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Near working distances adopted by university students while viewing printed materials

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Background: With the increased near visual requirements among university students needed for studying and reading, both on printed material and with digital devices being used for these activities now more than pre-coronavirus disease 2019 (COVID-19), the near working distance (NWD) may have shifted from the standard NWD of 40 cm.

Aim: This study aimed to investigate the working distance adopted by university students while viewing printed material at near.

Setting: The study took place within a South African university. The sample consisted of 455 students, predominantly female (63.7%) of African descent (90.8%). The age range was from 17 years to 33 years with the mean age and standard deviation (s.d.) of 20.93 ± 2.06 years.

Methods: While reading a 40 cm near chart in the seated position, in a room with a standardised chart luminance of 500 lux, three consecutive measurements of habitual near distance were measured.

Results: For the whole sample, the mean NWD was 39.99 cm ± 9.41 cm, with a maximum and minimum of 64 cm and 16.17 cm, respectively, and a range of 47.83 cm. Females presented with larger mean NWD (40.19 cm ± 9.74 cm). Although white people were the smallest sample, they also had the smallest mean NWD (N = 9; 31.37 cm ± 7.91 cm). Finally, mixed-race people presented with the greatest variation in results (s.d. = 11.48 cm), whereas Indian Asian people had the smallest variation in NWD measurements (s.d. = 5.81 cm).

Conclusion: University students have a mean NWD close to the standard clinical testing distance of 40 cm used for near testing, with 0.01 cm difference.

Contribution: This study has established the NWD for university students compared to the standard of 40 cm that is used in the examination of patients in clinical practice. There are limited studies that have analysed the NWD in a South African university setting.

Keywords: near working distance; age; height; refractive error; race; gender; accommodative lag; lighting and contrast; posture.

Introduction

The near working distance (NWD) is an important parameter in determining the optimal distance at which individuals can comfortably perform near vision tasks without experiencing eyestrain or discomfort. Normative values for NWD provide valuable information for the design of visual aids, computer screens, and virtual reality displays.[1,2,3] A value of 40 cm is commonly used as a standard NWD in fields such as optometry and ophthalmology.[4] Most clinical procedures at near are performed at 33 cm or 40 cm, but sometimes at other distances. Most individuals hold their reading material at a distance smaller or larger than 40 cm.[5,6,7] It is also important to notice that NWD can vary between individuals and can be affected by several factors, including age, refractive error, hard and soft copy, accommodation and convergence, posture, height, ergonomics, among others.[8,9,10]

The Harmon distance, commonly referred to as the 'elbow distance' described by Harmon,[6] is one commonly referenced measurement, which is defined as the distance between the eyes and the task at hand when a person is comfortably focusing on a near object. Using the Harmon distance helps the visual system to function optimally by reducing an over-exertion on the accommodative, vergence and oculomotor systems, thereby improving performance, and decreasing stressors causing eye strain and fatigue.[5,6,7] Previous research suggests that taller individuals tend to have longer NWD than shorter individuals.[11,12] This can be attributed to the differences in anatomical dimensions and visual ergonomics between individuals of different heights. Posture also plays a vital role in determining NWD. Research has also shown that individuals with an upright posture tend to have shorter NWD compared to those with reclined posture.[8,9,10] A study on NWD among emmetropic Chinese children concluded that Harmon distance played a key role with handheld material.[13]

Age is one of the common factors in determining NWD. As people age, the crystalline lens loses its flexibility or elasticity making it more difficult to focus on near objects resulting in presbyopia.[14] These individuals often require accommodative assistance lenses for near targets because of reduction in amplitude of accommodation with age. Wolffsohn et al.[15] studied 237 subjects (16–39 years) and showed an average viewing distance of 35.0 cm ± 6.4 cm (95% CI: 33.9 cm – 36.1 cm) in the non-presbyopic group, and 39.0 cm ± 6.1 cm (95% CI: 37.8 cm – 40.2 cm) in the presbyopic group. A cross-sectional study by Boccardo[11] was also conducted to measure habitual NWD using smartphones in individuals of different age groups and identified factors influencing the near viewing distance. The mean and standard deviation (s.d.) for NWD was 36.1 cm ± 7.2 cm while sitting and 37.4 cm ± 6.8 cm while standing. In presbyopes, the average viewing distance was found to be 39.0 cm ± 6.1 cm, and 35.0 cm ± 6.4 cm in non-presbyopes. They concluded that the standard NWD of 40 cm matched in presbyopes with non-presbyopes having greater accommodative demand than presbyopes. They also found that the average viewing distance for females was shorter (34.7 cm ± 6.2 cm) than the average viewing distance found in males (38.2 cm ± 6.3 cm, $P < 0.001$).

Reading from electronic devices versus printed material has increased drastically specifically during the coronavirus disease 2019 (COVID-19) outbreak and with the Fourth Industrial Revolution (4IR) developments. These two types of reading materials play a key role in contrast sensitivity. Contrast sensitivity is the ability to distinguish between differences in lighting of an object and its background.[16] Contrast sensitivity plays a role in our visual perception, particularly in tasks performed at NWDs. Electronic devices are known to emit light to display information, thus resulting in so called self-luminance. This can affect contrast sensitivity because of factors such as pixel density, screen resolution and display settings. The lower the resolution, the lower the quality of displayed information and the poorer the contrast sensitivity. On the other hand, printed material relies on external illumination. The reading material itself can have a significant impact in NWD. Well-designed materials with clear fonts and appropriate spacing enhance readability. Therefore, maintaining a good posture, ensuring appropriate ergonomics, and using well-designed reading materials are important in limiting potential negative impacts of NWD.[1]

The appropriate functioning of accommodation is vital for near tasks, like reading, writing, or working on a computer.[17] Accommodative dysfunctions can lead to visual discomfort, reduced performance, and difficulties with tasks particularly at NWDs. Convergence is the inward movement of the eyes to maintain single binocular vision and keep images on corresponding points of retinas. By decreasing the NWD, increasing minus power, and decreasing target size, the accommodative demand increases.[18] Similarly, increasing separation between two targets and increasing working distance increase convergence demand. The impact of convergence and accommodative demand upon NWD can vary among individuals; however, prolonged and excessive demand can lead to eyestrain, fatigue, and symptoms of computer vision syndrome.[18,19,20]

Wang et al.[21] studied reading behaviour among emmetropic school children from grades 2–5 and factors influencing their reading. They suggested that better ergonomics and text design may decrease asthenopia, binocular abnormalities and even help children to read better. Conversely, if the accommodative or convergence demand is reduced, such as when focusing on objects at a larger distance or taking frequent breaks from near work, the NWD may increase. This means that individuals may be able to view objects up close at a slightly greater distance without experiencing discomfort or blurred vision.

Refractive error can have a significant impact on NWD. Myopes have difficulties viewing far objects but can see near targets clearly; however, they may still experience blurry vision, headaches and eyestrain when focusing on close tasks. Dutheil et al.,[22] in their meta analyses assessed the effect of near work on myopia and concluded that too much exposure to near work for adults could be associated with myopia, thereby shortening the NWD. Hyperopes, on the other hand, may struggle to see clearly at both near and far distance and may need to compensate by holding targets further to maintain focus. In 835 children aged 6–14 years old from the CLEERE (Collaborative Longitudinal Evaluation of Ethnicity and Refractive Error) study, Jones-Jordan et al.[23] found that the number of hours per week at each near work activity, such as reading for pleasure, studying, computer or TV were not significantly associated with annual myopia progression. Scheiman et al.[24] also reported on 469 children aged 6–11 years from the COMET (Correction of Myopia Evaluation Trial) study and demonstrated that for each additional hour spent on near work activities per week at baseline, the odds of having stable myopia by age 15 decreased by 2% ($P = 0.07$).

This study was conducted among a university student population aged between 17 years and 33 years, and the NWD measurements were taken subjectively and manually. By looking into relevant studies,[1,2,11,12,13,15,21,25,26,27,28] this research aims to investigate the working distance adopted by university students when viewing printed material at near.

Research methods and design

The study used a prospective observational quantitative design and took place in library settings across four campuses at a South African university.

The sample consisted of 455 students. Participants were mostly female (63.7%) and black (90.8%) participants'. The age range was from 17 years to 33 years with a mean of 20.93 ± 2.06 years. Participants were chosen via convenience sampling. Testing of all participants commenced with administration of a simple biographical, general health and ocular history questionnaire. Thereafter, all participants underwent a simplified optometric screening conducted by the researchers, by means of visual acuity and ophthalmoscopy. Inclusion criteria were any gender, race and participants with normal vision compensated (by spectacles or contact lenses) to 6/6 or better in both eyes. Any individuals with less than 6/6 Visual Acuity (VA) (compensated or uncompensated in both eyes) were excluded from the study. Presbyopes > 40 years were also excluded.

Each participant was given a Zeiss reading chart, which is a reading card designed using continuous words in a line, for use at 40 cm. Each participant was requested to put the chart at their near comfortable working distance where the reading material was seen clearly, and read from 32 pt line to 6 pt line, but they were also allowed to stop when the letters were blurry. Participants were also stopped at a point where no more words on a particular line of acuity were identified correctly, or when participants changed their NWD any time before the 6pt line, as this would no longer represent a habitual behaviour but rather a task-specific adaptation, introducing variability. Three consecutive measurements of the reading distance were taken from the spectacle plane for those who were wearing spectacles and from the nose bridge for those who were not wearing spectacles. These measurements were taken while the participant was reading the Zeiss reading chart. Participants were given a 5-min break between measures and asked to look in the distance to relax accommodation and prevent fatigue. The NWD of each participant was measured by a standing student researcher with a retractable measuring tape (1 cm – 150 cm) while the participant was sitting on a chair, behind a desk. To standardise posture as best as possible, participants were requested to sit upright, and the same chair and desk were used by all participants. To control for lighting, the data were collected during the day and under photopic conditions. Additionally, prior to testing, a spot light metre (illuminance metre) was used to measure the amount of light reflecting off the reading chart, and measurements of 500 lux as per the recommended test conditions for the measurement of VA were accepted.[29] Finally, to ensure reliability of measurements, the same student researcher performed all measurements using the same retractable measuring tape (1 cm – 150 cm), and the average of three consecutive measurements was used for analysis.

Statistical analysis

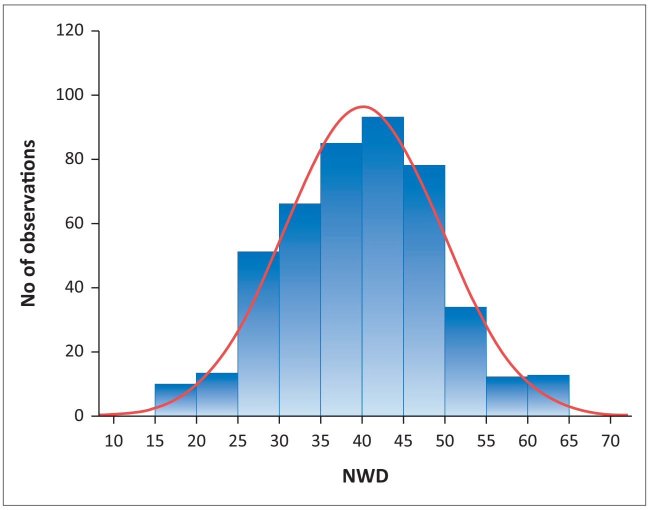
Once the data were obtained, the average of the three consecutive measurements per participant were analysed using the STATISTICA software program. Results were displayed graphically and quantitatively and were analysed using univariate statistics by means of normality histograms, box-and-whisker plots. Descriptive statistics such as medians, modes, means, frequencies, minimum and maximum values, measured variation such as s.d. and interquartile ranges (IQR), and skewness and kurtosis were also determined. Mathematical (statistical) procedures were carried out to test for normality such as the Kolmogorov–Smirnov test, Lilliefors test and Shapiro–Wilk test (S–W), or graphically by means of normality histograms.

Ethical considerations

The study was approved by the University of Johannesburg Research Ethics Committee, and the conduct of the study adhered to the tenets of the Declaration of Helsinki and was approved by Higher Degrees and Research Ethics Committees of the Faculty of Health Sciences, University of Johannesburg, South Africa (reference no. REC-1847-2022). Participants gave informed consent to participate in the study before taking part. Participants and the public were not involved in the design, conduct, reporting, or dissemination plans for the research. Consent forms and a questionnaire regarding general and ocular health were completed by each participant prior to testing, and participants were informed that their participation was voluntary thereby eliminating undue influence, and participation was conditional that anonymity of participants be maintained. In addition, participants were informed that they could withdraw consent before submitting the data. However, withdrawal may not take place beyond that point as the data became anonymous.

Results

In order to investigate the normality of the NWDs in the whole sample of 455 participants, a normality histogram plot suggests a bell-shaped symmetric, moderate tailed distribution (Figure 1). Additionally, when looking at results for the Kolmogorov-Smirnov normality test, the null



Note: NWD: Kolmogorov-Smirnov D = 0,0294. p > 0.20. Lilliefors-p > 0.20; N = 455. Mean = 39.9884. s.d. = 9.4106. Max = 64. Min = 16.1667; Shapiro Wilk = 0.9959. p = 0.2835.

s.d., standard deviation; Max, maximum; Min, minimum; NWD, near Working distance.

FIGURE 1: Normality histogram for the near working distance measurements of 455 young participants (17 years – 33 years) with values representing the Kolmogorov–Smirnov test, Lilliefors test and the Shapiro–Wilk test for normality (N = 455).

TABLE 1 : Summary statistics for near working distances: Central tendency, variability, and distribution characteristics (N = 455).

Variable	Near working distances (cm)								
	Mean	s.d.	Median	Minimum	Maximum	Range	IQR	Skewness	Kurtosis
Total	39.99	9.41	40.33	16.17	64.00	47.83	12.83	0.01	-0.22

NWD, near working distance; s.d., standard deviation; IQR, Interquartile range.

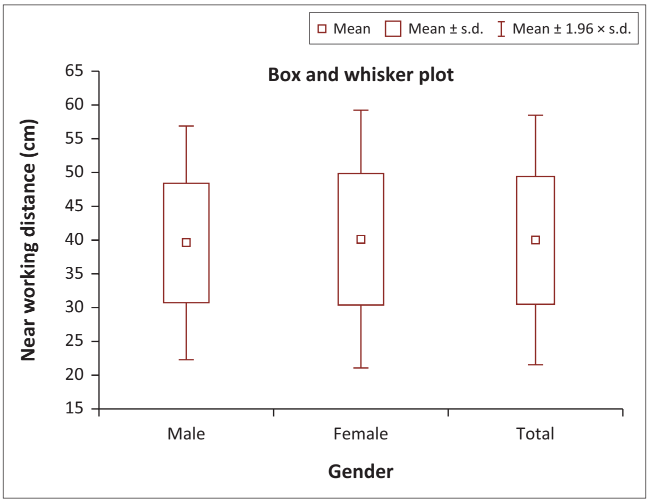


FIGURE 2: Box-and-whisker plots for the near working distances across genders and for the whole sample. The means of the data are represented by small squares within the larger boxes, the means ± 1 standard deviation (s.d.) are indicated by the larger box and the ends of the whiskers are means ± 1.96 × s.d.

hypothesis is rejected if the test statistic, D, is greater than the critical value obtained from a statistical table, and in this case, the critical value at 5% is 0.265. Regarding Figure 1, D = 0.0294, which does not exceed the critical value. Furthermore, the null hypothesis (H0) is accepted because the P-value is > 0.20. Thus, the data can be regarded as coming from a normally distributed population. The skewness coefficient (ɣ) of 0.01 in Table 1 suggests normally distributed data as it is very close to zero. The sample is also very slightly platykurtic as kurtosis coefficient $\kappa = -0.2$.

Central tendency, variability, and distribution characteristics for the near working distances of 455 participants

Table 1 includes the descriptive statistics for NWD measurements for the sample of 455 participants. For the whole sample, the mean NWD was 39.99 cm ± 9.41 cm, with a maximum and minimum of 64 cm and 16.17 cm, respectively, and a range of 47.83 cm. The mean NWD was found to be close to the standard clinical testing distance of 40 cm with 0.01 cm difference.

Gender and near working distance

In Figure 2, box-and-whisker plots illustrate the comparisons between the NWD across the whole sample (N = 455) and between gender. In addition, Table 2 gives the relevant descriptive statistics for these box-and-whisker plots.

For males (N = 165), the mean NWD and s.d. were 39.63 cm ± 8.81 cm, with a minimum and maximum NWD of 17 cm and 63 cm, respectively. The mean NWD was less than the standard 40 cm used in clinical testing with a negligible difference of 0.37 cm. The mean NWD within the male population was also less than those of the whole sample by a small difference of 0.35 cm.

TABLE 2: Gender and sample distribution of near working distances of the whole sample (N = 455).

Variable	n	Near working distance (cm)			
		Mean	Minimum	Maximum	s.d.
Gender					
Male	165	39.63	17.00	63.00	8.81
Female	290	40.19	16.16	64.00	9.74
Total	**455**	**39.99**	**16.17**	**64.00**	**9.41**

s.d., standard deviation.

For females (N = 290), the mean NWD and s.d. were 40.19 cm ± 9.74 cm, with a minimum and maximum NWD of 16.16 cm and 64 cm, respectively. The mean NWD was greater than the standard 40 cm used in clinical testing by a small difference of 0.19 cm. The mean NWD within the female population was greater than those of the whole sample by a small difference of 0.21 cm.

To investigate if there were any significant differences in the NWD between the two genders, an independent t-test was applied to the data. The t-value = 1,12 and P-value = 0.26 led us to not reject the null hypothesis (H_0); therefore, no significant differences were found and means between the two genders were equal.

Hence, female participants represented the largest sample (N = 290), with the largest mean NWD (40.19 cm) and greatest variation in results (s.d. = 9.74 cm).

Race and near working distance

In Figure 3, box-and-whisker plots represent the comparisons between the NWD across the four races as well as between the whole sample. In addition, Table 3 gives the relevant descriptive statistics for these box-and-whisker plots.

For black people (N = 413), the mean NWD and s.d. were 40.53 cm ± 9.22 cm, and the minimum and maximum were 16.16 cm and 64 cm, respectively. The mean NWD is 0.53 cm greater than the standard 40 cm clinical testing distance. The mean NWD of this group compared to the whole sample is greater by 0.55 cm.

For white people (N = 9), the mean NWD and s.d. was 31.37 cm ± 7.91 cm, and the minimum and maximum were 23.67 cm and 48 cm, respectively. The mean is 8.63 cm less than the standard 40 cm clinical testing distance. The mean NWD for this group was less than the whole sample by 8.61 cm.

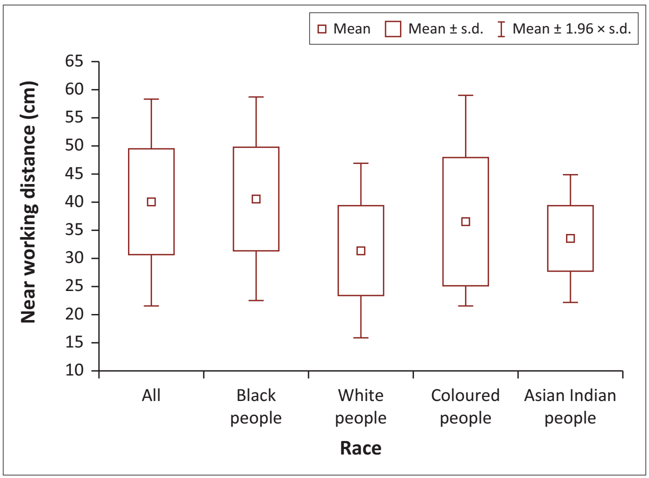


FIGURE 3: Box-and-whisker plots for the near working distances across different races and for the whole sample.

TABLE 3: Distribution of near working distances of the whole sample (N = 455).

Variable	n	Near working distance (cm)			
		Mean	Minimum	Maximum	s.d.
Race					
Black people	413	40.53	16.16	64.00	9.22
White people	9	31.37	23.67	48.00	7.91
Mixed-race people	22	36.52	16.17	61.00	11.48
Asian Indian people	11	33.50	18.00	39.00	5.81
Total	**455**	**39.99**	**16.17**	**64.00**	**9.41**

s.d., standard deviation.

For mixed-race people (N = 22), the mean NWD and s.d. was 36.52 cm ± 11.48 cm, and the minimum and maximum were 16.17 cm and 61 cm, respectively. The mean was 3.48 cm less than the standard 40 cm clinical testing distance. The mean NWD for this group was less than the entire sample by 3.46 cm.

Finally, the mean NWD and s.d. of Asian Indian people (N = 11) was 33.50 cm ± 5.81 cm, and the minimum and maximum were 18 cm and 39 cm, respectively. The mean was 6.5 cm less than the standard 40 cm clinical testing distance. The mean NWD for this group was less than the entire sample by 6.48 cm.

From the aforementioned, the largest sample and largest mean NWD were black people (N = 413; 40.53 cm). White people represented the smallest sample and smallest mean NWD (N = 9; 31.37 cm). The largest range of NWD belonged to black participants (40.53 cm + 16.16 cm = 56.69 cm), followed by white people (55.04 cm), mixed-race people (52.69 cm) and Asian Indian people (51.5 cm). Mixed-race people had the largest variation in results (s.d. = 11.48 cm), whereas the Indian Asian people had the smallest variation in NWD measurements (s.d. = 5.81 cm).

A one-way analysis of variance (ANOVA) test applied to the data to check for any differences between the mean NWDs among the race groups, showed that the P-value = 0.097. Because the P-value > α, the null hypothesis (H_0) is accepted, and the means NWDs of all races are assumed to be equal. Also, the Tukey honestly significant difference (HSD)/Tukey Kramer test applied to the data showed no significant differences between the means of any pair.

Discussion

The main purpose of this study was to investigate the working distance adopted by university students when viewing printed material at near. A mean NWD of 39.99 cm for the whole sample was established in this study, which is very similar to the standard and commonly used NWD of 40 cm.

The NWD was similar in both male and female participants, and black people had a higher mean NWD measurements compared to the other races but that could be because of the larger number of black participants. In contrast to our study, Drobe et al.[12] in their study found that French white people and Singaporean Chinese non-presbyopes read and write at a mean distance of 33.2 cm ± 5.3 cm and that women worked closer than men, possibly owing to a greater forearm length in men. A reason for the decreased mean NWD to our study could also be because of the differences in forearm length among black versus French white people and Singaporean Chinese people. In her thesis, Myburgh[30] found that black South African groups had greater limb and distal limb lengths than white South African groups, and in turn, the arm ratios were higher in white South African groups compared to in white North American and white European groups.

In the study by Boccardo,[11] although participants' viewing distance to their smartphones was measured, which is different from the near card used in this study, it was found that for the whole sample (N = 131), the mean viewing distance was 36.1 cm ± 7.2 cm while sitting, as compared to 39.99 cm ± 9.41 cm in this study. When comparing gender, the mean NWD was 34.7 cm ± 6.2 cm in females, and 38.2 cm ± 6.3 cm in males, as compared to 39.63 cm ± 8.81 cm for males, and 40.19 cm ± 9.74 cm for females in this study. When comparing the results to other studies involving electronic devices, two studies conducted in the United States and China measured the range of viewing distances at which smartphones were held by adults.[28,31,32] The mean and range of distances recorded for each study were 36.2 cm (17.5 cm – 58.0 cm) and 34.0 cm (19.0 cm – 51.3 cm), respectively, considerably less than the 39.99 cm mean NWD found in this study. Hence, results from this study may suggest that young adults hold their smartphones at a closer distance than printed material when reading, and some studies have found that screen size affects viewing distance and the smaller is the screen, the closer is the distance of use.[33]

In his master's thesis, Sharvit[34] found that when young adults were allowed to hold an electronic device at any comfortable distance while performing a 30 min reading task, they started reading at a mean distance of 32 cm, which decreased to 29 cm by the end of the test period. Therefore, there seems to be a difference in visual symptoms for electronic versus hard copy reading material, and Awan and Batool[35] indicated in their study that there is a greater overall percentage of change in visual symptoms in computer uses than hard copy. They concluded that it is easier to read from hard copy than from computer monitors.

Although the binocular statuses of patients were not investigated, as this is not the focus of this study, it is important to mention that accommodation and convergence play a significant role in NWDs. Convergence and accommodation aid in image projection on the fovea. Insufficiency, or excess of these two factors may also influence near tasks, thus affecting NWDs.[17,18,19,20] Nevertheless, the results of this study are still important as it established the NWD adopted by university students with normal vision.

This study has some limitations. The sample comprised of 455 university students between the ages of 17 and 33 years only. While this sample size was considered satisfactory for the main aims herein of investigating NWD, a larger sample would have provided more comprehensive and extensive normative data and further contributions towards a better understanding of the potential existing relationships that exist between the respective variables and NWDs. Also, it may not represent the cultural, age, race and gender diversity present in the general population. An attempt to get equal samples for different races could be important in studies such as this one. Most participants were black female university students. Data collection was carried out during examination season, and the binocular statuses of participants were not measured; therefore, factors that could have affected the measurements could be convergence dysfunctions, accommodative spasm, fatigue and asthenopia experienced by the university students. The influence of factors on NWDs such as refractive error, Harmon distance and height were also not included in this study. Another limitation was the variation in print sizes, and visual acuity, refractive status, and accommodative ability could influence the smallest readable print size. This variability could lead to differences in the measured NWD that are influenced by print size rather than reflecting true habitual working distance. The restriction on adjusting NWD may not have fully provided the natural reading behaviours of individuals, especially for those who habitually bring smaller print closer.

Nevertheless, this study has established the NWD opted by university students, while factors such as chart illumination and seat posture were standardised, and measurements were performed three times for everyone, using the same measuring tape and reading material. There are, at present, only a limited number of studies that have analysed the NWD in a South African university setting. Important results about NWD normality and measures of central tendency and dispersion (or variation) were obtained, which can be used comparatively with past or future studies.

Recommendations and areas for future research

Future studies should consider other age groups outside the range here such as school going children, the working class as well as presbyopes as well as taking into consideration environmental factors such as lighting, contrast and posture that may also have an impact on the results. Race and randomisation of selection must be taken into consideration for studies to come, ensuring a normal distribution among the different race groups for a reliable comparison between the groups. Future studies should also investigate the working distances using electronic devices, which have their own visual requirements. Finally, future studies could allow for the adjustment of NWD to measure the natural reading behaviours of individuals and could also measure how NWD varies with different print sizes.

Conclusion

Through analysis of the NWD, it was found that for the whole sample, the mean NWD was 39.99 cm ± 9.41 cm for university students, which is comparable to the norm of 40 cm that is used in optometric examinations, and females, and black university students presented with slightly larger mean NWD.

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Authors' contributions

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Data availability

Data are available on reasonable request from the corresponding author, N.H.

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