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Intraocular pressure responses to walking with surgical and FFP2/N95 face masks in primary open-angle glaucoma patients

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Abstract

Purpose The use of face mask is globally recommended as a preventive measure against COVID-19. However, the intraocular pressure (IOP) changes caused by face masks remain unknown. The objective of this study was to assess the impact of wearing surgical and FFP2/N95 face masks during a 400-m walking protocol on IOP in primary open-angle glaucoma (POAG) patients.

Methods Thirteen subjects diagnosed of POAG (21 eyes) were enrolled in this study. IOP was measured at baseline, during the 400-m walking protocol and after 5 min of passive recovery while POAG patients wore a surgical mask, FFP2/N95 mask and no mask in randomized order. From the 21 POAG eyes, we analyzed the IOP changes caused by physical exercise with two face masks and without wearing any face mask.

Results At rest (baseline and recovery measurements), the use of the different face masks did not affect IOP levels (mean differences ranging from 0.1 to 0.6 mmHg). During physical activity, wearing an FFP2/N95 mask caused a small (mean differences ranging from 1 to 2 mmHg), but statistically significant, IOP rise in comparison to both the surgical mask and control conditions (Cohen's $d = 0.63$ and 0.83, respectively).

Conclusion Face masks must be used to minimize the risk of SARS-CoV-2 transmission, and POAG patients can safely use FFP2/N95 and surgical masks at rest. However, due to the IOP rise observed while walking with the FFP2/N95 mask, when possible, POAG patients should prioritized the use of surgical masks during physical activity.

Key message

- Wearing face masks reduces the risk of COVID-19 infection, however, it has been associated with subjective breathing resistance and a reduced cardiopulmonary capacity.
- Primary open-angle glaucoma suffered a small significant intraocular pressure rise while walking with an FFP2 mask, but intraocular pressure did not differ between the surgical mask and control conditions.
- Face masks can be safely used by primary open-angle glaucoma, but surgical masks should be prioritized.

This article is Part of a topical collection on Perspectives on *COVID-19*.

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Introduction

The rapid spread of the current coronavirus (COVID-19), which is caused by severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2), has led to consider COVID-19 as a global pandemic. One of the preventive measures most used by health authorities around the world has been to recommend or force the use of face masks among the population both in open and close places. Face masks permit to minimize the risk of SARS-CoV-2 transmission [1], since the spread of droplets and aerosol particles is the main mode of person-to-person transmission [2, 3].

Physical exercise is linked to multiple health benefits [4], including improvements in the prevention and management of different ocular diseases [5, 6]. Regarding glaucoma, the only strategy that has proven to be effective to mitigate the progression of the disease is the reduction and stabilization of intraocular pressure (IOP) levels [7, 8]. The execution of low-intensity endurance exercise (e.g., walking, jogging, or cycling) has an IOP-lowering effect, which is highly recommended in glaucoma patients [9, 10]. However, recent investigations suggest that restricting the exchange of gases during resistance training exercises promotes an acute IOP rise [11, 12]. In addition, there are claims that face masks reduce cardiopulmonary exercise capacity and increase subjective breathing resistance, with these effects being more pronounced with FFP2/N95 in comparison to surgical masks [13, 14]. Nevertheless, some authors have questioned the validity of these findings, claiming that these results should in no way serve as a basis for avoiding mask use during exercise [14–16]. In view of the accumulated evidence, it is plausible to expect that wearing face masks during low-intensity endurance exercise may have an impact on the IOP behavior, which may have important implications for the management of glaucoma patients.

Based on the widespread use of face masks due to the COVID-19 pandemic and the lack of research in this regard, we designed a randomized clinical trial to determine the IOP responses to low-intensity endurance exercise (400-m walking) while wearing surgical and FFP2/N95 masks in primary open-angle glaucoma (POAG) patients. Considering the increments in IOP values reported in previous studies when the breathing pattern was restricted during the execution of resistance training exercises [11, 12] or under hypoxic and hypercapnic conditions [17, 18], we hypothesized that wearing face masks during walking would counteract the IOP-lowering effect frequently observed while performing low-intensity endurance exercises [9, 10].

Methods

Participants

Thirteen subjects (eight women) diagnosed of POAG were enrolled in this study (age = 68.3 ± 9.4 years). From the total number of patients, eight had bilateral POAG, and all of them were using hypotensive medications (nine patients were currently being treated with beta-blockers). Therefore, 21 eyes diagnosed of POAG were used for statistical analyses to increase the power of the study. This sample size permits a power of 0.80 for an assumed effect size of 0.25 and alpha of 0.05. The diagnosis of POAG was based on glaucomatous optic nerve head changes and visual field defects consistent with glaucoma, after the exclusion of other possible causes [19]. IOP was not considered for the diagnosis, and all 21 eyes had gonioscopically open anterior chamber angles. Optic disk damage was evaluated with Spectralis optical coherence tomography (Heidelberg Engineering Inc., Heidelberg, Germany), and visual field examinations were performed using Humphrey automated perimetry (24-2 Swedish Interactive Threshold Algorithm standard [20]; Humphrey Visual Field Analyzer; Carl Zeiss Meditec, Inc., Dublin, CA). This study followed the tenets of the Declaration of Helsinki and was approved by the local Ethical Committee of Biomedical Research. Signed informed consent was obtained from all participants.

Experimental design

The present multiple cross-over, self-controlled clinical trial was designed to determine the impact of wearing different face masks on the IOP response to a self-paced walking protocol in POAG patients (see Fig. 1 for a schematic illustration of the experimental design). Participants randomly performed the walking protocol under three conditions: (1) wearing a FFP2 face mask (Tomugi, CTT CO. LTD, Guangdong, China), (2) wearing a surgical face mask (3PLY, KRAPE SA, Madrid, Spain) masks, and (3) without wearing a face mask (control condition). The three walking protocols were performed in the same day separated by 10 min of passive rest. The time required to complete the walking protocol and the IOP were used as dependent variables.

Procedure

Upon arrival to the laboratory, participants were informed about the experimental procedure and signed the consent form. Afterwards, they performed a general warm-up

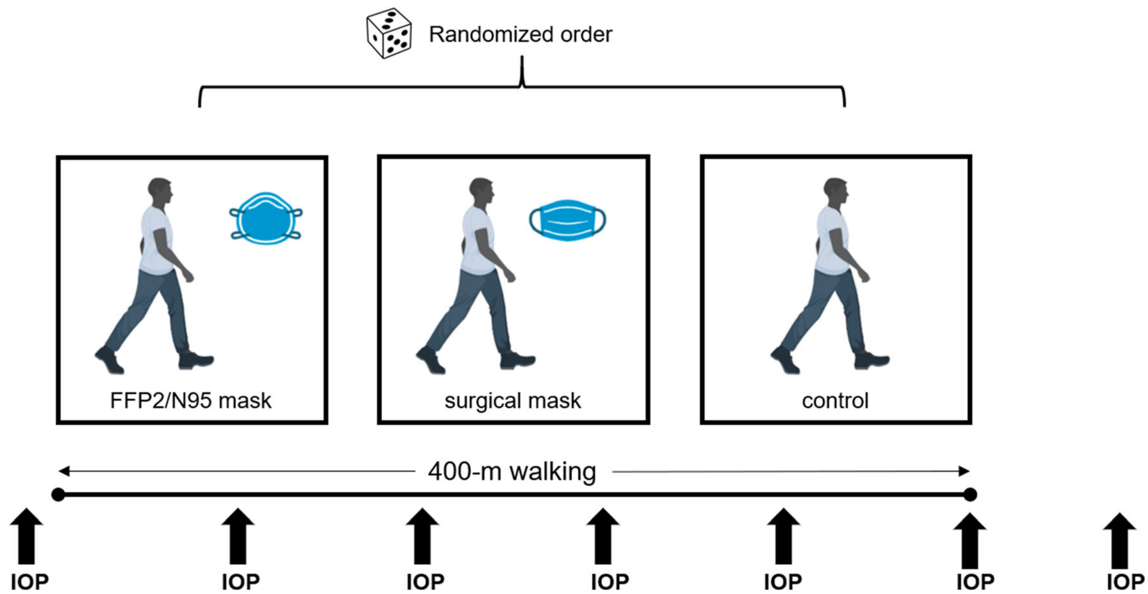

Fig. 1 Schematic illustration of the experimental design. IOP, intraocular pressure; m, meters

consisting of 5 min of joint mobility and dynamic stretching before the start of the 400-m walking protocols. The 400-m walking protocol consisted of 10 laps of 40 m. Each lap consisted of 20 m of walking in a straight line, a 180° change of direction, and 20 m of walking towards the starting line. A researcher always walked close to the participant and was responsible for measuring the time needed to complete each lap. Participants made a brief pause (~5–7 seconds) after two laps (i.e., 80 m), and another experienced researcher measured IOP from both eyes while the patients remained in a standing position. Participants performed the walking protocol in an indoor track at their usual pace.

IOP was measured from both eyes with a clinically validated rebound tonometer (Icare ic200, ICare Finland Oy, Helsinki, Finland), which has demonstrated to have a low intraobserver and interobserver variability [21, 22]. Following the manufacturer instructions, six rapid consecutive measurements were taken against the central cornea while the participants fixated on a distant target. In each of the three experimental conditions, IOP was obtained before walking, every 80 m of walking (five measurements, 80, 160, 240, 320, and 400 m), and after 5 min of passive recovery. Participants wore the mask of the specific experimental condition in the measurements that were performed before and after the walking protocols.

Statistical analyses

Descriptive data are presented as means ± standard deviation. The normal distribution of the data was confirmed with the Shapiro–Wilk test and the homogeneity of variances with the Levene's test ($P > 0.05$). A unifactorial analysis of variance (ANOVA) with the face mask (FFP2/N95, surgical, and control) as the only within-participant factors was used to check possible baseline differences on IOP. Afterwards, a two-way repeated-measure ANOVA was conducted on IOP values with the face mask (FFP2/N95, surgical, and control) and the point of measure (before exercise, during exercise [80, 160, 240, 320, and 400 m)], and after 5 min of passive recovery) as within-participant factors. Additionally, a unifactorial ANOVA with the face mask (FFP2/N95, surgical, and control) as the only within-participant factor was carried out to compare the time needed to complete the 400-m walking protocol (i.e., time needed to complete the 8 laps without considering the time required for IOP measurements). The Holm–Bonferroni procedure was applied when performing pairwise comparisons for the different points of measure. The magnitude of the changes was reported by the Cohen's *d* effect size (*d*) and partial eta squared (η^2_p) for *T* and *F* tests, respectively. Statistical significance was set at an alpha level of 0.05.

Results

Descriptive IOP values obtained for the three experimental conditions (FFP2/95, surgical, and control) at the different points of measure are depicted in Table 1. No significant differences in IOP values were observed at baseline between the three experimental conditions ($F_{2,40} = 0.95$, $P = 0.395$). Similarly, the time needed to complete the 400-m walking protocol did not differ between the experimental conditions ($F_{2,24} = 0.89$, $P = 0.423$; control = 332.9 ± 49.5 s; FFP2/N95 = 338.5 ± 50.0 s; surgical = 337.9 ± 57.3 s).

The two-way ANOVA revealed a statistically significant effect of the face mask ($F_{2,40} = 7.83$, $P = 0.001$, $\eta^2_p = 0.28$). Post hoc analyses revealed higher IOP values for the FFP2/N95

Table 1 Intraocular pressure values (average ± standard deviation) in the control, FFP2/N95 mask, and surgical mask conditions at the different points of measure

	Baseline	400-m walking protocol					Recovery
		80 m	160 m	240 m	320 m	400 m	5 min
Control (mmHg)	14.6 ± 2.3	13.7 ± 2.8	13.5 ± 3.2	13.5 ± 2.8	13.8 ± 2.6	13.4 ± 2.9	14.1 ± 3.1
FFP2/N95 (mmHg)	14.7 ± 2.6	14.6 ± 2.9	15.2 ± 2.9	15.4 ± 2.7	15.2 ± 2.6	15.7 ± 2.9	14.1 ± 2.9
Surgical (mmHg)	14.1 ± 2.9	13.4 ± 2.8	13.9 ± 2.9	14.1 ± 2.8	14.1 ± 2.8	14.7 ± 3.1	14.3 ± 3.2

mask condition in comparison to the surgical mask (corrected *P*-value = 0.013, d = 0.63) and control (corrected *P*-value = 0.001, d = 0.83) conditions, but no significant differences were detected between the control and surgical mask conditions (corrected *P*-value = 0.369, d = 0.20). The two-way ANOVA did not show a significant effect of the point of measure ($F_{6,120}$ = 1.72, P = 0.123). However, the interaction "face mask × point of measure" reached statistical significance ($F_{12,240}$ = 3.25, $P <$ 0.001, η^2_p = 0.14). Complementarily, we performed separate unifactorial ANOVAs for each experimental condition that revealed statistically significant effects of the "point of measure" for the control ($F_{6,120}$ = 2.94, P = 0.010, η^2_p = 0.13) and FFP2/N95 mask ($F_{6,120}$ = 4.64, P < 0.001, η^2_p = 0.19) conditions but not for the surgical mask condition ($F_{6,120}$ = 1.37, P = 0.234) (Figure 2). Lower IOP values during exercise compared to baseline were observed for the control condition, higher IOP values during exercise compared to baseline were observed for the FFP2/95 mask condition, and IOP remained stable during exercise compared to baseline for the surgical mask condition.

Discussion

Wearing face masks reduces the risk of COVID-19 infection, and, thus, the use of face masks is highly recommended or mandatory in many countries [1]. This study aimed to assess the impact of wearing different face masks on the IOP behavior while walking in POAG patients. Our data evidence that the IOP changes caused by wearing face masks are generally subtle. At rest (i.e., baseline and recovery measurements), no significant differences were observed between the experimental conditions, while during exercise, only the FFP2/N95 mask induced a heightened IOP response in comparison to both the surgical mask and control conditions (small increment of 1–2 mmHg). These results suggest that both face masks (FFP2/N95 and surgical) can be used at rest by POAG patients with no effect on IOP, while during walking, POAG patients are encouraged to wear surgical masks to maintain more stable IOP levels. Finally, if low-intensity aerobic exercise is prescribed to reduce IOP values, it seems that the only viable option would be to perform the exercise without wearing a face mask.

The regular practice of physical activity is an important strategy for maintaining a healthy lifestyle [4], even for reducing the risk of COVID-19 infection and complications [23, 24]. Glaucoma patients are encouraged to routinely perform low- to moderate-intensity aerobic exercise, since it has demonstrated to promote an IOP-lowering effect [9, 10]. The use of face masks has been associated with subjective breathing resistance and discomfort as well as with a reduced cardiopulmonary capacity [14]. However, a recent study found that wearing face masks during exercise has only minor effects on several physiological parameters (i.e., heart rate, blood pressure, respiratory rate), with these changes being more accentuated with greater

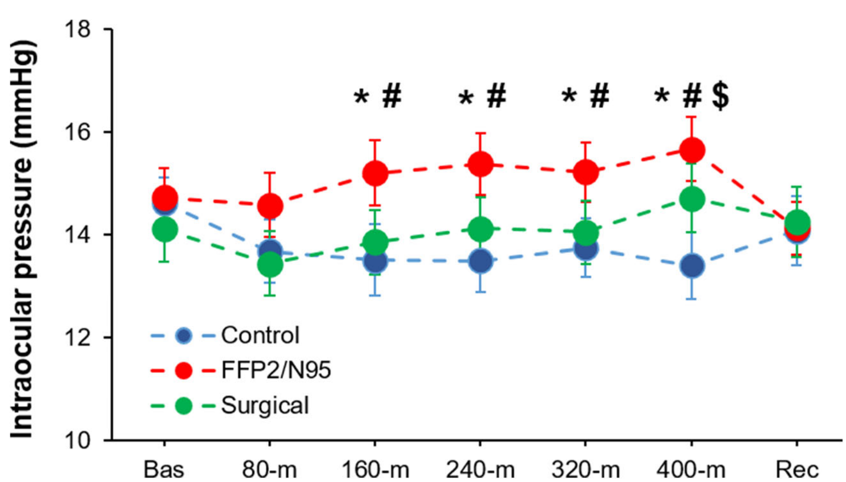

Fig. 2 Effects of wearing different face masks on IOP values collected in POAG patients before, during, and after a 400-m walking protocol. *, #, and $ denote statistically significant differences (corrected *P*-value < 0.05) at the different points of measure for the comparisons control vs. FFP2/N95, surgical vs. FFP2/N95, and control vs. surgical, respectively. Error bars represent the standard error. Note: Bas, baseline; Rec, recovery

levels of accumulated effort and a N95 mask [13]. These results are in line with our study in which we observed that the use of the FFP2/N95 mask while walking caused a significant, but relatively small, IOP rise in comparison to walking with a surgical mask or without a mask.

Hypercapnia has demonstrated to increase IOP levels [18], and the use of face masks during physical activity is associated with a rise in carbon dioxide and a decrease in oxygen levels [25]. Notably, these effects are dependent on exercise intensity, face mask type, and the presence of underlying conditions (i.e., chronic obstructive pulmonary disease, heart disease, etc.) [13, 14, 26, 27]. Therefore, eye care specialists should give individualized recommendations about the use of face masks to glaucoma patients based on the previously described mediating factors. Regarding IOP, Najmanová et al. (2019) [17] found a negative relationship between oxygen saturation and IOP levels during extreme normobaric hypoxia exposure. Also, the manipulation of the breathing pattern adopted during resistance training has demonstrated to alter the IOP behavior, observing a heightened IOP rise when the interchange of gases is compromised [11, 12]. Based on this, it is plausible that the alteration of gas concentration and the increased breathing resistance with face masks are responsible for the higher IOP values obtained in the FFP2/N95 mask condition, although further studies are needed to determine the physiological mechanisms responsible for these effects.

Due to the irruption of the COVID-19 pandemic, the effects of using face mask on the human physiology have recently gained researchers' attention. Indeed, eye care physicians must implement preventive strategies for SARS-CoV-2 transmission, including the use of face masks, in their clinical settings due to their proximity with the patient during visual examinations [28, 29]. However, there is no available scientific evidence about its impact on IOP, with this research question being of special relevance for glaucoma patients. In this population, maintaining or reducing IOP levels is highly desirable for the management of the disease [9, 10]. From the results of this study, we can state that wearing face masks while walking seems to be safe and feasible in POAG patients, but, when possible, surgical masks should be prioritized. Nevertheless, this study has some limitations that must be acknowledged for an appropriate interpretation of our findings. Due to the physical characteristics of the experimental sample and aiming to reproduce daily activities performed by an elderly population, we chose a 400-m walking task. However, the external validity of the current results to other physical efforts requires further investigation. This work is the first to analyze the impact of wearing different face masks during the execution of aerobic exercise on IOP, and, thus, future replication studies with larger sample sizes and including healthy control subjects are desirable. We consider of interest to explore whether the impact of wearing FFP2 face masks during low-intensity aerobic exercise on IOP levels could be compensated by non-POAG patients. In order to increase the power of the study, we have considered both eyes of patients with bilateral POAG. Nevertheless, the IOP changes caused by exercise may not be independent between eyes, and thus, we have repeated the analysis but only considering one eye (the most affected eye) from patients with bilateral POAG (n = 13). This analysis displayed very similar results to these observed in the main analysis, showing a statistically significant effect of face mask ($F_{2,24}$ = 4.02, P = 0.031, η^2_p = 0.25). Post hoc tests evidenced greater IOP values in the FFP2 condition in comparison to the control condition (corrected P-value = 0.043, d = 0.79), whereas no differences were obtained for the comparisons FFP2 vs. surgical masks (corrected P-value = 0.239, d = 0.47) and surgical mask vs. control (corrected P-value = 0.252, d = 0.33). Lastly, fitness level has demonstrated to be an important modulator of the IOP response to exercise [30, 31], and its role should be explored in future studies.

Conclusion

The IOP behavior while walking with an FFP2/N95 and surgical mask is mostly stable in POAG patients, which guarantees that this population can safely use face masks to minimize the risk of SARS-CoV-2 transmission. At rest, IOP levels were independent on the face mask used. However, wearing the FFP2/N95 mask during exercise caused a relatively small, but significant, IOP rise in comparison to both the surgical mask and control conditions. Therefore, when possible, surgical masks should be prioritized over FFP2/N95 masks while walking to avoid detrimental effects on IOP. Also, if low-intensity aerobic exercise is prescribed to reduce IOP values, the only effective strategy is performing exercise without any mask. In addition, health-care providers should give individualized recommendations about the use of face masks depending on the type of physical activity performed and underlying medical conditions in glaucoma patients.

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Declarations

Conflict of interest The authors declare no competing interests.

Ethics approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the University of Granada Institutional Review Board and with the 1964

Declaration of Helsinki and its later amendments or comparable ethical standards.

Consent to participate Informed consent was obtained from all individual participants included in the study.

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