Original Research Article

Functional Mobility, Balance and Gait in Individuals with Early, Moderate and Advanced Primary Open Angle Glaucoma: A Pilot Study

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ABSTRACT

Background: Primary open angle glaucoma (POAG) is believed to impact 6.48 million individuals agedabove 50 years, its prevalence increasing with advancing age. Declines in visualfunction serve as astrong predictorfor theemergence ofgait, balance and mobility limitations in older adults. Moreover, individuals classified within the lowest tier of visual acuity exhibit markedly increased likelihoods of developing disturbances in balance and gait and are at significantly greater risk of falls.

Methods: A pilot cross-sectional study was carried out in a tertiary hospital in Mangalore, Karnataka on older adults ($\geq$ 55 years) with POAG. Each participant was assessed using POMA, Timed Up and Go test (TUG) and MOCA. The scoresof outcome measures across the early, moderate, and advanced stages of POAG were compared.

Results: Comparison analysis revealed that a significant deterioration was seen in functional mobility, gait, and balance in individuals with glaucoma, and the deterioration varies with disease severity.

Interpretation and Conclusion: There is a clear and statistically significant deterioration in mobility, balance,and gait as glaucoma progresses from early to advanced stages. This emphasizes the importance of early intervention and fall risk assessments in glaucoma management. The results of this study suggest that incorporating mobility tests into routine physical therapy assessments of individuals with early glaucoma may be beneficial.

KEYWORDS: Hydrophthalmos, Mobility Limitations, Postural Equilibrium, Walking Ability.

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INTRODUCTION

Retinal ganglion cell degeneration and visual field loss are hallmarks of POAG, a chronic, progressive optic neuropathy that often starts in the peripheral visual field before moving towards central vision in later stages [1].

Over 111.8 million people are expected to be impacted by it by 2040, making it one of the primary causes of permanent blindness worldwide [2]. Intraocular pressure (IOP) control and visual field preservation have always been the main goals of POAG treatment. Nonetheless, a growing corpus of physiotherapy and neuroscience studies highlights that POAG's effects go beyond the eyes, perhaps affecting

gait, postural control, balance, and functional mobility [3,4].

In order to maintain postural alignment, negotiate obstacles, and walk safely, visual information is very important for motor control. Peripheral impairments are sometimes not noticed by people with glaucoma, particularly in intermediate and severe stages, until they start to experience functional challenges including tripping, bumping into objects, or unstable balance [5,6].POAG has a fall risk that is two to four times greater than that of visually normal older persons, which is mostly due to these deficits [7].In the elderly population, falls are a leading cause of fractures, hospitalization, loss of independence, and death [8].

Abnormal gait metrics, such as decreased gait speed, increased double support time, shorter step lengths, and higher stride variability— particularly in low-light or dual-task situations—have been identified in POAG patients by recent physiotherapy-based studies [9,10].Additionally, research employing the Dynamic Gait Index (DGI), Berg Balance Scale (BBS), and TUG has demonstrated moderate to high associations between mobility dysfunction and visual field loss [11,12,13].

Given that visual field abnormalities are sometimes asymmetrical or go undetected until function is limited, these functional assessments are useful screening toolsin early rehabilitation planning [14].

Impairments to functional mobility are not just biomechanical. Multisensory processing impairments and cortical reorganization that impact balance and movement may be part ofglaucoma, according to mounting evidence from functional MRI andgait studies [15,16].

Thisemphasizes the necessity of thorough physiotherapy evaluation techniques that incorporate dynamic postural and mobility examinations in addition to visual assessments [17].

Despite this data, there are still few glaucoma-specific rehabilitation guidelines available. Physiotherapyinterventions, such as proprioceptive tasks, visual-motor integration therapy, and static and dynamic balance training, are underutilized in this group, according to a recent systematic review by Rodrigues-Braz et al. [18]. Additionally, there is evidence to support the inclusion of focused balance training as a fundamental part of physiotherapeutic care for glaucoma, as it can considerably lower fall risk even in those with established visual impairment [20].

Furthermore, there is still a lack of clarity in the physiotherapy literature about the motor effects of POAGin the early, moderate, and later phases [19].

By employing standardized physiotherapy outcome measures to assess and compare functional mobility, balance, and gait across POAG severity stages, this pilot study seeks to close this gap. Physiotherapists will be better able to customize early therapies that increase functional independence, decrease falls, and promote safetyfor people with glaucoma if they have a better understanding of stage-pecific motor alterations.

METHODS

A pilot cross-sectional study was conducted at a tertiary care hospital in Mangaluru, Karnataka, involving 21 participants aged between 55 and 86 years who were clinically diagnosed with early to advanced POAG. Participants were selected using a convenience sampling method.

Procedure: Ethical clearance was obtained from the Institutional Ethical Committee, and written informed consent was taken from all subjects. Each participant received a brief explanation of the testing procedures prior to assessment. An initial evaluation was conducted, including the collection of demographic data.

Inclusion criteria comprised both genders, the ability to ambulate independentlywithout assistive devices, and adequate cognitive function (MoCA score $\geq$ 26). The severity of POAG was classified by an ophthalmologist using the Humphrey Visual Field (HVF) test based on mean deviation values: Stage 1 ($\leq$ 6.00 dB), Stage 2 (6.01– 12.00 dB), and Stage 3 (12.01–20.00 dB). Participants with neurological or musculoskeletal disorders, significant sensory impairments, use of mobility aids, or

medications affecting balance were excluded. Functional mobility

wasassessedusingthe TUG test [21,22], and balance and gait were evaluated using thePOMA [23]. Data collected was tabulated and subjected to statistical analysis.

Statistical analysis: Descriptive statistics, including means, standard deviations, and standard errors, were calculated for TUG, POMA balance, and gait scores across early, moderate, and advanced glaucoma stages. Categorical variables were summarized using frequencies and percentages, and bar charts were used for data visualization. One- way ANOVA was performed in Jamovi (version 2.4.11) to compare groups, with significance set at p < 0.05. Significant ANOVA results were followed by Tukey's HSD test for pairwise comparisons. A total of 21 older adults 18 men and 3 women (7 per group) meeting the inclusion criteria completed all assessments for functional mobility, balance, and gait.

RESULTS

Table1: GroupDescriptive

Glaucoma stage	N	AGE (Mean ± SD / SE)	TUG (Mean ± SD / SE)	BALANCE (Mean ± SD / SE)	GAIT Mean ± SD / SE)
Early	7	67.9 ± 2.67 / 1.01	12.7 ± 1.7 / 0.643	12.14 ± 1.069 / 0.404	9.86 ± 1.215 / 0.459
Moderate	7	66.1 ± 1.68 / 0.634	14.8 ± 1.47 / 0.555	9.43 ± 0.976 / 0.369	8 ± 1.0 / 0.378
Advanced	7	69.3 ± 4.5 / 1.7	18.5 ± 1.08 / 0.407	8.86 ± 0.9 / 0.34	7 ± 0.816 / 0.309

The table summarizes mean scores with standard deviation (SD) and standard error (SE) across glaucoma stages for age, TUG test, balance, and gait. Participants in the advanced stage weres lightly older (mean=69.3) com pared to early (67.9) and moderate (66.1) stages. TUG times increased with glaucoma severity, indicating reduced mobility—from 12.7 seconds (early) to 18.5 seconds (advanced). Balanceand gait scores decreased with advancing stages, showing a decline in stability and walking performance: balance scores dropped from 12.14 (early) to 8.86 (advanced), and gait from 9.86 to 7.

Table2: One-WayANOVA(Fisher's).

	F	df1	df2	p-value
TUG TEST	31.8	2	11.5	< .001
BALANCE	19.8	2	11.9	< .001
GAIT	12.6	2	11.7	0.001

The ANOVA results show no significant difference in a gea cross glaucoma stages (p=0.18). However, there were significant differences in Timed Upand Gotest (p<.001), balance (p<.001), and gait scores (p=0.001), indicating that functional mobility, balance, and gait significantly declined with glaucoma severity.

Table3: TukeyPost-HocTest.

TEST	Comparison	Mean Difference	t-value	df	p-value
TUG TEST	Early vs Moderate	-2.09	-2.71	18	0.036
	Early vs Advanced	-5.77	-7.5	18	< 0.001
	Moderate vs Advanced	-3.68	-4.79	18	< 0.001
BALANCE	Early vs Moderate	2.71	5.16	18	< 0.001
	Early vs Advanced	3.286	6.25	18	< 0.001
	Moderate vs Advanced	0.571	1.09	18	0.534
GAIT	Early vs Moderate	1.86	3.39	18	0.009
	Early vs Advanced	2.86	5.22	18	< 0.001
	Moderate vs Advanced	1	1.83	18	0.189

The Tukey post-hoc test revealed significant differences in TUG, balance, and gait scores between early and advanced glaucoma stages (p<.001), and between early and moderate stages for TUG and balance (p<0.05). Moderate vs. advanced comparisons showed significant differences for TUG (p<.001) but not for balance (p=0.534)or gait(p=0.189). This indicatesa progressive decline inmobility, balance, and gait with glaucoma severity, especially from early to advanced stages.

DISCUSSION

The TUG test and the POMA, two standardized physiotherapy outcome measures, were used in this study to examine stage-specific variations in functional mobility, balance, and gait among patients with early, moderate, and advanced POAG. Consistent with findings from many physiotherapy-based research [5,24,25], theresults showed a statistically significant deterioration in TUG performance as well as POMA balance and gait scores with increasing glaucoma severity.

TUG timings were much slower for participants

in the advanced POAG group than for those in the early and moderate phases (mean 18.5 vs. 12.7 and 14.8 seconds, respectively). Theseresults areconsistent with those of Ramulu et al., whodiscovered that when visual field loss increases, mobility dysfunction deteriorates proportionately. This is mainly because peripheral vision impairment impairs anticipatory and reactive balance regulation [3]. Persons with POAG have also been found to have altered gait, including shorter strides andlonger double supporttimes, particularly while doing tasks that require visual or cognitive processing [26,27].

In line with the findings of Haymes et al. and Black et al., who observed impaired balance strategies in moderate and advanced glaucoma due to delayed postural responses and poor visual-spatial feedback [6,28], balance scores in this study clearly declined from early to advanced stages. The declining scores in the gait component of POMA highlight the mounting evidence that POAG affects dynamic stability as opposed to static balance, which physiotherapists need to take into account during rehabilitation [9].

The progressive character of motor impairment in POAG is highlighted by the notable post-hoc variations in TUG and balance scores betweenearly and advanced stages as well as between moderateandadvanced stages. This is consistent with thefindings of Freeman et al., who hypothesized that in certain people, changes in mobility occur before obvious vision loss, indicating that motor assessments might be a moreaccurate indicator of thecourse of a disease than visual field tests alone [29].

According to current gait and neuroimaging research, these abnormalities are not just biomechanical from the standpoint of physiotherapy; they also represent neuronal adaptations anddeficiencies in multisensory integration[30,31]. Dual-task gaittests are essential for assessing the interaction between movement and cognition in POAG, especially in moderate and advanced phases, according to Tinetti et al. and De Lunaet al. [32,33].

Proprioceptive and visual-motor training are two balance-focused physiotherapy interventions that have demon strated no table improvements in functional outcomes for older persons with visual impairments [34]. In order to minimize falls and enhance safety and independence, our findings support early screening and stage-specific physiotherapy procedures for glaucoma patients.

The overall conclusions of the study emphasize how crucial it is to incorporate functional mobility and balance evaluations into routine therapy for glaucoma patients. Since even mild vision impairments can have quantifiable impacts on postureand gait, physiotherapists should use focused therapies from the outset. The data from the complete study will further add to the body of research, concerning mobility dysfunction in individuals with glaucoma.

CONCLUSION

The studyhighlights aprogressive declinein mobility, balance, and gaitwith advancing glaucoma severity. These findings support the need for early physiotherapy assessment and targeted interventions to reduce fall risk and maintain functional independence in individuals with POAG.

ABBREVIATIONS

POAG-PrimaryOpen-AngleGlaucoma
TUG-TimedUpandGo(Test)
POMA-Performance-OrientedMobilityAssessment
BBS -Berg Balance Scale
DGI - Dynamic Gait Index
IOP - Intraocular Pressure
MoCA-MontrealCognitiveAssessment
HVF-HumphreyVisualField
SD-StandardDeviation
SE-StandardError
Df- DegreesofFreedom
MRI-MagneticResonanceImaging
ANOVA-AnalysisofVariance
HSD-HonestlySignificantDifference
ICC-IntraclassCorrelationCoefficient

Author's Contribution

HaripriyaS: Conceptualization/Investigation/Resources/Writing–originaldraft.
Devika P: Conceptualization/ Methodology/Data curation/ Supervision/ Validation/ Writing original draft.
PrajwalU: Projectadministration/Methodology/Supervision/Writing–originaldraft.

Conflicts of interest: **None**

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