



# Dynamic and Static Pupil Changes After Near Work: Comparison Between Reading a Book and Using a Smartphone

Ali Mirzajani,<sup>1</sup> Narges Akhgar,<sup>1</sup> Ebrahim Jafarzadehpour,<sup>1</sup> Jamileh Abolghasemi,<sup>2</sup>  
 Alireza Jamali,<sup>1</sup> Zohreh Fakhimi<sup>3</sup>

<sup>1</sup>Rehabilitation Research Center, Department of Optometry, School of Rehabilitation Sciences, Iran University of Medical Sciences, Tehran, Iran

<sup>2</sup>Department of Biostatistics, School of Public Health, Iran University of Medical Sciences, Tehran, Iran

<sup>3</sup>Department of Optometry, School of Paramedical Sciences, Mashhad University of Medical Sciences, Mashhad, Iran

## Abstract

**Objectives:** Decreased static pupil size due to accommodation is a common clinical finding; however, changes in pupillary dynamic responses after near-work activities such as reading a book and using a smartphone are not well understood.

**Methods:** The present study was performed on 76 right eyes of 76 volunteers (mean age: 20.95±2.34 years) who had ocular near activity more than 4 h per day. The participants were divided into two groups based on the dominant activity, reading a book (Group 1) or using a smartphone (Group 2). Evaluation of dynamic and static parameters of the pupil was performed before and after 1 h of continuous routine eye activity in both groups and compared.

**Results:** Near work reduced pupil diameter (PD) in all static components ( $p<0.001$ ) and the amount of change in the min PD ( $p=0.039$ ) and mesopic PD ( $p=0.043$ ) were different between two groups and were higher in Group 1 (both,  $p<0.05$ ). Dynamic elements showed a decrease in initial diameter, amplitude and velocity of contraction and dilation, and an increase in other components so that the changes after using smartphone were significant in all dynamic parameters (all,  $p<0.05$ ), but reading the book only made a significant difference in the initial diameter, amplitude, and velocity of contraction and duration of dilation (all,  $p<0.05$ ); the changes were only different in the initial diameter between the two studied groups, which was higher in Group 1 ( $p=0.047$ ).

**Conclusion:** The present study showed that reading a book and using smartphone cause changes in the pupil components, which were decreasing in diameter components and velocity of changes and increasing in latency of changes; the type of ocular work may affect the changes.

**Keywords:** Static Pupillometry, Dynamic Pupillometry, Near Work, Metrovision Monopack 1.

## Introduction

Pupil diameter (PD) is determined by the balance of the parasympathetic and sympathetic nervous systems, which causes the pupil to dilate and contract (1). The pupil contracts under the influence of light and near distances, which occurs

due to the effect of the sympathetic system and stimulation of the circular muscles of the iris, and dilatation of the pupil is caused by the contraction of the radial muscles of the iris by innervating the sympathetic system (2). Other external factors such as age, sleep, increased intraocular pressure, seizures, ex-

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**Address for correspondence:** Alireza Jamali, MD. Rehabilitation Research Center, Department of Optometry, School of Rehabilitation Sciences, Iran University of Medical Sciences, Tehran, Iran

**Phone:** +989122816388 **E-mail:** alirezajamali.1371@gmail.com

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citement, and panic also affect the pupil diameter (3,4).

Near induced transient myopia represents a temporary, limited myopic shift after a period of continuous near work activity; (5) this phenomenon actually indicates the inability of the visual system to relax the crystalline lens and return to baseline when looking far distances (6). The function of the accommodation, convergence, and miosis depends on the common nerve impulse, and the changes in the activity of each component affects the other components so that the decreasing PD simultaneously or after ocular near work can be considered as one of the side effects that result from continuous accommodation and stimulation of the parasympathetic system (7).

In different studies, pupil changes have been evaluated under different conditions and using different methods; most of these studies have performed on the static components and provided valuable information about PD changes (3,8-13). One of less noticed in this regard is changes in pupillary dynamic responses while providing different stimuli. Limited studies have provided these characteristics in different eye conditions including amblyopic patients, (14) people with multiple sclerosis, (15) people with diabetic retinopathy, (16) people with retinitis pigmentosa, (17) and finally while reducing or increasing accommodation (10). However, a review of available studies shows that evaluation of dynamic pupil changes after near ocular work has not been performed yet.

One of the features of daily life is continuous ocular activities at near distances; on the other hand, the advancement of technology has increased the use of smart screens by all experts and non-experts (18). Since the type of stimulus presented to the ocular system may be different in various ocular activities such as reading a book and using a smartphone, it is predictable that they will also make different changes in pupil function after near work. In the present study, the static and dynamic characteristics of the pupil after 1 h of continuous ocular near work are evaluated and a comparison is made between the two activities of reading a book and using a smartphone.

## Methods

### Study Participants

The present study was performed in the Optometry Clinic of Iran University of Medical Sciences, Tehran, Iran, from July 2020 to October 2020. Inclusion criteria included ages between 18 and 30 years, having ocular near activity more than 4 h per day, best-corrected visual acuity equal to 20/20, spherical equivalent between  $-0.50$  D and  $-3.00$  D, intraocular pressure  $<20$  mmHg, not using any systemic or ophthalmic medications, and no ocular pathology. Participants were selected to be in one of the following groups: Group 1 usually spends more time in a day reading books (on average, more than 4 h a day) and Group 2 usually spends more time in a day using smartphone (on aver-

age, more than 4 h a day). It should be noted that the placement of all participants in each group was based on the person's responses and without any direction from the researchers.

### Examinations

Evaluation of inclusion criteria was done by measuring uncorrected and best-corrected visual acuity at a distance of 4 m and using a Snellen chart in a logMAR criteria, objective refraction was done by Huvitz HRK-8000A auto-refracto-keratometer and Heine Beta 200 retinoscope, the best optical correction was recorded by subjective refraction, and finally, a clinical examination was performed to examine the presence of any ocular pathological by a slit lamp device (Haag-Streit Corp., Switzerland).

After checking the inclusion criteria, binocularity evaluation was performed for all subjects. For this purpose, the accommodation system was evaluated by dynamic retinoscopy and accommodation facility tests, and finally, fusional vergences were measured with prism bar at near and far distances. All the obtained information was interpreted and any cases with binocular vision system problems were excluded from the study.

One day after binocular evaluation, the process of receiving dynamic and static pupillometric information was performed after 15 min without near activity for all participants with the Metrovision device (MonoPack One, Metrovision, Perenchies, France) in the first evaluation. All the individuals were then asked to do their habitual near work activity for 1 h continuously, reading a book in Group 1 and using a smartphone in Group 2. It should be noted that no explanation was given to the individuals regarding the type of ocular activity and only the participants engaged in their routine activities under room lightning (500 Lux) (19) behind a desk in 40 cm working distances. In the next step, dynamic and static pupillometry was repeated in the second evaluation in times  $<2$  min after finishing the ocular activities by the above device in the same lightning condition for all participants.

### Pupillometry

The pupillometry system in the Metrovision device (MonoPack One, Metrovision, Perenchies, France) is used to evaluate the dynamics and statics components of the pupil in different lighting conditions. The device has infrared light and a high-resolution camera (940 nm) that allows you to control the stimulus parameters such as light and background color and can measure the pupil changes even in complete darkness. Static evaluation of the pupil is performed by examining the PD in different light conditions, including low mesopic ( $0.1$  cd/m<sup>2</sup>), high mesopic ( $1$  cd/m<sup>2</sup>), low photopic ( $10$  cd/m<sup>2</sup>), high photopic ( $100$  cd/m<sup>2</sup>), min, max, and average PD. This device also evaluates the dynamic elements of pupil changes by measuring resting diameter, amplitude, latency, duration, and velocity of pupil contraction and dilation.

### Statistical Analysis

Mean, standard deviation, and minimum and maximum values were calculated for all studied parameters. The normality of data distributions was assessed by the Kruskal–Wallis test. Independent t-test was used to examine the age difference between the two groups, Mann–Whitney U-test was used to evaluate the difference between the initial values measured between the two groups, Wilcoxon signed-rank test was used to examine changes in each parameter compared to before near work and one-way ANOVA was used to investigate the differences each parameter before and after near work between the two groups of. Furthermore, the correlation between the parameters was evaluated by Spearman or Pearson correlation coefficient according to the normality of the distributions. All statistical analyses were performed by SPSS software version 25 for Windows (SPSS, IBM Corp., Armonk, NY, USA). Furthermore, the significance level in this study was considered to be lower than 0.05.

### Ethical Issues

The present study was reviewed by the Ethics Committee of the School of Rehabilitation of Iran University of Medical Sciences and approved by the code IR.IUMS.REC.1398.1210. The process of obtaining information from individuals was done based on the Helsinki Declaration and after obtaining written consent from individuals and providing sufficient explanations about the research process.

### Results

In the present study, data from 76 right eyes of 76 individuals with a mean age of  $20.9 \pm 2.34$  (18–29) years were evaluated, so that 60% of the subjects were male. The mean age of the participants in Groups 1 and 2 was not statistically different ( $21.02 \pm 2.77$  vs.  $20.70 \pm 1.82$ , respectively,  $p=0.140$ ).

As shown in Table 1, the static components of pupillometry, including the minimum, mean, maximum, scotopic, and

**Table 1.** Mean values of static parameters of pupil in each group

	Book				Smart Phone						
	Before	After	MD	p1	Before	After	MD	p2	p3	p4	
Min PD (mm)											
Mean±SD	3.27±0.64	3.06±0.57	-0.21±0.13	< 0.001	2.87±0.50	2.72±0.48	-0.15±0.10	< 0.001	0.002	0.039	
Range	1.80 to 4.60	1.80 to 4.00	-0.60 to 0.20		2.00 to 4.30	1.90 to 4.00	-0.40 to 0.10				
Average PD (mm)											
Mean±SD	4.72±0.74	4.52±0.70	-0.19±0.15	< 0.001	4.26 to 0.62	4.04±0.64	-0.22±0.15	< 0.001	0.001	0.529	
Range	3.00 to 6.00	3.00 to 5.60	-0.40 to 0.20		3.10 to 5.70	2.90 to 5.50	-0.60 to 0.10				
Max PD (mm)											
Mean±SD	6.09±0.51	5.71±0.55	-0.38±0.49	< 0.001	5.80±0.51	5.53±0.54	-0.27±0.47	0.001	0.012	0.334	
Range	5.40 to 7.50	4.80 to 6.80	-1.60 to 0.90		4.90 to 6.90	4.50 to 6.70	-1.60 to 0.50				
Scotopic PD (mm)											
Mean±SD	6.56±0.73	6.38±0.71	-0.18±0.27	< 0.001	6.25±0.86	6.08±0.79	-0.17±0.23	< 0.001	0.025	0.930	
Range	5.00 to 8.30	4.80 to 8.20	-0.70 to 0.90		4.00 to 8.30	4.10 to 8.20	-0.70 to 0.20				
Mesopic PD (mm)											
Mean±SD	4.40±0.93	3.90±0.96	-0.50±0.34	< 0.001	3.98±0.90	3.70±1.00	-0.28±0.57	< 0.001	0.030	0.043	
Range	2.80 to 6.10	1.90 to 5.50	-1.00 to 0.40		2.80 to 6.50	0.90 to 6.20	-3.20 to 0.40				
Low photopic PD (mm)											
Mean±SD	3.28±0.76	2.88±0.74	-0.39±0.58	< 0.001	3.09±0.60	2.90±0.45	-0.18±0.50	< 0.001	0.318	0.084	
Range	1.90 to 4.50	0.30 to 4.20	-3.30 to 0.40		0.90 to 4.50	1.70 to 4.20	-1.00 to 2.60				
High photopic PD (mm)											
Mean±SD	2.40±0.45	2.30±0.38	-0.10±0.16	< 0.001	2.80±1.12	2.64±1.03	-0.16±0.20	< 0.001	0.197	0.193	
Range	1.50 to 3.20	1.50 to 3.10	-0.70 to 0.20		1.70 to 6.10	1.70 to 5.80	-0.70 to 0.30				

PD: Pupil Diameter; MD: mean difference; P value 1: differences between before and after reading the book (Wilcoxon-Signed rank test); P value 2: differences between before and after using the Smartphone (Wilcoxon-Signed rank test); P value 3: differences between the primary evaluation between two groups (U Mann-Whitney test); P value 4: comparative evaluation of the amount of differences between before and after near work between the two groups (one-way ANOVA). P values less than 0.05 considered significant.

mesopic PD in the first evaluation, were higher in the Group 1 (all,  $p < 0.05$ ) and two components of low photopic PD ( $p = 0.318$ ) and high photopic PD ( $p = 0.197$ ) were not significantly different between the two groups. Static pupillometry after 1 h of near work showed a decrease in PD in all static components in both groups (all,  $p < 0.001$ ). One-way ANOVA showed that regardless of the initial values of the parameters, the amount of change in only two components PD min ( $p = 0.039$ ) and PD mesopic ( $p = 0.043$ ) was different between the two groups, so that reading book caused a greater reduction in PD. The amount of changes in other static parameters between the two groups was not statistically significant (all others,  $p > 0.05$ ). Figures 1 and 2 show the static parameters of pupil in two groups.

Table 2 presents the dynamic components of the pupil changes. According to the values in the table, it can be stated that the dynamic performance of the pupil has changed after performing near work in both groups. So that, while knowing the difference between the initial values of the initial diameter ( $p = 0.002$ ) and latency of contraction ( $p = 0.032$ ) and no difference in other parameters between the two groups in the first evaluation (all,  $p > 0.05$ ), near work caused a decrease in the values of the initial diameter, amplitude, and velocity of contraction and an increase in the values of other components in both groups. The differences in Group 2 were statistically significant in all elements (all,  $p < 0.05$ ) but the reading book only caused a significant difference in the

initial diameter, amplitude, and velocity of contraction and duration of dilation (all,  $p < 0.05$ ). The pattern of changes in other components of latency and duration of contraction and latency and velocity of dilation after performing near work in Group 1 was similar to smartphone users, but the differences were not statistically significant (all,  $p > 0.05$ ). Finally, the one-way ANOVA test showed that the observed difference in the values of the initial diameter was statistically different between the two groups ( $p = 0.045$ ), so that book reading caused the further reduction. Figures 3 and 4 show the dynamic parameters of pupil in two groups.

The values in Table 3 indicate the frequency of changes in each parameter in the two studied groups. As the values show, all the static parameters in more than 71% of the smartphone users and in more than 60% of the book readers have decreased in comparison to before the activity. Furthermore, in 23.7% of the eyes of Group 2, the amount of mesopic PD has increased after 1 h near work, while the increase in this parameter has occurred in 2.6% of the eyes of Group 2. These percentages in the component of latency of contraction and duration of dilation were 63.2% versus 34.2 and 76.3 versus 63.2% in Group 2 compared to Group 1, respectively; while the increase in velocity of contraction and dilation was higher in Group 1 (28.9% vs. 15.8% and 39.5 vs. 23.7%, respectively).

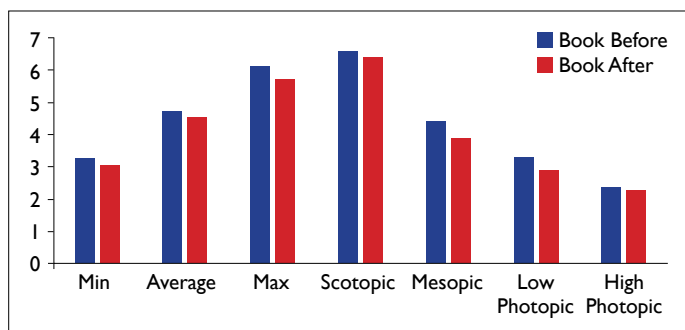


Figure 1. Changes in the static parameters of pupil after reading the book (mm, millimeter).

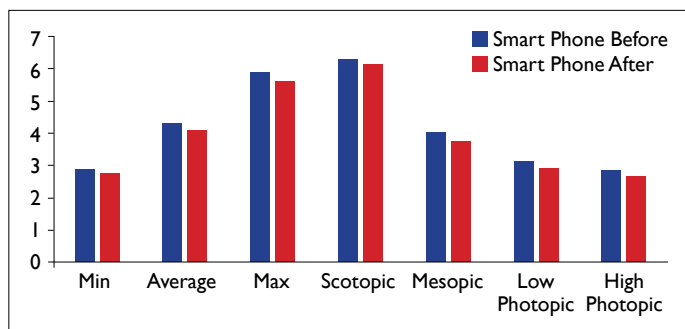


Figure 2. Changes in the static parameters of pupil after using the smartphone (mm, millimeter).

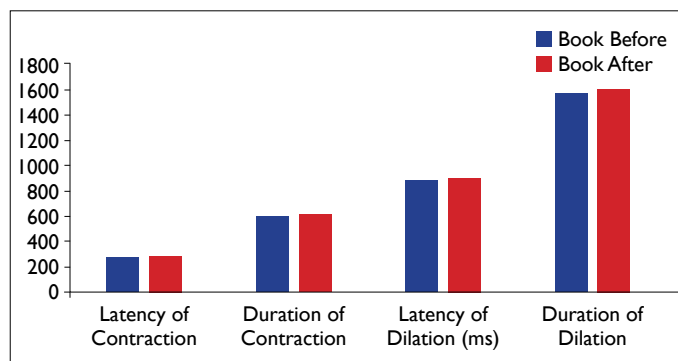


Figure 3. Changes in the dynamic parameters of pupil after reading the book (ms, millisecond).

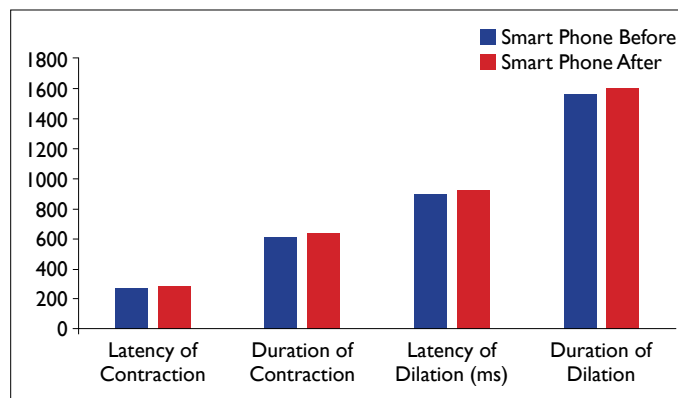


Figure 4. Changes in the dynamic parameters of pupil after using the smartphone (ms, millisecond).

**Table 2.** Mean values of Dynamic parameters of pupil in each group

	Book				Smart Phone					
	Before	After	MD	p1	Before	After	MD	p2	p3	p4
Initial Diameter (mm)										
Mean±SD	5.45±0.75	5.14±0.82	-0.31±0.28	< 0.001	4.98±0.72	4.77±0.71	-0.21±0.17	< 0.001	0.002	0.047
Range	3.70 to 6.70	3.60 to 6.40	-1.10 to 0.30		3.50 to 6.70	3.40 to 6.40	-0.66 to 0.10			
Amplitude of Contraction (mm)										
Mean±SD	2.01±0.25	1.93±0.25	-0.07±0.14	0.002	2.03±0.26	1.94±0.26	-0.08±0.12	0.001	0.499	0.873
Range	1.60 to 2.60	1.40 to 2.50	-0.50 to 0.20		1.40 to 2.60	1.40 to 2.50	-0.40 to 0.20			
Latency of Contraction (ms)										
Mean±SD	284.22±32.80	289.47±30.55	5.25±46.48	0.267	269.22±39.45	285.47±37.74	16.25±28.00	0.001	0.032	0.204
Range	167 to 333	167 to 333	-133 to 133		167 to 333	167 to 333	-50 to 100			
Duration of Contraction (ms)										
Mean±SD	598.27±55.14	613.00±57.34	15.02±68.42	0.201	618.10±64.38	640.87±72.54	22.77±61.95	0.007	0.138	0.507
Range	500 to 767	500 to 733	-134 to 200		500 to 800	500 to 833	-200 to 100			
Velocity of Contraction (mm/s)										
Mean±SD	5.78±0.75	5.58±0.63	-0.20±0.52	0.008	5.71±0.63	5.44±0.69	-0.27±0.45	< 0.001	0.758	0.547
Range	4.55 to 7.32	4.19 to 7.16	-1.65 to 1.26		4.30 to 7.27	4.10 to 7.06	-1.80 to 0.54			
Latency of Dilatation (ms)										
Mean±SD	883.52±60.86	903.10±53.36	19.57±61.85	0.048	901.50±64.47	925.92±67.54	24.42±52.15	0.007	0.147	0.706
Range	767 to 1000	767 to 1033	-133 to 133		767 to 1033	800 to 1067	-100 to 133			
Duration of Dilatation (ms)										
Mean±SD	1568.07±79.01	1607.30±61.91	39.22±75.73	0.004	1567.07±75.28	1602.47±67.28	35.40±58.36	0.001	0.864	0.801
Range	1400 to 1733	1500 to 1733	-133 to 233		1433 to 1733	1433 to 1700	-133 to 133			
Velocity of Dilatation (mm/s)										
Mean±SD	1.94±0.32	1.89±0.24	-0.05±0.21	0.056	1.95±0.43	1.76±0.33	-0.19±0.46	0.001	0.758	0.088
Range	1.35 to 3.30	1.30 to 2.35	-1.16 to 0.30		1.27 to 3.30	1.03 to 2.28	-1.91 to 0.40			

MD: mean difference; P value 1: differences between before and after reading the book (Wilcoxon-Signed rank test); P value 2: differences between before and after using the Smartphone (Wilcoxon-Signed rank test); P value 3: differences between the primary evaluation between two groups (U Mann-Whitney test); P value 4: comparative evaluation of the amount of differences between before and after near work between the two groups (one-way ANOVA). P values less than 0.05 considered significant.

Finally, the correlation between the variables showed that the patient’s age was inversely related to the maximum diameter in the first evaluation (p=0.01) and directly related to the latency of contraction (p<0.01). It was also shown that males have less amplitude of contraction (p<0.05), less latency of contraction and dilatation (all, p<0.05), and more duration of contraction and dilatation (all, p<0.05) in both groups.

### Discussion

In the present study, changes in dynamic and static parameters of pupillary responses were evaluated before and 1 h after two different near-work activities of reading a book and using a smartphone. The chosen age range is important

because in this age group, people spend a lot of time of their day on ocular activities, which puts a lot of stress on the visual system. Furthermore, the largest amount of refractive surgery is performed in this age range, as the diameter of the pupil plays a very important role in pre-operative examinations, any factor that changes it will lead to misinterpretation and improper decisions.

The results of the present study showed that continuous near work reduces all components of the pupil diameter. As we know, the iris regulates the amount of light entering the eye by changing the dimensions of the pupil, which can be changed in the range of 1.5–8 mm as needed; (11) it has also been shown that there is a direct relationship between the size of the pupil and the degree of visual

**Table 3.** The frequency of parameters change in group after near work

	Book, %			Smart Phone, %		
	Increase	Constant	Decrease	Increase	Constant	Decrease
Max PD (mm)	5.3	5.3	89.5	18.4	10.5	71.1
Average PD (mm)	5.3	10.5	84.2	5.3	13.2	81.6
Min PD (mm)	2.6	2.6	94.7	5.3	2.6	92.1
Scotopic PD (mm)	10.5	15.8	73.7	18.4	2.6	78.9
Mesopic PD (mm)	2.6	5.3	92.1	23.7	-	76.3
Low Photopic PD (mm)	5.3	2.6	92.1	7.9	-	92.1
High Photopic PD (mm)	10.5	28.9	60.5	10.5	2.6	86.6
Initial Diameter (mm)	-	10.5	89.5	2.6	15.8	81.6
Amplitude of Contraction (mm)	23.7	10.5	65.8	18.4	7.9	73.7
Latency of Contraction (ms)	34.2	44.7	21.1	63.2	26.3	10.5
Duration of Contraction (ms)	57.9	15.8	26.3	68.4	7.9	23.7
Velocity of Contraction (mm/s)	28.9	-	71.1	15.8	-	84.2
Latency of Dilation (ms)	63.2	7.9	28.9	76.3	2.6	21.1
Duration of Dilation (ms)	65.8	15.8	18.4	65.8	15.8	18.4
Velocity of Dilation (mm/s)	39.5	-	60.5	23.7	2.6	73.7

PD: Pupil Diameter; mm: millimeter; ms: millisecond; s: second.

acuity (11). The evaluation of the frequency of static and dynamic changes in the pupil components after near work showed that at least in more than 60% of two groups, the dimensions of all static parameters decreased compared to before ocular activity and statistical analysis showed a significant decrease in the mean of each static parameter. Various studies have been performed to evaluate changes in pupil size during or after near work; Gray et al. observed a significant increase in PD during 20 min of near work using smart screens (20). Besides, Tsuchiya et al. found that in 33% of the subjects, the pupil was in a contracted state after a continuous near work (12). Decreased pupil size after near work in both groups is a finding that was clearly shown in the present study, since it is not possible to evaluate pupil changes during ocular work with Metrovision device, it can be concluded that the spasm created in the iris sphincter due to the continuous accommodation during near work has reduced the size of the pupil, which is in line with the hypothesis presented in the study of Saito et al. (21).

A comparative study between the two groups shows that despite the decrease in the mean of each parameter in both groups, differences in the frequency of changes between the two groups were also observed. Among these differences, we can mention the higher rate of pupil contraction after near work in the two parameters min PD and mesopic PD in

the Group I. It was also shown that in all static parameters, the frequency of eyes that had an increase in PD after near work in Group 2 was either equal to or increased compared to Group I, with the largest difference being related to mesopic PD. Chi and Lin noted in their study that an increase in pupil size during near work is likely to indicate the presence of visual fatigue, which is due to a reduction in the depth of field (22). In fact, the higher frequency of pupil enlargement in the smartphone users probably indicates more fatigue. Furthermore, it can be inferred that the use of a smartphone will probably cause the most symptoms in mesopic lighting conditions.

The evaluation of the changes in the dynamical components showed that both ocular activities cause changes in some of these elements so that all the parameters in Group 2, alongside with the velocity of contraction, and duration of dilation in Group I has changed after near work. A comparative study between the two groups showed that the average amount of change was different only in the initial diameter between the two groups which was higher in Group I. While surveying the frequency of changes in each component, it was shown that a higher percentage of eyes in the smartphone users group experienced an increase in latency of contraction and dilation; while even the rate of increase in the velocity of contraction and dilation has increased in a higher percentage of people in the Group I. As



it commonly accepted, the type of near work is effective in the rate of pupil changes so that the faster the images presented on the pages (23) or the need to follow objects (not just reading or viewing), (22) the rate of reduction in PD will be greater (24). The combination of this information shows that the use of smartphone in the dynamic elements of the pupil evaluation makes different changes than the reading a book, differences in the case-by-case study between the two groups were observable, but the mean differences of most dynamic parameters in the two groups were not statistically significant.

Finally, the results of the present study on the difference in PD between the two genders are contrary to the results of other previous findings. Various studies have shown that there is no difference in pupil size between the two genders, (25-27) the results of the present study showed that there was no difference between the two genders in static parameters and their changes, while the changes in most of the dynamic parameters were different between the two genders in both groups, which show a weaker dynamic performance of the males. Further studies are needed to evaluate the functional and neurological causes of the differences observed in the dynamic performance of pupil changes in males compared to females.

Among the limitations of the present study are the limited age range of the subjects and the lack of evaluation of changes in binocular vision parameters and their impact on the results. It is suggested that this information be analyzed in the future studies.

## Conclusion

Our study shows changes in dynamic and static elements of pupil changes after near work. So that both types of activities, reading a book and using smartphone make changes in the pupil components that can be shown to reduce pupil size, increase latency, and reduce the speed of change. It was also shown that the amount of changes in the three components of minimum, mesopic, and primary diameter was different between the two groups, and reading the book made more changes. The findings of the present study indicate that performing continuous ocular near work before ocular examinations can alter the results obtained in pupil dimension-dependent measurements; this issue should be considered by practitioners.

## Disclosures

**Ethics Committee Approval:** The present study was reviewed by the Ethics Committee of the School of Rehabilitation of Iran University of Medical Sciences and approved by the code IR.IUMS.REC.1398.1210.

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