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Comparison of Push-Up and Minus Lens Techniques for Measuring Amplitude of Accommodation in Emmetropic Individuals: A Cross-Sectional Study

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ABSTRACT

Background: *Amplitude of accommodation (AA) is a key clinical measure of near focusing capacity that declines with age and is used to identify accommodative dysfunction. Common subjective techniques—push-up and minus lens—often yield different AA values, complicating clinical interpretation and comparability across studies.* ***Objective:*** *To compare AA measured using push-up and minus lens techniques in emmetropic individuals and to evaluate age-related variation in technique-derived differences.* ***Methods:*** *A descriptive cross-sectional observational study was conducted at Chaudhry Muhammad Akram Teaching Hospital, Lahore, Pakistan (October 2021–July 2022). Seventy-five emmetropic participants aged 7–35 years (38 males, 37 females) were enrolled using purposive sampling (25 per age group: 7–12, 13–20, 21–35). Monocular AA was measured using a Royal Air Force (RAF) ruler with push-up and minus lens techniques under standardized conditions. Paired comparisons were performed using paired t-tests; correlations were assessed using Pearson's r (SPSS v25; p<0.05).* ***Results:*** *Push-up AA exceeded minus lens AA across all age groups (all p<0.001). Mean AA (push-up vs minus lens) was 15.52±1.08 D vs 13.48±1.03 D (7–12), 12.16±1.37 D vs 9.72±1.27 D (13–20), and 9.76±1.02 D vs 6.80±0.95 D (21–35). The overall mean paired difference was 2.48 D (95% CI 2.12–2.84; p<0.001), increasing with age (2.04 D to 2.96 D).* ***Conclusion:*** *Push-up technique systematically overestimates AA relative to the minus lens method in emmetropic individuals, with a clinically meaningful discrepancy that increases with age; technique consistency is essential for accurate diagnosis and follow-up.*

Keywords: *Amplitude of accommodation; Push-up method; Minus lens method; RAF ruler; Emmetropia; Age-related change.*

INTRODUCTION

Accommodation is a dynamic dioptric adjustment of the crystalline lens that enables the eye to maintain retinal image clarity during near viewing. The maximal accommodative capacity, defined as the amplitude of accommodation (AA), declines physiologically with age and serves as a fundamental clinical parameter in the diagnosis of accommodative insufficiency, accommodative excess, and early presbyopic changes. Accurate quantification of AA is therefore essential for appropriate refractive and binocular vision management, particularly in children and young adults where accommodative dysfunction may mimic or coexist with refractive and vergence anomalies (1). In clinical practice, subjective techniques remain the most widely used methods for assessing AA because they are inexpensive, accessible, and easily implemented in routine optometric settings despite the availability of objective autorefractive or dynamic retinoscopic approaches (1,2).

Among subjective techniques, the push-up method and the minus lens method are most frequently employed. The push-up technique determines AA by advancing a near target toward the eye until sustained blur is perceived, converting the near point of accommodation into dioptric power. In contrast, the minus lens method increases accommodative demand

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by introducing incremental negative lenses at a fixed working distance until blur is reported, summing the added lens power with the baseline near demand (2). Although both methods aim to quantify the same physiological construct, accumulating evidence suggests that they are not interchangeable and may yield systematically different results (3). The push-up technique has been consistently shown to produce higher AA values, partly due to increased angular target size as the stimulus approaches the eye, which enhances depth of focus and delays subjective blur perception (1,3). Conversely, the minus lens method minimizes target magnification effects but may underestimate accommodative amplitude because the imposed lens-induced demand does not fully replicate natural proximal and convergence cues present during real-world near tasks (2,4). These methodological differences introduce potential measurement bias that may influence clinical interpretation and diagnostic thresholds.

From a PICO perspective, the population of interest comprises emmetropic individuals without refractive error or ocular pathology, as refractive status can independently affect accommodative performance and introduce confounding variability. The intervention/exposure involves measurement of AA using the push-up technique, while the comparator is the minus lens technique. The primary outcome is the measured amplitude of accommodation in diopters, with particular interest in the within-subject mean difference between techniques and its variation across age strata. Age is a critical modifier because accommodative amplitude decreases predictably with advancing years, and measurement bias may not be uniform across developmental stages (4). Previous investigations in diverse populations have reported discrepancies between these techniques; however, reported magnitudes of difference vary considerably, likely reflecting differences in study design, age distribution, endpoint criteria, and measurement protocols (1–3). Moreover, most available data originate from non-local populations, and there remains limited evidence evaluating these techniques specifically in emmetropic cohorts within Pakistan, where demographic and clinical practice patterns may differ.

The absence of locally generated comparative data limits evidence-based interpretation of AA values in routine clinical settings. Without understanding the magnitude and direction of systematic differences between push-up and minus lens techniques, clinicians may inadvertently overestimate or underestimate accommodative capacity, potentially leading to misclassification of accommodative disorders or inappropriate management decisions. Furthermore, age-stratified analysis is essential to determine whether the discrepancy between techniques remains constant or widens across developmental stages. Addressing this gap has direct clinical relevance, particularly in pediatric and young adult populations where accommodative anomalies are commonly encountered.

Therefore, the present study aims to compare amplitude of accommodation measured using push-up and minus lens techniques in emmetropic individuals aged 7–35 years and to evaluate age-related variations in the magnitude of difference between methods. The primary research question is whether a statistically and clinically significant difference exists between push-up and minus lens measurements of AA within the same individuals, and whether this difference varies across predefined age groups. It is hypothesized that the push-up technique will yield significantly higher AA values than the minus lens method across all age strata, with the magnitude of discrepancy differing by age.

MATERIAL AND METHODS

This descriptive cross-sectional observational study was conducted at Chaudhry Muhammad Akram Teaching Hospital, Lahore, Pakistan, between October 2021 and July 2022 to compare amplitude of accommodation (AA) measured using push-up and minus lens techniques in emmetropic individuals. A cross-sectional within-subject comparative design was selected to allow direct evaluation of measurement differences between techniques under standardized clinical conditions, minimizing inter-individual variability and enhancing statistical efficiency for paired comparisons (5). The study population comprised healthy emmetropic participants aged 7–35 years. Emmetropia was operationally defined as spherical equivalent refractive error between –0.50 diopters (D) and +0.50 D, with astigmatism ≤0.75 D and anisometropia ≤0.75 D, determined through non-cycloplegic objective refraction followed by subjective refinement to best-corrected visual acuity of 6/6 or better in each eye. Individuals with any history of ocular pathology, prior ocular surgery, manifest strabismus, amblyopia, systemic disease known to affect accommodation, current use of medications influencing accommodative function, or presence of symptomatic binocular vision anomalies were excluded to reduce confounding influences on accommodative measurements (6).

Participants were recruited using non-probability purposive sampling from patients and attendants presenting to the outpatient department who met eligibility criteria. Potential participants were screened through detailed ocular and medical history, visual acuity assessment, refraction, and anterior and posterior segment examination using slit-lamp biomicroscopy and direct ophthalmoscopy. Written informed consent was obtained from adult participants and from parents or legal guardians for minors, with verbal assent obtained from children in accordance with ethical standards for research involving human subjects (7). Enrollment continued until the predetermined sample size was achieved.

Amplitude of accommodation was measured monocularly in the right eye for all participants to maintain methodological consistency and avoid inter-eye correlation effects. Measurements were conducted under standardized ambient illumination (approximately 300–500 lux) in a quiet examination room to minimize distraction. A Royal Air Force (RAF) ruler with a standardized high-contrast near target equivalent to N5 print (approximately 0.4 logMAR at 40 cm) was used for all assessments. For the push-up technique, the target was initially positioned at 40 cm and advanced toward the participant at a controlled rate of approximately 1–2 cm per second along the RAF ruler. Participants were instructed to maintain clear fixation and report the first point at which sustained blur occurred for at least two seconds. The near point distance in centimeters was recorded and converted to diopters using the formula AA (D) = 100/near point distance (cm). To improve reliability, two consecutive measurements were obtained with a one-minute rest interval, and the mean value was used for analysis.

For the minus lens technique, the near target was maintained at a fixed distance of 40 cm, corresponding to a baseline accommodative demand of 2.50 D. With the participant wearing best distance correction (plano for emmetropes), minus spherical lenses were introduced binocularly in 0.25 D increments in a trial frame while the fellow eye was occluded to ensure monocular assessment. Participants were instructed to report the first sustained blur lasting at least two seconds. The total minus lens power added at blur was recorded, and AA was calculated as the sum of the baseline near demand (2.50 D) and the total minus lens power introduced. Vertex distance was standardized at approximately 12 mm to minimize variability in effective lens power. As with the push-up method, two measurements were taken and averaged. To control for potential order effects and accommodative fatigue, the sequence of techniques was alternated between participants using simple random allocation generated prior to data collection, and a minimum rest period of two minutes was provided between techniques.

The primary outcome variable was amplitude of accommodation in diopters measured by each technique. The main independent variable was measurement technique (push-up versus minus lens), and age group (7–12 years, 13–20 years, and 21–35 years) was treated as a stratification variable for subgroup analysis. Sex was recorded as a demographic variable. Operational definitions were standardized before data collection, and all examiners underwent calibration training sessions to ensure uniform endpoint criteria and measurement procedures. Inter-examiner variability was minimized by assigning measurements to a limited number of trained optometrists following a predefined protocol. Data were recorded immediately on structured data collection forms and double-entered into a secure electronic database to ensure data integrity and minimize transcription errors.

The sample size of 75 participants was determined based on feasibility within the study period and was considered adequate to detect a moderate paired mean difference (effect size ≥0.5) between techniques with 80% statistical power at a two-sided alpha level of 0.05 (8). Statistical analysis was performed using IBM SPSS Statistics version 25 (IBM Corp., Armonk, NY, USA). Data were assessed for normality using the Shapiro–Wilk test and visual inspection of histograms and Q–Q plots. Continuous variables were summarized as mean ± standard deviation (SD), and categorical variables as frequencies and percentages. The primary comparison of AA between push-up and minus lens techniques was conducted using paired-sample t-tests for normally distributed differences. Mean paired differences with 95% confidence intervals (CI) were calculated to quantify effect magnitude. Age-stratified analyses were performed to assess variation in mean differences across predefined groups. Pearson's correlation coefficient (r) was used to evaluate the linear association between measurements obtained by the two techniques within each age group. A two-tailed p-value <0.05 was considered statistically significant. Missing data were minimized through immediate verification at the time of examination; complete-case analysis was applied as no missing outcome data were observed. Ethical approval was obtained from the Institutional Review Board of Chaudhry Muhammad Akram Teaching Hospital prior to study initiation, and the study adhered to the tenets of the Declaration of Helsinki (7). Participant confidentiality was maintained through anonymization of data using unique identification codes. Only the principal investigators had access to the password-protected dataset. All procedures were standardized and documented in a protocol manual to facilitate reproducibility by other researchers.

RESULTS

Table 1 summarizes the sample profile of 75 emmetropic participants. Gender distribution was essentially balanced, with 38 males (50.7%) and 37 females (49.3%). The age distribution was intentionally uniform across strata: 25 participants (33.3%) were aged 7–12 years, 25 (33.3%) were 13–20 years, and 25 (33.3%) were 21–35 years, ensuring comparable group sizes for age-stratified analyses.

Table 2 presents the core within-subject comparison of amplitude of accommodation (AA) measured by the two techniques and shows a consistent, statistically robust pattern across every age group: the push-up method produced higher AA values than the minus lens method. In children aged 7–12 years (n = 25), mean AA was 15.52 ± 1.08 D by push-up versus 13.48 ± 1.03 D by minus lens, yielding a mean paired difference of 2.04 ± 1.54 D (95% CI: 1.40 to 2.69; t = 6.62; p < 0.001) with a large paired effect size (Cohen's dz = 1.32). In participants aged 13–20 years (n = 25), mean AA decreased as expected but the method gap persisted: push-up 12.16 ± 1.37 D versus minus lens 9.72 ± 1.27 D, with a mean difference of 2.44 ± 1.87 D (95% CI: 1.66 to 3.21; t = 6.52; p < 0.001; dz = 1.30). In the oldest stratum (21–35 years; n = 25), mean AA was lowest overall, yet the discrepancy was largest: push-up 9.76 ± 1.02 D versus minus lens 6.80 ± 0.95 D, with a mean paired difference of 2.96 ± 0.59 D (95% CI: 2.73 to 3.18; t = 25.09; p < 0.001; dz = 5.02). When all participants were pooled (n = 75), mean AA was 12.48 ± 2.79 D by push-up compared with 10.00 ± 3.08 D by minus lens, corresponding to an overall mean difference of 2.48 ± 1.57 D (95% CI: 2.12 to 2.84; t = 13.54; p < 0.001), again indicating a large overall paired effect (dz = 1.56). Numerically, the mean technique gap increased with age from 2.04 D (7–12) to 2.44 D (13–20) to 2.96 D (21–35), suggesting that the magnitude of method-related bias was not constant across age groups.

Table 3 evaluates age-related changes in AA within each technique and quantifies the expected decline across age groups. Using the minus lens method, mean AA fell from 13.48 ± 1.03 D (7–12 years) to 9.72 ± 1.27 D (13–20 years) and further to 6.80 ± 0.95 D (21–35 years), with a highly significant overall age effect (F = 182.4; p < 0.001). The push-up method demonstrated the same monotonic decline: mean AA decreased from 15.52 ± 1.08 D (7–12 years) to 12.16 ± 1.37 D (13–20 years) and then to 9.76 ± 1.02 D (21–35 years), again with a strong age effect (F = 163.7; p < 0.001). Taken together, these values show that AA declines substantially with increasing age regardless of technique, while push-up values remain consistently higher than minus lens values at each age.

Table 4 describes the association between the two techniques by age group using Pearson correlation. In the 7–12-year group (n = 25), the correlation between push-up and minus lens AA was moderate-to-strong (r = 0.65) with a 95% CI of 0.35 to 0.83 (p = 0.001), indicating that participants with higher AA by one method tended to also have higher AA by the other. In the 13–20-year group (n = 25), the association strengthened (r = 0.72; 95% CI: 0.45 to 0.87; p < 0.001). The strongest relationship was observed in the 21–35-year group (n = 25), where measurements were almost perfectly aligned in rank order (r = 0.98; 95% CI: 0.95 to 0.99; p < 0.001).

Table 1. Demographic characteristics of study participants (n = 75)

Variable	Category	n	%
Gender	Male	38	50.7
	Female	37	49.3
Age group (years)	7–12	25	33.3
	13–20	25	33.3
	21–35	25	33.3

Table 2. Comparison of amplitude of accommodation (D) measured by push-up and minus lens techniques across age groups

Age Group (years)	n	Minus Lens Mean ± SD (D)	Push-Up Mean ± SD (D)	Mean Difference (Push-Up – Minus) (D) ± SD	95% CI of Difference	t-value	p-value	Cohen's dz
7–12	25	13.48 ± 1.03	15.52 ± 1.08	2.04 ± 1.54	1.40 to 2.69	6.62	<0.001	1.32
13–20	25	9.72 ± 1.27	12.16 ± 1.37	2.44 ± 1.87	1.66 to 3.21	6.52	<0.001	1.30
21–35	25	6.80 ± 0.95	9.76 ± 1.02	2.96 ± 0.59	2.73 to 3.18	25.09	<0.001	5.02
Overall (7–35)	75	10.00 ± 3.08	12.48 ± 2.79	2.48 ± 1.57	2.12 to 2.84	13.54	<0.001	1.56

Table 3. One-way ANOVA showing age-related variation in amplitude of accommodation (D)

Technique	Age Group (years)	Mean ± SD (D)	F-value	p-value
Minus Lens	7–12	13.48 ± 1.03	182.4	<0.001
	13–20	9.72 ± 1.27		
	21–35	6.80 ± 0.95		
Push-Up	7–12	15.52 ± 1.08	163.7	<0.001
	13–20	12.16 ± 1.37		
	21–35	9.76 ± 1.02		

Table 4. Correlation between push-up and minus lens measurements by age group

Age Group (years)	n	Pearson's r	95% CI for r	p-value
7–12	25	0.65	0.35 to 0.83	0.001
13–20	25	0.72	0.45 to 0.87	<0.001
21–35	25	0.98	0.95 to 0.99	<0.001
Overall (7–35)	75	0.89	0.83 to 0.93	<0.001

Overall, across all 75 participants, push-up and minus lens AA were strongly correlated ($r = 0.89$; 95% CI: 0.83 to 0.93; $p < 0.001$). This pattern indicates that, despite systematic differences in absolute AA values (push-up higher), both techniques track accommodative capacity similarly, with agreement in relative ordering becoming especially pronounced in the older age group.

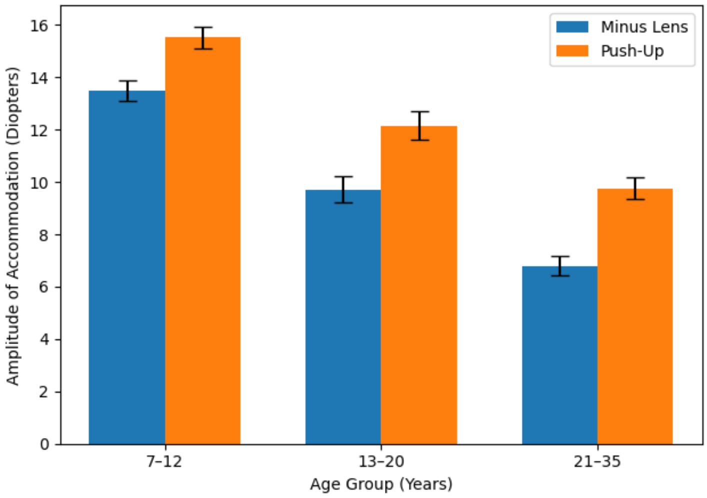

Figure 1 . Age-stratified comparison of amplitude of accommodation (D) measured by push-up and minus lens techniques with 95% confidence intervals

This figure demonstrates a clear age-dependent decline in amplitude of accommodation (AA) for both techniques, alongside a progressively widening absolute difference between methods. In the 7–12-year group, mean AA measured by push-up was 15.52 D (95% CI approximately 15.09–15.95) compared with 13.48 D (95% CI approximately 13.08–13.88) by minus lens, reflecting a mean gap of 2.04 D. In adolescents aged 13–20 years, AA declined to 12.16 D (95% CI approximately 11.62–12.70) with push-up and 9.72 D (95% CI approximately 9.22–10.22) with minus lens, increasing the absolute method difference to 2.44 D. In adults aged 21–35 years, AA further decreased to 9.76 D (95% CI approximately 9.36–10.16) and 6.80 D (95% CI approximately 6.43–7.17) for push-up and minus lens, respectively, yielding the largest observed discrepancy (2.96 D). Notably, the non-overlapping confidence intervals between techniques within each age stratum reinforce the statistical significance (p < 0.001 across groups) and suggest a clinically meaningful systematic overestimation by the push-up method that becomes proportionally greater as accommodative amplitude declines with age

DISCUSSION

The present study demonstrates a statistically and clinically significant discrepancy between push-up and minus lens techniques for measuring amplitude of accommodation (AA) in emmetropic individuals aged 7–35 years. Across all age groups, the push-up method yielded consistently higher AA values than the minus lens method, with a pooled mean paired difference of 2.48 D (95% CI: 2.12–2.84; p < 0.001).

Importantly, the magnitude of this difference increased with age, from 2.04 D in children (7–12 years) to 2.96 D in adults (21–35 years), indicating that method-related bias is not constant across the accommodative lifespan. These findings confirm the primary hypothesis that push-up measurements overestimate accommodative capacity relative to minus lens measurements and extend prior evidence by quantifying the age-stratified gradient of this discrepancy within a Pakistani emmetropic population.

The observed systematic overestimation by the push-up technique is consistent with established optical and perceptual mechanisms. As the near target advances toward the eye during push-up testing, the angular size of the target increases, effectively enhancing depth of focus and delaying subjective blur detection (1,3).

This optical magnification effect artificially elevates the measured near point, leading to higher dioptric conversion values. In contrast, the minus lens method maintains a constant target size and working distance, thereby minimizing depth-of-focus amplification; however, it introduces lens-induced accommodative demand that may not fully replicate the natural integration of proximal, convergence, and blur cues present during real-world near viewing (2,4). The consistent 2–3 D difference observed in this study falls within the range reported in previous comparative investigations, which have documented clinically meaningful inter-method variability attributable to these methodological differences (3).

A clinically important insight emerging from the present analysis is the progressive widening of the absolute inter-method gap with advancing age. Although both techniques demonstrated the expected physiological decline in AA across age strata—minus lens values decreasing from 13.48 D (7–12 years) to 6.80 D (21–35 years), and push-up values from 15.52 D to 9.76 D—the relative bias of the push-up method became proportionally larger as accommodative amplitude diminished.

This pattern suggests that when true accommodative reserve is lower, perceptual and depth-of-focus factors may exert a proportionally greater influence on subjective endpoints. Clinically, this has direct implications for borderline cases in older adolescents and young adults, where a 2.5–3.0 D overestimation could mask early accommodative insufficiency or delay identification of reduced accommodative reserve.

Despite systematic differences in absolute values, a strong positive correlation was observed between techniques overall (r = 0.89, p < 0.001), with correlation strength increasing across age groups and reaching r = 0.98 in participants aged 21–35 years. This indicates that while the two techniques differ in scale, they track accommodative capacity similarly in terms of rank ordering. In other words, individuals with higher AA by one method tend to have higher AA by the other, particularly in older participants. This strong linear association supports the construct validity of both methods in assessing accommodative function, yet the consistent upward shift in push-up values confirms that they are not interchangeable. Agreement in ranking does not imply agreement in absolute magnitude, and clinical thresholds derived from one technique should not be directly applied to measurements obtained by the other.

From a diagnostic perspective, the magnitude of the observed bias is clinically meaningful. For example, accommodative insufficiency is often defined relative to age-expected norms; if push-up values overestimate AA by approximately 2–3 D, patients with marginal accommodative performance may be misclassified as normal when assessed exclusively with this method.

Conversely, minus lens measurements may appear comparatively reduced, potentially prompting earlier intervention. These differences underscore the importance of methodological consistency in both clinical follow-up and research comparisons. Using mixed techniques within the same patient or study cohort may introduce artificial variability that is unrelated to true accommodative change.

The strengths of this study include its within-subject paired design, equal age-stratified sampling, standardized measurement protocol using the same instrument (RAF ruler), and calculation of effect sizes and confidence intervals to quantify clinical magnitude rather than relying solely on p-values.

The controlled definition of emmetropia minimized refractive confounding, and randomization of test sequence reduced potential order effects. However, several limitations warrant consideration. First, accommodative amplitude was assessed using subjective blur endpoints, which are influenced by individual perceptual thresholds and depth-of-focus effects. Objective measures of accommodative response could have provided complementary data (1,2).

Second, the cross-sectional design precludes evaluation of longitudinal change or repeatability over time. Third, although the sample size was adequate for detecting moderate-to-large paired effects, broader population sampling would improve external validity.

Future research should explore agreement analysis using Bland–Altman methodology to quantify systematic bias and limits of agreement between techniques and determine clinically acceptable interchangeability thresholds (9).

Additionally, incorporating objective accommodative response measurements could clarify whether the minus lens method more closely approximates true accommodative ability or whether both techniques deviate from objective benchmarks under certain age conditions. Investigating symptomatic versus asymptomatic subgroups may further refine the diagnostic utility of each method.

In summary, this study confirms that the push-up technique significantly overestimates amplitude of accommodation relative to the minus lens method in emmetropic individuals aged 7–35 years, with a mean discrepancy of approximately 2.5 D that increases with age. Although both techniques are strongly correlated and demonstrate similar age-related decline patterns, they are not interchangeable for clinical or research purposes. Recognition of this systematic bias is essential to ensure accurate diagnosis of accommodative dysfunction and to maintain methodological consistency in both practice and future investigations.

CONCLUSION

In emmetropic individuals aged 7–35 years, amplitude of accommodation measured using the push-up technique was consistently and significantly higher than that measured using the minus lens technique, with an overall mean difference of approximately 2.5 D that increased progressively with age. Although both techniques demonstrated a strong positive correlation and reflected the expected age-related decline in accommodative amplitude, the systematic upward bias associated with the push-up method indicates that the two approaches are not interchangeable. Clinicians should therefore interpret values within the context of the specific measurement technique used and avoid applying normative thresholds derived from one method to results obtained by another. Methodological consistency is essential for accurate diagnosis of accommodative dysfunction and for ensuring valid comparisons in both clinical practice and research settings.

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DECLARATIONS

Ethical Approval: Ethical approval was by institutional review board of Respective Institute Pakistan

Informed Consent: Informed Consent was taken from participants.

Authors' Contributions:

Concept: ZM, AJ, SN, SI, SJ; Design: ZM, AJ, SN, SI, SJ; Data Collection: ZM, AJ, SN, SI, SJ; Analysis: ZM, AJ, SN, SI, SJ; Drafting: ZM, AJ, SN, SI, SJ

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