Amplitude of Accommodation in young caucasian adults in Greece

ABSTRACT

Objective: This study aims to determine the prevalence of accommodation insufficiency among young Caucasian adults in Greece.

Methods: Accommodation amplitude was assessed using the minus to blur method (PRA). Results were compared against Donder's and Hofstetter's values. Participants were categorized into "normal," "borderline," and "insufficient" based on deviations from expected values.

Results: Over 50% of participants exhibited accommodation insufficiency. Men had significantly lower rates of normal accommodation amplitude compared to women. Further research is required to explore the impact of refractive errors on accommodation issues.

Conclusions: Accommodation insufficiency is a significant issue among young adults, necessitating further studies and the establishment of standardized measurement methods. Investigating the role of the ciliary muscle in accommodation is also recommended.

Keywords: accommodation, amplitude of accommodation, accommodation insufficiency, binocular dysfunctions

Introduction

Accommodation refers to the eye's ability to adjust its refractive power to focus on objects at varying distances. This function is influenced by numerous psychological and physical factors. Specifically, factors include refractive errors, light exposure, ethnicity, urbanization, ambient temperature, dyslexia, learning difficulties, intraocular pressure (IOP), diabetes, Down syndrome, thyroid dysfunction, alcohol, premature birth, time of day, etc. [12].

In modern times, close working distances have become a significant part of our vision. Research has shown that in Korea in 2018, 89.6% of individuals over the age of three were mobile phone users, with 19.1% categorized as "addicted" [1]. Long-term use of digital screens has been correlated with various visual and ocular issues, including adaptation problems, due to intense and prolonged use [1,12,14,24,25]. Furthermore, close working distances have been associated with the onset and progression of myopia [28-29]. This is based on studies suggesting that the lag of accommodation plays a role in myopia development. However, there is also a contrary view that suggests the lag of accommodation was present before myopia appeared. Interestingly, children with early-onset myopia and adults with delayed-onset myopia exhibit greater accommodation instability compared to emmetropic individuals under similar visual stimuli. This instability may potentially contribute to myopia development [24,25]. Finally, close working distances (10–40 cm) in combination with poor posture can lead to different accommodation needs.

For many, measuring the maximum range to which an individual can accommodate (amplitude of accommodation) is a routine assessment that should take place regardless of age. Furthermore, it is a key measurement for the onset and progression of presbyopia. The ability to accommodate exists from birth but improves dramatically in the first months of life [16]. Previous studies have shown that the most significant changes are observed between the ages of 20 and 50 [7]. Measuring the accommodation amplitude is a very important method for identifying various dysfunctions related to accommodation, with the most common being accommodation insufficiency (A.I.). Specifically, A.I. is a non-strabismic condition characterized by the inability of a non-presbyopic individual to activate accommodation to a degree considered normal based on their age group. As a condition, it can lead to a variety of problems with close-range tasks, such as blurred vision, diplopia, headaches, etc. The prevalence of accommodation insufficiency varies from 1% to 61.6%, depending on the research. Specifically, the prevalence has been recorded to reach up to 17% in children aged 8 to 16, while in the Caucasian population, this percentage is estimated at 6.2%. Conversely, lower values are reported for students in countries such as Iran and South Africa, with rates of 4% and 4.5%, respectively. Higher rates are recorded in children with learning difficulties, syndromes, and special needs. Specifically, in children with learning difficulties, the prevalence of accommodation insufficiency is 26%, and in children with Down syndrome, this percentage ranges between 55% and 76% [10]. Finally, it has been recorded that symptoms are more commonly observed in individuals with a difference of more than 2D from the expected age value [2,16]. Therefore, in this study, pure A.I. is recorded in individuals with a difference of 2D or more.

There are several methods for measuring the amplitude of accommodation, such as push-up, push-down, minus-to-blur, dynamic retinoscopy (DR), modified push-up,etc. In clinical practice, subjective techniques are used most commonly to measure the amplitude of accommodation.

Push-Up Method (PU)

The push-up method is the most common and simplest clinical technique for measuring the A.I. In this method, the patient is fully corrected for distance vision, and as the target is brought closer, they are asked, "At what distance does the first minimum sustained blur occur?" This method has statistically significant errors due to subjectivity, primarily in reaction time. Finally, studies show that this method yields higher values compared to other methods [7,12].

Modified Push-Up (MPU)

An alternative subjective technique is the modified push-up (MPU), where the amplitude of accommodation is measured through an additional minus lens added over the distance refractive correction. The push-up technique is then performed through this lens combination. The advantage of the modified push-up over the conventional push-up procedure is that the target appears smaller when viewed through the minus lens, and therefore, subjects will detect the presence of a blur earlier [26]. Modified push-up method produced lower measures of the amplitude of accommodation than the conventional push-up method.

Push-Down Method (PD)

The push-down method is a modification of the push-up method. In this method, the object is gradually moved away from the eyes until the examinee reports that they see it clearly for the first time. This method is simpler and easier, as it requires less target resolution compared to the push-up method [12].

Minus to blur (PRA)

In this method, negative lenses are added to the correction, with simultaneous observation of a near-fixed target until permanent blur occurs. In the PRA method, there is minification of the retinal image due to the optical properties of the concave lenses. Unlike the push-up method, the relative distance magnification is absent, and proximal stimulation remains constant. Generally, the above-mentioned reasons indicate why the push-up amplitude is higher than the PRA amplitude. For some, this method should only be used in monocular vision, as it can disrupt binocular vision in an optically susceptible system, especially between convergence and accommodation. However, it is the most reliable and objective method with the highest repeatability, although its results yield lower values compared to other methods [7,12,26].

Dynamic retinoscopy (DR)

Dynamic retinoscopy provides a straightforward method of determining the accommodative response using an inexpensive instrument. The limitations of the retinoscopy technique are that it takes longer to complete and the accuracy of the retinoscopy procedure will vary both with the skill of the examiner, and any irregularities in the eye being examined such as media opacities, an unstable tear film, blinks or variations in accommodation [27].

Methods

For this experiment, individuals with visual acuity for distance or near, binocular or monocular, which was less than 6/6–3, were excluded. The experiment was conducted in a well-lit examination room to ensure optimal visibility for participants (Figure 1). A chart of letters (Figure 2) with a size of 20/30 was used as the target, placed at a distance of 35 cm from the examinee (Figure 3). The size of the letters and the distance of the target were chosen to make the test more demanding for the examinee. In the final measurement, an addition of 2.5D corresponding to a distance of 35 cm was added. The chosen measurement method was the "PRA" method, in which negative lenses are added until permanent minimum blur occurs despite the examinee's efforts to clear the image. The "PRA" method was selected due to its greater objectivity compared to other methods and its highest repeatability. It is important to note that the "minus lens" method yields smaller values for the adaptation range compared to the other methods. Instructions given to the examinees were to focus on letters on the 20/30 chart and report when they could no longer clear the letter despite their best effort. This was repeated three times per person, once binocularly and twice monocularly (once for each eye). For the categorization of the results, considerations were made based on suggestions that accommodation insufficiency should be considered a deviation greater than 2D from the normal value for the respective age. Furthermore, there are two other categories: "borderline," which refers to deviations from 1.25D to 1.75D or 2D with at least one eye having a deviation less than 1.75D, and "normal," which refers to zero to deviations on the order of 1D.This is because the "minus to blur" method either underestimates or is quite strict in terms of the adaptation range compared to other methods in free space (e.g., push-up). Finally, for better and more accurate categorization, the values given by Donder for the age group measured and Hofstetter's equation were used. Regarding the Hofstetter equation, the lowest value was considered, as it appears to be the most accurate.

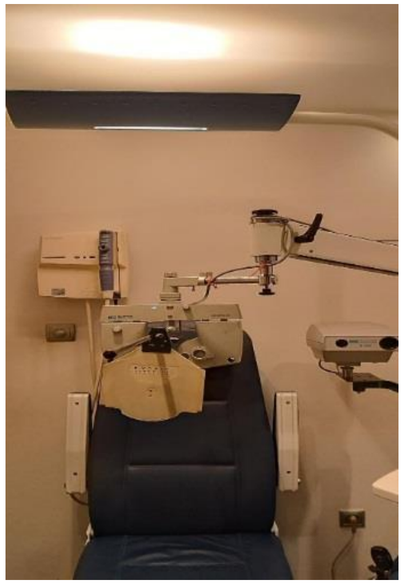

Figure 1: The examination room and lighting conditions used for the measurements

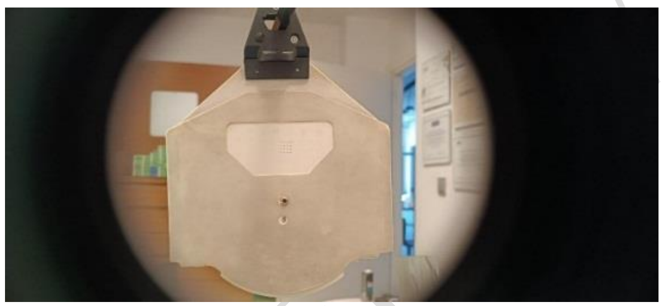

Figure 2: The near-visual acuity chart with a size of 20/30 was used as the target.

Figure 3: The distance of 35 cm at which the near-visual acuity chart was placed as the target.

Table 1. Donder's Amplitude of accommodation chart

Donder's Amplitude of accommodation chart	
Age	Normal Amplitude of Accommodation
5	15D
10	12.50D
20	9.75D
30	7.25D
40	4D
50	2.5D
60	1.25D
70	0.50D
75	0.00D

Table 2. Hofstetter's Amplitude of Accommodation equation

Hofstetter's Amplitude of Accommodation equation	
Max	expected 25 - (0.4 x Age)
Normal	18 - (0.3 x Age)
Minimum	expected 15 - (0.25 x Age)

Statistical analysis

Table 3. Amplitude_of_accommodation_binocular

Amplitude_of_accommodation_binocular	
Sample size	41
Lowest value	3,2500
Highest value	9,7500
Arithmetic mean	6,7439
95% CI for the mean	6,2994 to 7,1884
Median	6,7500
95% CI for the median	6,4404 to 7,2500
Variance	1,9828
Standard deviation	1,4081
Relative standard deviation	0,2088 (20.88%)
Standard error of the mean	0,2199
Coefficient of Skewness	-0,1409 (P=0,6881)
Coefficient of Kurtosis	0,09811 (P=0,7134)
D'Agostino-Pearson test for Normal distribution	accept Normality (P = 0,8624)

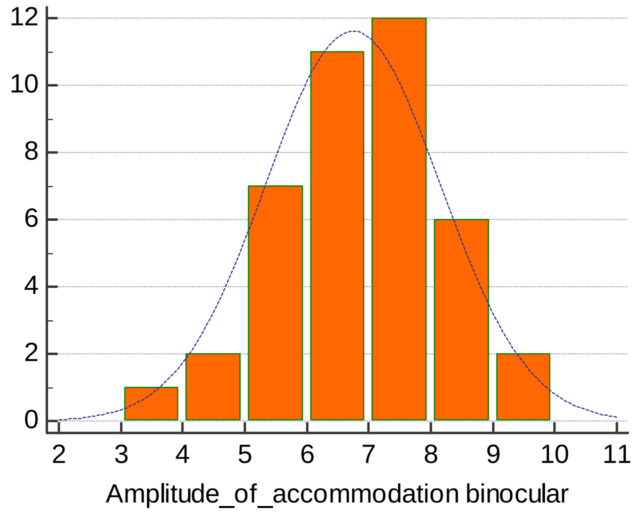

Figure 4: Diagram showing a normal distribution plot of the amplitude of accommodation binocular

Table 4. Amplitude_of_accommodation_binocular for male

Amplitude_of_accommodation_binocular for male	
Sample size	19
Lowest value	3,2500
Highest value	8,7500
Arithmetic mean	6,2368
95% CI for the mean	5,5812 to 6,8925
Median	6,7500
95% CI for the median	5,2500 to 7,0545
Variance	1,8505
Standard deviation	1,3603
Relative standard deviation	0,2181 (21.81%)
Standard error of the mean	0,3121
Coefficient of Skewness	-0,4906 (P=0,3288)
Coefficient of Kurtosis	0,001913 (P=0,8147)
D'Agostino-Pearson test for Normal distribution	accept Normality (P=0,6039

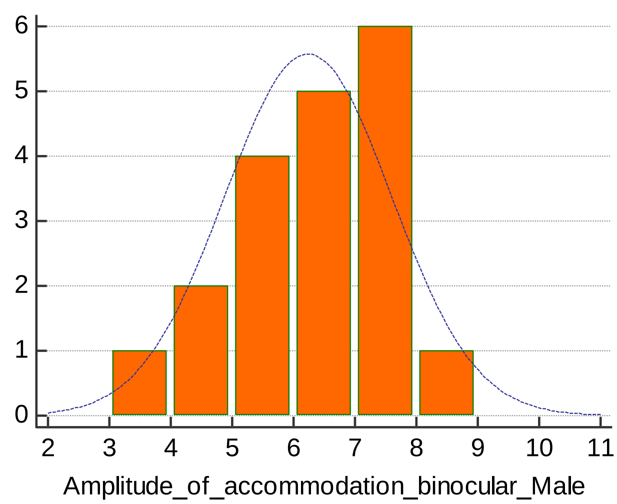

Figure 5: Diagram showing a normal distribution plot of the amplitude of accommodation binocular for male

Table 5. Amplitude_of_accommodation_binocular for female

Amplitude_of_accommodation_binocular for female	
Sample size	22
Lowest value	5,0000
Highest value	9,7500
Arithmetic mean	7,1818
95% CI for the mean	6,5941 to 7,7695
Median	7,1250
95% CI for the median	6,4766 to 8,0117
Variance	1,7570
Standard deviation	1,3255
Relative standard deviation	0,1846 (18.46%)
Standard error of the mean	0,2826
Coefficient of Skewness	0,1741 (P=0,7069)
Coefficient of Kurtosis	-0,5226 (P=0,6447)
D'Agostino-Pearson test for Normal distribution	accept Normality (P=0,8378

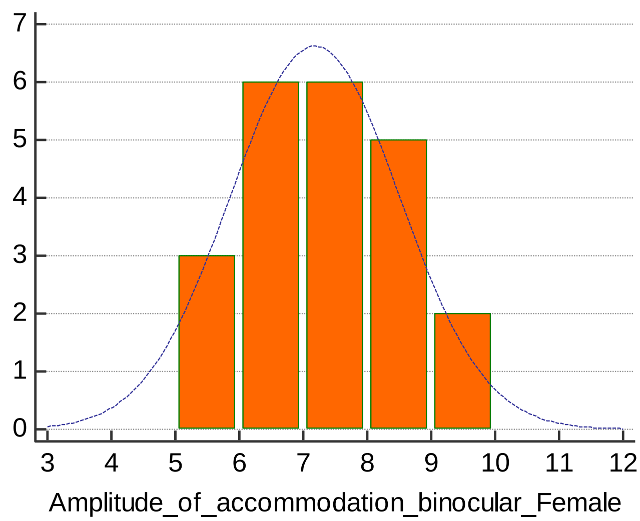

Figure 6: Diagram showing a normal distribution plot of the amplitude of accommodation binocular for female

Results & discussion

The total sample collected for the study consisted of 41 individuals and a total of 82 eyes. Of the 41 participants, 53.66% (22) were female and 46.34% (19) were male, with an average age of 23.71 years. Furthermore, out of the total 41 individuals, 78.04% (32 individuals) had myopia, 17.07% (7 individuals) had emmetropia, and 4.87% (2 individuals) had hypermetropia. Among the total 41 individuals, 24.39% (10 individuals) had a normal amplitude of accommodation (deviation up to 1D from the lowest expected based on age), 19.51% (8 individuals) had a borderline amplitude of accommodation (deviation from 1.25D to 1.75D or 2D with at least one eye deviating less than 1.75D from the lowest expected based on age), and 56.10% (23 individuals) had a low amplitude of accommodation (Table 5). Among the 32 individuals with myopia, 9 (28.125%) had a normal amplitude of accommodation, 4 (12.5%) had a borderline amplitude of accommodation, and the remaining 19 (59.375%) had a low amplitude of accommodation. Regarding the emmetropic individuals, out of the total of 7 individuals, 1 (14.29%) had a normal amplitude of accommodation, 4 (57.14%) had a borderline range, and 2 (28.57%) had low amplitude of accommodation. As for the hypermetropic individuals, none had a normal or borderline amplitude of accommodation, so both of the 2 individuals (100%) had a low amplitude. Safe comparisons cannot be made due to the lack of samples in the emmetropic and hypermetropic categories. Regarding gender, as mentioned, 53.66% were females and 46.34% were males. Among females, 36.37% had a normal amplitude of accommodation, 13.63% had a borderline range, and 50% had a low amplitude, while the corresponding percentages for males were 10.53%, 26.32%, and 63.15%. Therefore, it is observed that females have higher percentages in both normal and borderline categories. Now, regarding the binocular and monocular amplitude of accommodation, 46.34% (19 individuals) had a binocular amplitude of accommodation greater than the respective monocular range. None had a binocular amplitude of accommodation identical to the monocular amplitude of accommodation; 14.63% (6 individuals) had a binocular amplitude of accommodation identical to the greater monocular range, 2.34% (1 individual) had a binocular amplitude of accommodation identical to the smaller monocular range; 17.07% (7 individuals) had a binocular amplitude of accommodation between the monocular ranges; and 19.5% (8 individuals) had a binocular amplitude of accommodation smaller than the monocular range. Additionally, a deviation of monocular amplitude of accommodation from binocular range greater than 0.5D was observed in at least one eye for 41.46% (17 individuals), while a deviation smaller than 0.5D was observed in 58.54% (24 individuals). Finally, identical monocular ranges of accommodation between the two eyes were recorded in 8 individuals, while different values were recorded in 34 individuals. These results may be influenced by factors such as body posture, eye dominance, and potential errors in the estimation of accommodation by the examiner or the examinee.

Table 6. Gender Comparison of Accommodation Amplitude

Gender Comparison of Accommodation Amplitude		
Accommodation Category	Female (%)	Male (%)
Normal	36.37	10.53
Borderline	13.63	26.32
Low	50.00	63.15

6. Conclusions

This study concludes that using the employed methods and parameters, a significant percentage of young adults exhibit accommodation insufficiency, highlighting the need for further research and standardized measurement method. Firstly, the percentage of inadequate accommodation (which exceeds a deviation of 2D from the lower or normal value for age) is very high and affects 56.10% of the individuals who participated in this study. Furthermore, it is observed that females have higher percentages of the normal range of adaptation compared to males, with these percentages reaching 36.37% and 10.53%, respectively. Additionally, the binocular range of adaptation was higher than the monocular range of adaptation in 46.34%, while a lower binocular range of adaptation was observed in 19.5%. Differences were also observed in the maximum dioptric power between the two eyes. The cause cannot be confirmed; however, possible causes could be that one eye is dominant and functions at better levels, incorrect body posture resulting in one eye accommodating more than the other (as observed in other studies), incorrect estimation of the first curvature by the examinee or examiner, and other reasons.

Regarding the values used to compare our results, the Donder's physiological values, though old, seem to still yield realistic results even today. In contrast, Hofstetter's equation regarding the upper and normal limits for age does not appear realistic. However, if we maintain the lower expected value from Hofstetter's equation as normal, then the results are indeed realistic and similar to Donder's, with a deviation of about 0.25D between the two values.

In a broader context, inadequate accommodation seems to be a significant problem in young age groups, and further studies need to be conducted to thoroughly analyze the issue and its prevalence. Furthermore, a universal system for measuring the range of accommodation should be established to obtain safer results. Additionally, it would be interesting to observe the action and contribution of the ciliary muscle in the accommodation process in young adults, as theoretically, the crystalline lens is almost transparent, so the problem in accommodation primarily concerns the inability of the ciliary muscle to act effectively. Finally, inadequate accommodation implies problems with close-range work, but this is unlikely to improve overall, as orthoptic exercises and vision training cannot be universally used to manage or address this problem. Consequently, among other factors, presbyopia is likely to begin at even younger ages.

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Details of the AI usage are given below:

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