate for deviations from the nominal MD. Corrected IPD values can be obtained using the following equation, where MD represents the actual measurement distance:

$$IPD_{corrected} = IPD_{Plusoptix} \times (MD/100cm)$$

The mathematical derivation of this geometric relationship, including the formulation based on similar triangles and the theoretical development of the correction factor, is detailed in Appendix 1.

Experimental validation of the theoretical model (Bench testing)

The technical validation was designed to assess the effect of MD on IPD values obtained with the Plusoptix A12R under controlled conditions. The experimental setup consisted of an optical bench, in which the Plusoptix A12R was mounted on a fixed platform joined to a movable rail system positioned in front of the subject (Fig. 2). This setup allowed the examiner to control the movement of the device to systematically vary the MD, without changing orientation or inducing lateral displacement.

Three young adults were recruited from the staff of the University of Santiago de Compostela (mean age: 26.67 ± 1.15 ; 33.3% female). Subjects were sat resting their head on a headrest and were instructed to fixate on the internal fixation target of the device (nose of the smiling face). Five measurements were performed at 5 different MD (100, 103, 106, 109 and 112 cm) using the automatic mode of the Plusoptix A12R.

Fig. 2A) illustrates the experimental setup, and Fig. 2B) presents an image of the Plusoptix A12R screen showing the face of the subject, the detected pupils, the horizontal line that joins both pupils, and the green vertical bars at both sides of the screen indicating that the device is going to take the measurement automatically. This setup minimized potential confounding factors and enabled a direct evaluation of the relationship between MD and IPD values, providing an experimental validation of the theoretical model.

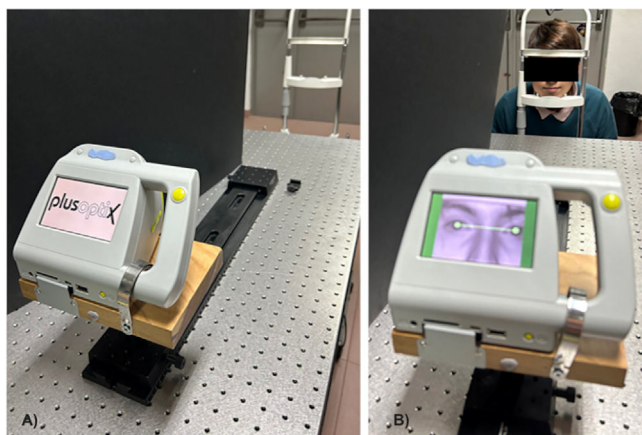


Fig. 2. Experimental setup of the optical bench validation.

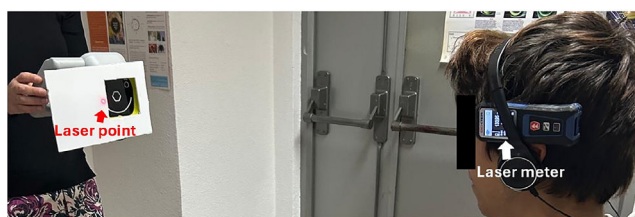


Fig. 3. Experimental setup for pilot validation study. Picture shows screen placement around the Plusoptix and laser meter.

Correction factor and pilot validation study

Based on the theoretical model and the results of the experimental validation, a **correction factor** was developed to compensate for the effect of MD on IPD values obtained with the Plusoptix A12R. A pilot study was conducted to evaluate the applicability of this correction factor under habitual Plusoptix use conditions. A group of eight young adults (mean age: 25.50 ± 3.07 ; 65.5% female) was recruited from the university of Santiago de Compostela. Three consecutive IPD measurements were recorded per subject with the Plusoptix device. In order of being able to apply the correction factor, the actual MD at the moment of each measurement acquisition was recorded using a laser distance meter mounted on the subjects' head with a head band as represented in Fig. 3. During the measurements, a screen was positioned around the Plusoptix device, and it was verified that the laser beam was directed onto the screen, near the nose of the smiling face (fixation target) of the device. Corrected IPD values were then calculated and compared with measurements obtained using a pupillometer (HX-400), which is considered the reference method for IPD assessment.¹¹¹³

Ethics

This work includes data from two research projects. It was conducted in accordance with the tenets of the Declaration of Helsinki, after having obtained both approvals from the research ethics committee of the University of Santiago de Compostela (Spain) (USC 31/2022; USC 19/2024). Participants in both studies were required to present refractive errors within the measurement range of the Plusoptix device (-7.00 to $+5.00$ D). Exclusion criteria in both studies included any active ocular infection (e.g., conjunctivitis), any mental disability (e.g., autism spectrum disorder) and/or any ocular condition that may alter the ocular alignment (e.g., strabismus). Prior data collection, written informed consent was obtained from all adult participants, and parental/carer consent was obtained for all child participants.

Statistical and mathematical analysis

Data analysis was performed using Microsoft Excel and MATLAB (MathWorks, Natick, MA, USA). The statistical analysis was carried out in two main stages: validation of the theoretical relationship between IPD and MD, and to assess the applicability of the proposed correction factor.

According to the theoretical model (see appendix 1), it is expected to obtain a linear relation between the IPD and MD, so the results should be adjusted to a line. To make the linear adjust and being able of comparing the IPD values of the different subjects, the IPD and the MD were normalised. The normalised IPD was defined as $IPD_N = IPD_1/IPD_j$, where IPD_1 represents the IPD value provided by the Plusoptix A12R at 100 cm, and IPD_j corresponds to values IPD obtained at different MDs. The normalised MD was defined as $MD_N = MD_j/MD_1$, being MD_1 100 cm and MD_j the MD at which the measurement takes place. The mean values and standard deviations of the IPD_N at each MD for each subject were calculated. Then IPD_N vs MD_N was represented for each subject, and R^2 and regression coefficient (RC) were calculated. R^2 is a statistical measure that indicates how well a linear regression model fits the observed data. $R^2 = 1$ corresponds to a perfect fit, meaning that all the points lie exactly on the regression line. The RC characterises the strength of the linear relationship between an independent variable (MD) and a dependent variable (IPD) within a regression model. This approach allowed identification of systematic changes in IPD associated with variations in MD, independently of any individual subjects' characteristics.

For the pilot study, the agreement between corrected IPD values obtained with the Plusoptix A12R and those obtained using a pupillometer was evaluated. Data normality was assessed using the Shapiro–Wilk test, and non-parametric statistical methods were applied when normality assumptions were not followed. Differences between pupillometer measurements, uncorrected Plusoptix measurements, and corrected Plusoptix measurements were evaluated using the Friedman test, followed by Bonferroni-adjusted pairwise comparisons when appropriate. Agreement and clinical interchangeability between methods were further assessed using Bland–Altman analysis, including calculation of mean bias and 95% limits of agreement. All statistical tests were two-tailed, and p-values <0.05 were considered statistically significant.

Results

IPD measurements with the Plusoptix in a paediatric population

The mean IPD measured in the paediatric population using the Plusoptix A12R was 64.01 ± 3.73 mm. Analysis of intra-subject variability revealed a lack of measurement stability across the cohort. As shown in Fig. 4, which presents the mean IPD and standard deviation (SD) for each individual participant, the degree of variability differed substantially among subjects. In 42% of subjects ($n = 28$), IPD measurements were relatively stable, with a SD below 1 mm. However, 49% of children showed a SD between 1 and 4 mm, and 9% exhibited a SD greater than 4 mm.

The presence of high SD values in a considerable proportion of subjects, as illustrated in the individual distribution plot (Fig. 4), indicates that IPD measurements obtained with the device are highly sensitive to external measurement conditions.

Experimental validation of the theoretical model (Bench testing)

Bench testing results showed that the IPD values decreased as MD increased. Table 1 shows the average of the five IPD measurements obtained at different MDs in each subject.

The theoretical model predicted a linear relationship between normalised IPD (IPD_N) and normalised MD (MD_N), with an expected slope of 1. As shown in Fig. 5, the experimental data from the three subjects

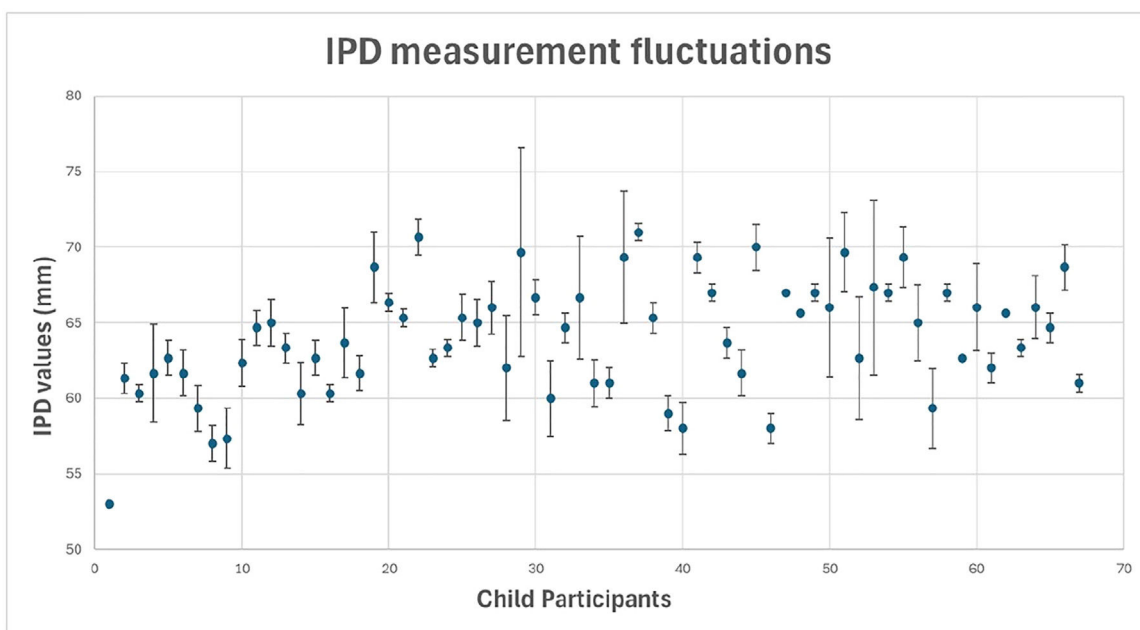


Fig. 4. Mean ± SD of the IPD values obtained with the Plusoptix in the paediatric cohort.

Table 1

Average of IPD values (mean ± sd) at the different MD.

Subject	IPD (mm)				
	100 cm	103 cm	106 cm	109 cm	112 cm
S1	67.00±0.00	65.00±0.00	63.40±0.54	61.80±0.45	60.00±0.00
S2	62.00±0.00	61.00±0.00	59.00±0.00	57.80±0.45	56.00±0.00
S3	67.00±0.00	65.00±0.55	65.00±0.00	62.00±0.00	60.80±0.45

IPD: Interpupillary distance; MD: measurement distance.

followed this linear trend. Linear regression analysis revealed similar slopes for all participants, with values close to the theoretical expectation value of 1. This result indicates excellent agreement between the experimental measurements and the theoretical model.

Pilot study and correction factor use

To evaluate the clinical performance of the proposed correction factor, IPD measurements obtained with the Plusoptix A12R were compared with those obtained using a pupillometer. Three methods were used to obtain the mean IPD and SD: a pupillometer (M1), the Plusoptix A12R measurements (M2), and the Plusoptix A12R after applying the correction factor based on the MD recorded by a laser distance meter (M3). The results are illustrated in Fig. 6.

Fig. 6 presents the distribution of IPD measurements obtained with the three mentioned methods. A clear difference is observed between M1 and M2, whereas a close similarity is observed between M1 and M3.

M1 showed a mean IPD of 62.01 ± 3.01 mm (IQR = 5.00). M2 showed higher values and greater variability, with a mean of 67.04 ± 4.87 mm (IQR = 8.50). After application of the correction factor, the Plusoptix measurements from M3 were comparable to those obtained in M1, with a mean value of 61.99 ± 3.11 mm (IQR = 5.46). The mean difference between M1 and M2 was -5.03 mm, indicating systematic overestimation by the Plusoptix device. After correction, the mean difference between M1 and M3 was very low (0.02 mm).

The Friedman test revealed significant differences among the three measurement methods ($\chi^2 = 9.25, p = 0.001$). Post-hoc comparisons with Bonferroni correction showed that M2 differed significantly from M1 ($p = 0.018$), whereas no significant differences were found between

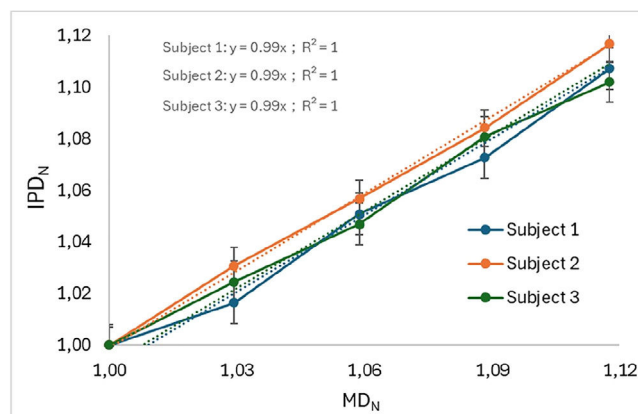


Fig. 5. Linear adjust showing the variation on the IPD value when the MD changes. Dotted lines are the corresponding trend lines for each subject.

M3 and M1 ($p = 1.000$), with a median difference of -0.11 mm. The magnitude of the improvement provided by the correction factor was confirmed by calculating Cohen’s *d* for paired samples. M2 presented a very large error effect ($d = -1.978$), whereas M3 showed a negligible effect size ($d = 0.031$), confirming the effective elimination of systematic bias.

Bland–Altman analysis confirmed the improvement in agreement between methods after correction. The original mean bias of +5.03 mm was reduced to -0.02 mm, and the SD of the differences decreased from 2.72 mm to 0.65 mm. Consequently, the 95% limits of agreement narrowed from a range of 10.6 mm to a much smaller interval of -1.29 to +1.26 mm, demonstrating a substantial improvement in both accuracy and precision.

Discussion

Interpupillary distance (IPD) can be measured using a variety of techniques specifically designed for this purpose, such as pupillometers and manual pupillary distance rulers. Although these methods do not rely on image scale or working distance assumptions and are therefore not affected by distance-dependent errors, they still exhibit a certain degree of

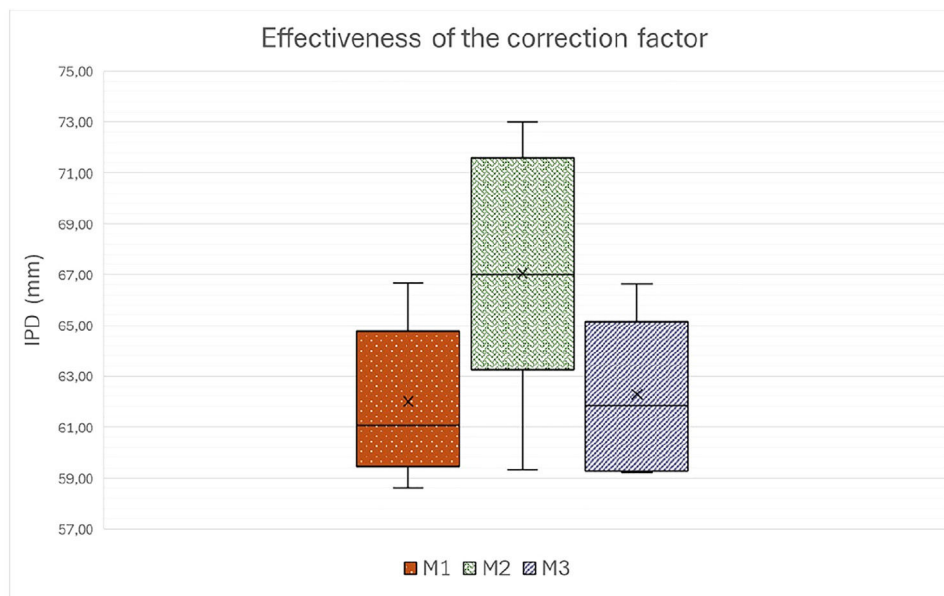


Fig. 6. Distribution of IPD measurements with the three methods using box plots. M1: Pupillometer, M2: Plusoptix, M3: Plusoptix-corrected.

measurement variability. For instance, Walsh et al.¹² reported high variability and low consistency using Viktorin's method (a specific ruler-based method), with a standard deviation of ± 1.54 mm. Similarly, Gantz et al.¹¹ found even greater variability with the traditional manual ruler method (± 3.0 to ± 3.4 mm), mainly due to human error and parallax effects. More recently, Jung and Chu¹³ reported lower variability for manual ruler measurements (± 0.74 mm) compared with earlier studies; however, this variability remained higher than that obtained with digital pupillometers and was largely attributed to human factors. Both Gantz et al.¹¹ and Jung and Chu et al.¹³ compared manual methods with pupillometer and concluded that pupillometers provide more reliable and accurate IPD measurements. However, pupillometers require professional handling and direct contact with the patient's face, which may limit their applicability in certain paediatric settings. In this regard, the use of handheld photorefractive to assess IPD values is a valuable technique to use with paediatric populations and people with limited collaboration.

In the present study, IPD values obtained with the Plusoptix A12R in the paediatric cohort were higher than expected when compared with previously published epidemiological data, with a mean IPD of 64.01 ± 3.73 mm. This value exceeds those reported for children of similar age. For instance, MacLachlan et al.¹⁹ reported mean IPD values of 55.84 ± 3.20 mm in females and 56.54 ± 2.56 mm in males aged 10 years, measured using a manual ruler. Likewise, Emeka et al.²⁰ reported mean IPD values of 59.66 ± 2.24 mm in males and 58.05 ± 3.33 mm in females, also obtained using manual methods. The discrepancies with the present work cannot be attributed to examiner-related error, as the Plusoptix device was used in automatic mode. Additionally, Singman et al.²¹ reported mean IPD values of 55.6 ± 3.4 mm in children aged 9–11 years using a Plusoptix A09 device. A possible explanation for the differences between their findings and those of the present study may lie in differences in measurement acquisition procedures. In our study, measurements were obtained following the manufacturer's recommendations, so the examiner was close to the patient and gradually moved backward until a valid measurement was obtained. If Singman et al.²¹ employed an alternative approach, such as starting at a greater distance and moving the device closer, this could have resulted in systematically larger measurement distances and, consequently, smaller IPD values. Notably, despite their mean IPD values being consistent with previous literature, Singman et al.²¹ concluded that the Plusoptix device was not suitable for IPD assessment due to measurement variability.

The present study demonstrates that the variability observed in IPD values obtained with the Plusoptix A12R is not random and cannot be attributed to true anatomical variation. Instead, MD was identified as a key source of systematic variability. As the Plusoptix is a handheld device based on the principle of eccentric photorefractive,²² small variations in MD during acquisition result in predictable changes in image scale, leading to systematic errors in IPD estimation.

To our knowledge, no previous studies have investigated the effect of MD on IPD measurements obtained with Plusoptix devices or other handheld photorefractors. It therefore remains unclear whether the distance-dependent effect observed in this study is specific to the Plusoptix A12R or represents a more general limitation of handheld photorefractive devices. Future studies should include comparative assessments across different devices to evaluate the generalisability of these findings. In this regard, Williamson et al. reported statistically significant yet clinically acceptable differences in IPD measurements obtained with the Welch Allyn VS100 compared with conventional methods.²³ The Welch Allyn VS100 is a handheld photorefractor based on eccentric infrared photorefractive and operates at working distances comparable to those of the Plusoptix. Therefore, minor discrepancies between studies may reflect device-specific characteristics (e.g., measurement range) rather than fundamental methodological differences.

The present study proposes a correction factor that can be applied when the actual MD during acquisition is known. Future work should explore automatic monitoring of MD or the implementation of software-based correction algorithms, including the use of reference objects, to further improve the accuracy of IPD measurements obtained with Plusoptix A12R device. The use of reference objects is implemented by some mobile applications designed to estimate IPD values, which rely on facial image analysis and are therefore affected by the distance at which the photo is taken. To compensate for this distance-related effect, a reference object of known dimensions, such as a standard credit card, is used to convert pixel measurements into real millimetres.¹³

As mentioned, all IPD measurement techniques present some degree of variability, manual ruler-based methods are sensitive to examiner-related error, whereas digital pupillometry offers a more robust and reproducible alternative. However, in infants, uncooperative children, or patients with disabilities, the use of this technique is limited by the need for direct contact, for whom handheld photorefractors offer a useful alternative. In this context, application of the proposed correction factor effectively eliminates the distance-dependent error. After

correction, IPD measurements obtained with the Plusoptix were statistically indistinguishable from those obtained with the reference method. This resulting measurement precision supports the practical applicability of the correction factor in routine clinical and screening settings.

Conclusions

This study demonstrates that IPD measurements obtained with the Plusoptix A12R are systematically affected by the MD at which this device is used. The application of a developed correction factor effectively compensates for this error with results comparable to those obtained with a pupillometer, improving the usefulness of the Plusoptix for IPD assessment in clinical practice.

Declaration of generative AI in scientific writing

During the preparation of this work the authors used ChatGPT GPT-5.2 in order to improve the writing. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Ethics approval

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of University of Santiago de Compostela (Spain) (USC 31/2022; USC 19/2024).

Declaration of competing interest

The authors have no relevant financial or non-financial interests to disclose.

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Supplementary materials

Supplementary material associated with this article can be found in the online version at [doi:10.1016/j.optom.2026.100613](https://doi.org/10.1016/j.optom.2026.100613).

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