Weightlessness and Space Travel Induced Ocular Adaptations: A Systematic Review

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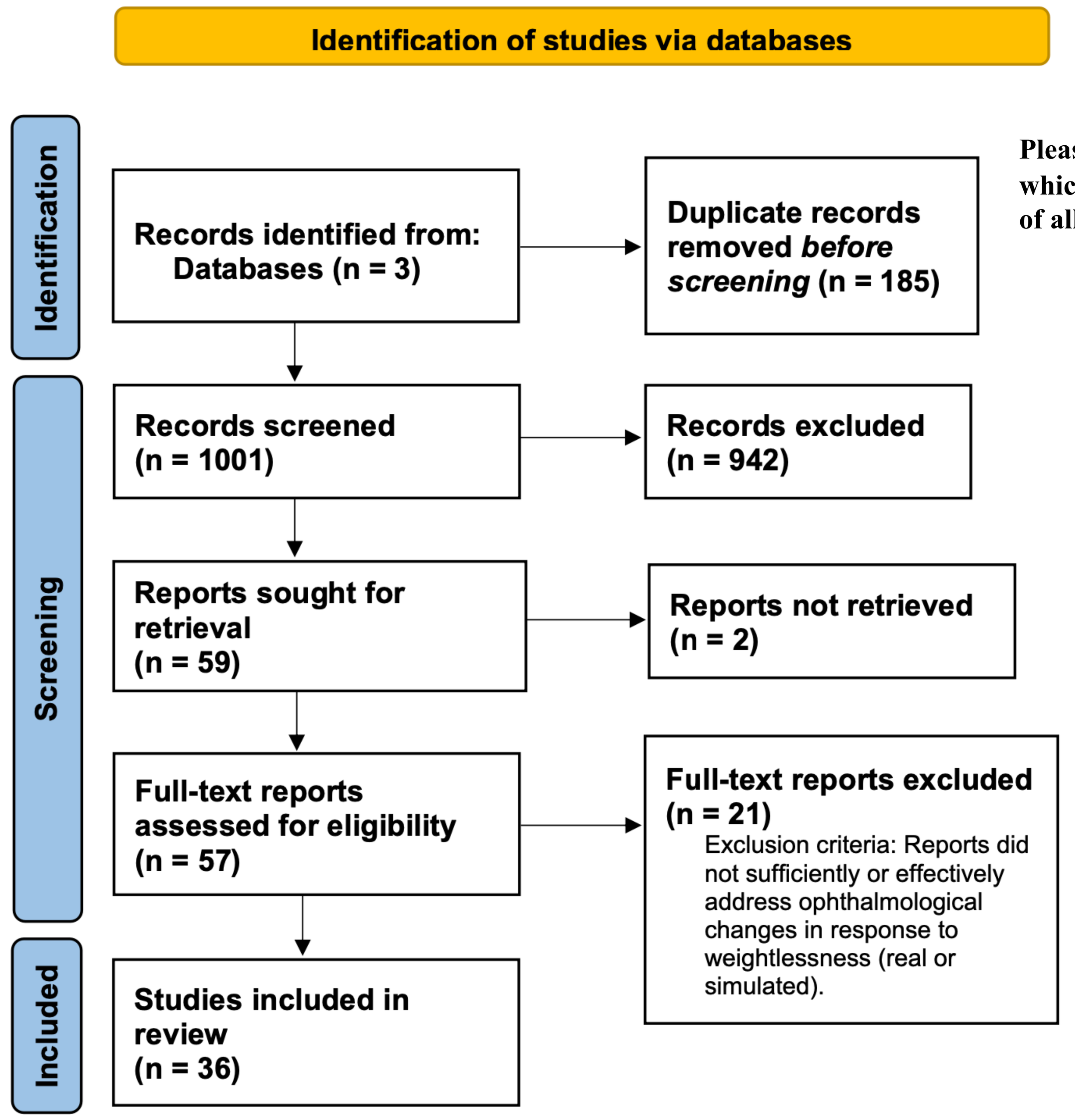
Purpose & Methods

- **Unique conditions in space**, such as weightlessness and radiation, **may induce significant ophthalmological adaptations** that pose risks to astronaut health. We conduct the first systematic review regarding the present landscape of space ophthalmology.



Please scan the QR code to access Table 1 which includes the full results summary of all 36 articles included for review.

Figure 1: PRISMA flow diagram.

- **The PubMed, Embase Cochrane databases** were searched in Nov 2023 with keywords related to space and ophthalmology.
- Only basic science and clinical studies in English concerning the study of ophthalmology and space were included. Case series, prospective and retrospective studies, and clinical trials that reported effects of space or simulated space conditions on the eye were retrieved.
- **A total of 36 studies** were included for final analysis for this review

Cellular Findings

Elevated levels of retinal oxidative stress, a critical marker of cellular damage, have been consistently observed in the spaceflight environment.

- Mao et al. studied 26 mice aboard the ISS for 35 days, reported that **mouse retinal oxidative stress was elevated** in spaceflight conditions (4-HNE fluorescent intensity marking oxidative stress increases from 24 to 33, p<0.05).
- Nguyen et al. reported **an increase in intracellular reactive oxygen species** (ROS) levels (DCFDA positive cell percentage in DMSO is 7 in 1G and 17 in microgravity on Day 3, p<0.001, and 19 in 1G and 28 in microgravity on Day 5, p<0.001).
- Overbey et al. noted significant **degradation of cone photoreceptors** (1199 counts/mm^2 to 950 counts/mm^2, p=0.06) and **increased oxidative stress in the retina** (4-HNE fluorescent intensity increases from 33 to 41, p<0.05).

The space environment also appears to enhance the rate of apoptosis.

- Mao et al. reported that **apoptotic cell death was 67% higher in spaceflight conditions** than on ground.
- Mao et al. reported **spaceflight-induced apoptosis in photoreceptors** (80 counts/mm^2 to 150 counts/mm^2, p<0.05) and **retinal vascular endothelial cells** (30 counts/mm^2 to 50 counts/mm^2, p<0.05). This suggests that vascular levels of blood-retinal barrier integrity-related proteins, including AQP-4, PECAM-1, and ZO-1 may have changed.
- Mao et al. reported that **retinal vascular endothelial cells in spaceflight underwent a significant amount of apoptosis**, with the weightlessness group experiencing the greatest amount of this (2.25 fold-change in microgravity, p<0.05), compared to all other groups including those exposed to artificial gravity.
- However, Cialdai et al. reported that **three days** on the **ISS had no effect on cell viability or apoptosis**, suggesting the effects of space conditions on cellular apoptosis might be influenced by the **duration of exposure.**

Clinical Adaptations

Important clinical findings include optic disc edema, choroidal folds, peripapillary tissue thickening, and globe flattening associated with weightlessness.

- Valencia et al. reported that **17.35% of the astronauts' images** showed evidence of grade 1 optic disc edema.
- Buckey et al. reported that the **heaviest weight quartile (55%)** had a higher chance of developing disc edema than the lightest (9%).
- Ferguson et al. reported that out of the 72 eyes in the study, **12 had chorioretinal folds (17%; affecting six crew members).**
- Hearon et al. reported that over the course of **three days of bed rest**, supine central venous pressure increased, resulting in choroid engorgement (increase in choroid area is 0.10 mm^2, p<0.001, and volume is 0.24 mm^3, p<0.001). Buckey et al. found that the mean weight of astronauts who experienced choroidal folds was **88.6 kg while the weight of those without was 78.6 kg**, p=0.02.
- Pardon et al. found a significant **peripapillary tissue thickening** in astronauts aboard the ISS (mean increase in minimum rim width (MRW) of 33.8 μm, p<0.001, on flight day 150 compared to preflight).
- Alperin et al. reported that only the **long-duration cohort showed significant increases in globe flattening and optical nerve protrusion** from pre- to post- flight.
- Mader et al. observed functional measurements indicating significant hyperopic shifts postflight, with changes ranging from **-0.25 to +1.75 diopters.** Notably, during long-duration ISS missions, **12% of astronauts reported decreased distance visual acuity, while 47.7% reported decreased near visual acuity.**