Original Research Article

Video-Based Measurement of the Pupillary Light Reflex for Baseline Neurological Analysis

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ABSTRACT

The pupillary light reflex (PLR) is a rapid, involuntary constriction of the pupil in response to light and is increasingly recognized as an objective marker of brainstem and autonomic function. Clinical pupillometers can quantify the PLR but are expensive and largely confined to medical settings, limiting access in the school and community sports environments where rapid neurological screening could be most valuable. This study evaluated whether key features of the PLR can be quantified using only consumer video equipment. Ten healthy participants (ages 15–35 years) were each tested three times, for a total of 30 trials. The pupillary response to a white light-emitting diode (LED) stimulus was recorded with a smartphone camera at a fixed distance, and pupil diameter was measured manually, in pixels, across extracted video frames. From these measurements, baseline diameter, minimum diameter, constriction magnitude, percent constriction, and time to minimum diameter were calculated. Baseline pupil diameter ranged from 138 to 161 pixels and minimum diameter from 112 to 122 pixels. Pupil constriction averaged 32.9 pixels, and the mean time to minimum diameter was approximately 0.55 seconds (range 0.4–0.7 seconds), with low within-subject variability (coefficients of variation ≤ 1.7%). Baseline diameter was positively associated with absolute constriction magnitude, and constriction scaled with initial pupil size rather than converging to a fixed minimum. These results show that core PLR features can be measured consistently in this small healthy sample and under the specific device and conditions used, without specialized clinical equipment. They provide preliminary, setup-specific descriptive values and support the feasibility of further developing and validating accessible, video-based PLR measurement, such as a portable sideline concussion scanner.

Keywords: pupillary light reflex; video-based measurement; pupillometry; concussion screening; neurological assessment

INTRODUCTION

Sports-related concussions remain a persistent public-health concern, particularly among young athletes. In the United States alone, an estimated 1.6 to 3.8 million sports- and recreation-related concussions occur each year, and many go unrecognized or are identified only after the initial period of risk has passed (1). A concussion, classified as a mild traumatic brain injury (mTBI), results from rapid linear and rotational acceleration of the head and can produce transient neurological dysfunction without visible structural damage (2). Because these changes are often subtle and may not produce obvious symptoms, concussions are difficult to recognize immediately after impact. On the sideline, trainers and

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Accepted July 15, 2026
https://doi.org/10.70251/HYJR2348.44327335

coaches must decide whether to remove an athlete from play within minutes of a collision, yet they rely largely on symptom checklists, balance assessments, and athlete self-report—methods prone to underreporting and delayed symptom onset (3). Athletes also have incentives to minimize or conceal symptoms in order to keep competing; surveys of high school players indicate that a large fraction of concussions go unreported, most often because the athlete does not think the injury is serious or does not want to be withheld from competition (4).

Part of what makes concussion difficult to detect is that the injury is functional rather than structural. The rapid acceleration and deceleration of the brain triggers a transient cascade of ionic and metabolic disturbances—indiscriminate neuronal firing, disrupted ion balance, and a temporary mismatch between the energy the brain demands and the energy it can supply—that impairs how neural circuits operate without leaving damage visible on standard imaging (2). Because the disturbance is physiological and often short-lived, conventional clinical scans typically appear normal, and the injury must instead be inferred from changes in function. This is precisely why measures that probe the timing and integrity of neural circuits, rather than their gross structure, are so valuable for detection at the point of injury.

The stakes of a missed concussion are high. Continuing to play while symptomatic exposes an athlete to repeat impacts before the brain has recovered, and recurrent concussions have been associated with cumulative and longer-lasting neurological effects (5). Yet the tools available at the moment of injury are largely subjective. Symptom checklists depend on accurate self-report; balance testing is affected by fatigue and effort; and both can appear normal in the minutes immediately after an impact even when the underlying neurology is disturbed (3). An objective measurement that can be taken quickly on the sideline would complement these methods by providing data that does not depend on what the athlete chooses to report.

Efforts to make sideline assessment more objective have produced standardized batteries that combine symptom inventories with brief cognitive and balance testing (3). Adjunct measures targeting eye movements have also been explored, since oculomotor functions such as saccadic speed and accuracy are sensitive to concussion (Table 1). These approaches add useful structure, but they still depend to varying degrees on athlete effort and cooperation, often require pre-season baseline testing for individual comparison, and may demand specialized equipment or trained administrators. A measurement that is quick, largely involuntary, and equipment-light would complement this toolkit rather than replace it.

The pupillary light reflex (PLR) offers a more objective window into this impairment. The reflex is mediated by a fast subcortical circuit: light detected in the retina is relayed through the midbrain to the parasympathetic pathway that constricts the iris, while sympathetic input governs the subsequent recovery of pupil size (6). Because this circuit passes through brainstem regions vulnerable to diffuse injury, the timing and magnitude of the PLR can change within milliseconds of a concussive impact, making it among the first systems to show measurable change after mTBI (7). Studies using automated infrared pupillometry have reported differences in PLR metrics—including longer constriction latency and reduced constriction velocity and amplitude—between concussed and healthy individuals (8, 9), and quantitative pupillometry is increasingly regarded as a candidate physiologic biomarker for concussion because it yields measurable data rather than relying on subjective report (10). A further advantage is that the reflex is largely involuntary: unlike symptom reporting or effort-dependent balance and cognitive tasks, the PLR cannot easily be suppressed or exaggerated by an athlete motivated to keep playing. Table 1 summarizes neurological indicators commonly

Table 1. *Neurological indicators commonly affected immediately after mild traumatic brain injury (mTBI), with associated brain pathways, typical timescale, and observed effects of concussion.*

Neurological Indicator	Brain Pathway Involved	Typical timescale	Effect of Concussion
Pupillary constriction latency	Brainstem (midbrain)	Milliseconds	Delayed constriction (8, 9)
Pupillary constriction velocity	Parasympathetic pathway	Milliseconds	Reduced constriction speed (8, 9)
Pupillary dilation recovery	Sympathetic pathway	Seconds	Prolonged recovery time (6, 10)
Saccadic eye movements	Cortical–brainstem network	Milliseconds	Reduced accuracy and smoothness (16)

affected after mTBI, together with their associated pathways and typical timescale.

Despite this potential, the equipment used to quantify the PLR objectively—automated clinical pupillometers—is expensive, stationary, and largely confined to hospitals, research laboratories, and elite athletic programs (8, 10). The settings where concussions occur most frequently, including school and community sports, typically have the least access to such tools (1, 11). Compounding the problem, the traditional bedside alternative—judging the pupil response subjectively with a penlight—has only moderate interrater reliability, which is precisely why objective, quantitative measurement is preferred (12, 13). This creates a gap between the moment of injury and any objective neurological assessment. If the same core measurements could be obtained with inexpensive, widely available video equipment, objective PLR screening could be brought much closer to the point of injury. Modern smartphones are nearly ubiquitous and now capture high-resolution video at high frame rates, and recent work has shown that a smartphone can be used to record and quantify the PLR for brain-injury assessment, making it a plausible platform for this kind of measurement (14).

The present study was designed as a measurement-feasibility study in healthy participants. The primary objective was to determine whether a smartphone camera and simple white-light stimulus could consistently quantify selected pupillary light reflex measurements across repeated trials. The prespecified primary outcome was time to minimum pupil diameter, defined as the interval from stimulus onset to the smallest measured pupil diameter. Secondary outcomes included baseline pupil diameter, minimum pupil diameter, absolute constriction magnitude, percent constriction calculated for each trial, and the relationship between baseline diameter and constriction magnitude. This study was not designed to diagnose concussion; rather, it evaluated whether a low-cost video-based workflow could produce repeatable descriptive PLR measurements that may support future development of accessible neurological screening tools.

METHODS AND MATERIALS

Participants

Ten healthy participants, aged 15 to 35 years, participated in this study. The investigator recruited participants as a convenience sample of volunteers and classmates between January and March 2026. The sample included 6 male participants and 4 female participants. The age distribution included 7 participants under 18 years of age and 3 participants who were 18 years of age or older. For this study, "healthy" was defined as having no self-reported current concussion symptoms, no recent head injury, no known neurological disorder, no known ocular disease affecting pupil response, and no use of medications known to affect pupil size or autonomic function. Participants were excluded if they reported a recent concussion or head injury, a history of neurological disease, significant ocular disease, current eye injury or infection, or medication use that could alter pupillary response. Consistent with the exclusion criteria, none of the participants reported a current neurological disorder, recent head injury, ocular disease affecting pupil response, or use of medications known to alter pupillary function. Participants were also asked about corrective-lens use, caffeine intake, sleep status, and recent exercise; these factors were queried informally but not systematically quantified, so their distributions are not reported, and the omission is acknowledged as a limitation. Because this study involved human participants, informed consent was obtained before data collection. For participants under 18 years of age, both parental or guardian consent and participant assent were obtained. Participant data were de-identified by assigning each participant a numerical code. Names and other identifying information were not included in the analyzed dataset. Video recordings and measurement files were stored securely and were accessible only to the investigator. Formal review or an exemption determination from an Institutional Review Board or equivalent ethics committee was not obtained because the study was conducted independently outside an affiliated institutional research program. Participation was voluntary; informed consent was obtained from adult participants, and parental or guardian consent and participant assent were obtained for minors. Data were de-identified and securely stored. The absence of prospective ethics-committee review is acknowledged as a limitation.

Apparatus, Stimulus, and Recording Conditions

Pupillary responses were recorded using the rear camera of an Apple iPhone 16 Pro at 120 frames per second and 4K resolution. The camera was positioned approximately 8 inches, or about 20 cm, from the participant's eyes. No external lens attachment was used. The zoom setting and camera-to-eye distance were kept constant across trials. Automatic exthis factor ise and

focus were not manually locked, and video stabilization remained at the smartphone's default automatic setting. Because automatic camera processing can affect apparent pupil size and brightness, this is acknowledged as a limitation of the study. A white light-emitting diode (LED) wall light was used as the visual stimulus. The stimulus was presented binocularly, with both eyes exposed to the same change in illumination and both eyes visible in the recording frame. The LED was first presented at a lower intensity to allow a baseline pupil measurement, then increased to a brighter level to elicit pupillary constriction, and finally switched off while recording continued. Each trial included an approximately 5-second baseline low-light phase, a 5-second brighter-light constriction phase, and a 5-second post-stimulus recovery phase. Testing was conducted indoors under controlled lighting conditions, with the same room and general setup used across participants. Participants were seated facing the camera and were asked to keep their gaze directed toward the camera area during recording. Before each trial, participants were allowed an adaptation period of approximately 30 seconds under the lower-light condition before the brighter LED stimulus was applied. The specific make and model of the LED wall light were not recorded, and room illumination, LED intensity at the eye, and LED wavelength or color temperature were not measured with a light meter or spectrometer. Therefore, the stimulus should be interpreted as a device-specific white-light stimulus rather than a precisely calibrated optical stimulus. This limitation is addressed in the Discussion.

Procedure

Each participant was seated facing the camera at the fixed distance described above, with both eyes within the frame. The eyes were first recorded at the lower light level to capture the baseline pupil diameter. The brighter LED stimulus was then applied, and recording continued as the pupils constricted and through the period after the light was switched off. This procedure was repeated three times per participant under the same conditions.

Measurement and Data Analysis

The complete video-based measurement workflow, from smartphone recording through manual frame measurement to the calculation of each outcome, is summarized in Figure 1. Each recorded video was separated into individual frames. Pupil diameter was measured manually in pixels using the ruler tool in Photopea, a free browser-based image editor. No automated pupil-detection software or computer-vision algorithm was used, and diameters were not calibrated to physical units. Therefore, all diameter measurements are reported in pixels and are specific to the camera, distance, resolution, zoom, lighting, and measurement workflow used in this study. Although both eyes were visible in the recording frame, they were measured separately for each trial, and the two measurements were averaged to obtain one pupil-diameter value per frame. Direct and consensual pupillary responses were not analyzed separately because the stimulus was presented binocularly rather than to one eye alone. The same measurement procedure was applied across all trials to maintain consistency. Pupil diameter was defined as the horizontal distance across the visible dark pupil, measured from the left pupillary border to the right pupillary border at the widest clearly visible portion of the pupil. Frames were excluded from measurement if the pupil border was obscured by blinking, eyelid obstruction, glare, gaze deviation, motion blur, or poor image quality. When brief artifacts occurred, the nearest usable frame with a clearly visible pupil boundary was used. Participants were asked to keep their gaze directed toward the camera area during recording to reduce gaze-related distortion. The 5-second pre-stimulus low-

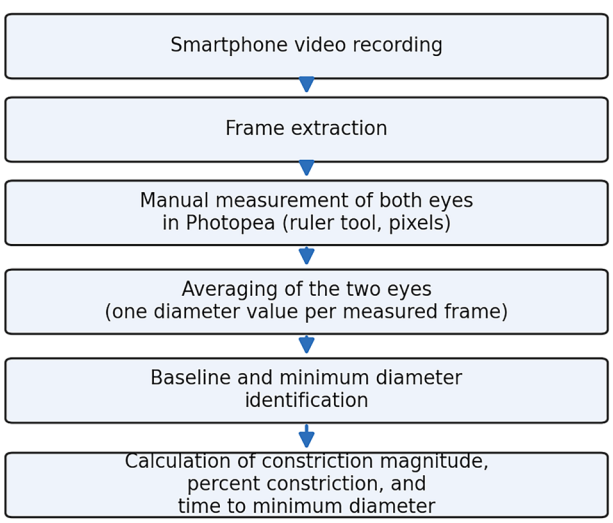

Figure 1. *Video-based measurement workflow. Pupillary responses to a white light-emitting diode (LED) stimulus were recorded with a smartphone camera; the video was segmented into frames, and pupil diameter was measured manually (in pixels) in selected frames. Baseline and minimum diameters were used to compute constriction magnitude, percent constriction, and time to minimum diameter.*

light period contained approximately 600 video frames. For each trial, five evenly spaced, artifact-free frames from the final 2 seconds of this period were selected for measurement, and the mean of their averaged (both-eye) pupil-diameter values was used as the baseline pupil diameter. The minimum pupil diameter was defined as the smallest clearly measurable pupil diameter observed during the brighter-light constriction phase. Time values were derived from frame position in the video sequence and the 120 frames-per-second recording rate, with each frame corresponding to approximately 8.3 milliseconds.

Three main outcomes were computed for each trial:

$\Delta d = d_{baseline} - d_{min}$

$\%C = (d_{baseline} - d_{min}) / d_{baseline} \times 100$

$t_{minimum} = t_{min} - t_{stimulus}$

Constriction magnitude, Δd, captures the absolute change in pupil size. Percent constriction, %C, expresses that change relative to the baseline pupil diameter for that individual trial. Time to minimum pupil diameter, minimum, measures the interval from stimulus onset to the smallest measured pupil diameter. This outcome was not interpreted as pure constriction latency because it includes both the delay before constriction begins and the duration of the constriction response.

All measurements were made manually by a single operator using the same procedure for every trial. The operator was not blinded to trial identity, and intra-rater repeatability, inter-rater reliability, and formal measurement error were not evaluated. These unresolved sources of measurement uncertainty are acknowledged as limitations of the study.

Statistical Analysis

Because the study was a feasibility evaluation with a small sample, analyses emphasized descriptive estimation rather than formal hypothesis testing. For each metric, the mean, standard deviation, range, and within-subject coefficient of variation across the 30 trials were computed, together with one-way intraclass correlation coefficients (ICC(1,1)) based on the three trials per participant. Associations between baseline diameter and the other measures were summarized using Pearson correlation coefficients with 95% confidence intervals, and percent constriction was calculated for each trial as (baseline − minimum) / baseline × 100 and summarized as the mean ± standard deviation. No null-hypothesis significance tests or prespecified significance thresholds were applied, because the sample was not intended to support inferential claims; instead, the consistency of values across repeated trials—both within and across participants—was used as an informal indicator of measurement reliability. This descriptive framing is appropriate for an early feasibility study, whose purpose is to establish whether the measurement can be made consistently at all rather than to test a specific clinical hypothesis.

RESULTS

Baseline and Minimum Pupil Diameter

Across the 30 trials, baseline pupil diameter ranged from 138 to 161 pixels, and the minimum diameter reached during constriction ranged from 112 to 122 pixels. Baseline diameters were tightly clustered within this range, indicating low inter-participant variability in resting pupil size under the controlled lighting conditions used.

Pupil Constriction Magnitude

Pupil constriction averaged 32.9 pixels. Constriction magnitudes ranged from 26 to 40 pixels, with most trials clustered near the mean of 32.9 pixels (Figure 2). Calculated per trial, percent constriction averaged 22.0% ± 1.5% (mean ± SD), ranging from 18.8% to 24.8% across the 30 trials.

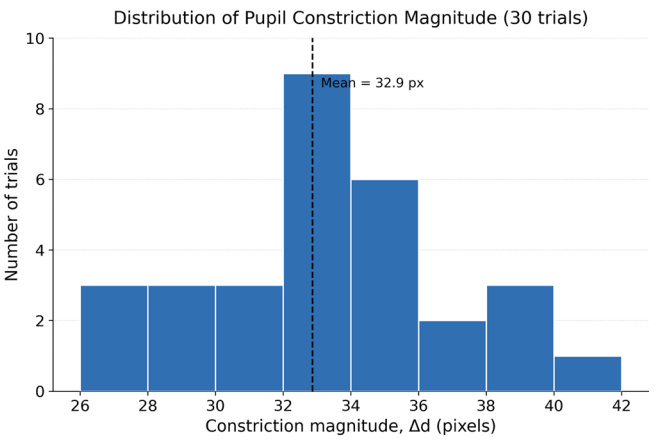

Figure 2. *Distribution of pupil constriction magnitude (Δd), in camera pixels, across all 30 trials (10 participants × 3 trials each). Δd is the difference between the baseline and minimum pupil diameter within a trial. Bars show the number of trials falling in each 2-pixel interval; the dashed line marks the mean of 32.9 pixels (SD 3.6; range 26–40). SD, standard deviation. Pixel values are specific to the camera, viewing distance, resolution, zoom, lighting, and manual measurement workflow used in this study and are not calibrated physical units.*

Relationship Between Baseline and Minimum Diameter

Minimum pupil diameter increased with baseline diameter: participants with larger baseline pupils reached larger minimum diameters, and baseline and minimum diameter were strongly positively correlated across the 30 trials (Pearson r = 0.96, 95% CI 0.92–0.98; Figure 3). The analytical unit was the individual trial (n = 30, three trials per participant); because trials were nested within participants, the same association computed on the ten participant means was similar (r = 0.98, 95% CI 0.90–0.99). A positive baseline–minimum correlation alone does not establish that larger baseline pupils constricted more, so baseline diameter was analyzed directly against constriction: baseline diameter was positively associated, at the trial level, with both absolute constriction magnitude (r = 0.98, 95% CI 0.95–0.99) and percent constriction (r = 0.93, 95% CI 0.86–0.97); as with the baseline–minimum correlation, these trial-level values should be interpreted with the caveat that the 30 trials were nested within ten participants. These direct analyses indicate that constriction scaled with initial pupil size rather than converging toward a single fixed minimum. Consequently, a normalized metric such as percent constriction provides a more comparable basis for comparison across individuals than absolute constriction alone.

Time to minimum diameter

The mean time to minimum diameter was approximately 0.55 seconds. Across the 30 trials, times to minimum diameter ranged from about 0.4 to 0.7 seconds, with most values clustered between 0.5 and 0.6 seconds. Time to minimum diameter was highly repeatable within participants: each participant's three trials clustered tightly around their own mean, while means differed across participants (Figure 4). Table 2 summarizes the key measured values, including the mean, standard deviation, and range for each metric. Repeatability across the three trials per participant was high: within-subject coefficients of variation were 1.7% or lower for every metric, and one-way intraclass correlation coefficients (ICC(1,1)) ranged from 0.89 to 0.99, indicating that most of the observed variation reflected genuine differences between participants rather than trial-to-trial measurement noise. These values should be read as within-study repeatability under a single operator and device, not as agreement against a reference instrument.

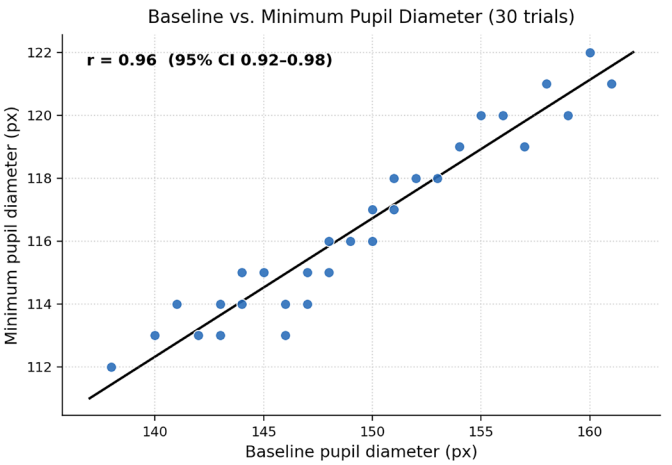

Figure 3. *Relationship between baseline and minimum pupil diameter across all 30 trials (10 participants × 3 trials each; one point per trial). Baseline and minimum diameter were strongly positively correlated (Pearson r = 0.96, 95% CI 0.92–0.98); the solid line is the least-squares fit. This plot shows the association between baseline and minimum diameter only; the direct relationship between baseline diameter and constriction magnitude is analyzed in the text. Because pixel values are device- and setup-specific, axis units are camera pixels rather than calibrated physical units. CI, confidence interval.*

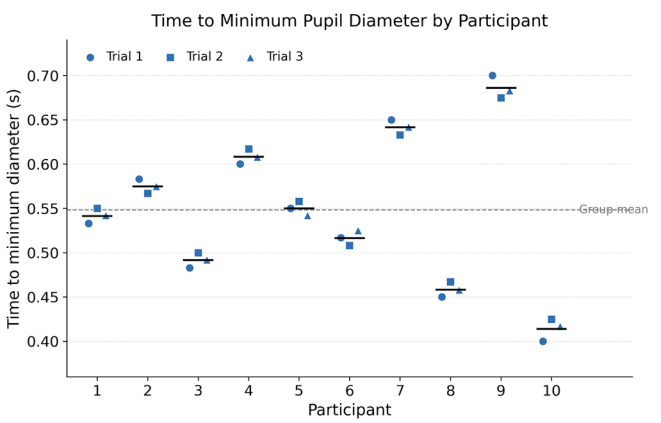

Figure 4. *Time to minimum pupil diameter for all 30 trials, grouped by participant. Each participant completed three trials, plotted as separate markers (circle, trial 1; square, trial 2; triangle, trial 3). The short horizontal bar shows that participant's mean; the dashed line shows the group mean (0.548 s). Trials are not connected, and no trend across trials is implied. Grouping by participant shows within-participant repeatability directly: the within-subject coefficient of variation (CV) was 1.7%, and the one-way intraclass correlation coefficient (ICC(1,1)) was 0.99.*

Table 2. *Summary of measured pupillary metrics across all 30 trials. Values are given as mean ± standard deviation (SD) with range. ICC, intraclass correlation coefficient (ICC(1,1), computed across the three trials per participant); CV, coefficient of variation; %C, percent constriction; px, pixels.*

Measurement	Value
Participants	10
Total trials	30
Baseline pupil diameter	149.3 ± 6.3 px (range 138–161); ICC 0.97; CV 0.7%
Minimum pupil diameter	116.4 ± 2.9 px (range 112–122); ICC 0.89; CV 0.9%
Average constriction (Δd)	32.9 ± 3.6 px (range 26–40); ICC 0.98; CV 1.5%
Average time to minimum diameter	0.548 ± 0.081 s (range 0.40–0.70); ICC 0.99; CV 1.7%
Percent constriction (%C)	22.0 ± 1.5% (range 18.8–24.8); ICC 0.97; CV 1.3%

DISCUSSION

These results show that core features of the pupillary light reflex—constriction magnitude and time to minimum diameter—can be quantified using only a smartphone camera and a simple white-LED stimulus. Constriction averaged 32.9 pixels, and time to minimum diameter was approximately 0.55 seconds, and both measures were consistent across repeated trials. This consistency suggests that meaningful PLR data can be captured without specialized clinical instrumentation in a form that could plausibly be deployed in non-clinical settings.

A deliberate feature of this study is that it measured only healthy participants. Although this means the data cannot speak directly to concussion detection, characterizing the normal range of a signal is a prerequisite for ever using it diagnostically. A measurement taken from an injured athlete is interpretable only against a backdrop of how the same measurement behaves in uninjured individuals—how large the typical constriction is, how quickly it occurs, and how much it varies from trial to trial and from person to person. By quantifying that backdrop with an accessible method, the present work supplies the kind of reference behavior that any future video-based screening effort would need before an abnormal response could be recognized as abnormal.

The proportional relationship between baseline and minimum diameter has a practical implication for measurement. Because absolute constriction scales with initial pupil size, comparisons across individuals are more reliable when expressed as percent constriction rather than as an absolute pixel change. The approximately 22 percent constriction observed here, together with the narrow range of baseline diameters, provides preliminary, setup-specific descriptive values in this small, healthy sample of individuals against which future, potentially abnormal, responses could eventually be compared. The stability of time to minimum diameter across trials is similarly encouraging, since a measure that varies little under normal conditions is better positioned to reveal change after injury.

Although this study did not compare its measurements against a clinical instrument, the quantities it captures—the magnitude of constriction and the time to reach minimum diameter—are conceptually the same measures that automated pupillometers report and that prior work has linked to concussion (8, 10). Characterizing how these quantities behave in healthy individuals is a necessary first step, because without preliminary descriptive values under comparable conditions, a later measurement from an injured athlete cannot be interpreted. A practical screening pathway would therefore proceed in stages: first confirming that consumer video can capture the relevant features reliably, as attempted here and demonstrated in related smartphone-pupillometry work (14, 15); then automating and calibrating the measurement; and finally validating it against clinical pupillometry and in populations with diagnosed concussion before any claim of screening utility could be made.

It is worth situating these pixel-based measurements relative to clinical pupillometry more carefully. Automated infrared pupillometers report constriction in calibrated physical units and derive parameters such as constriction latency, constriction velocity, and percentage change, several of which have been linked to concussion (8, 10). The present study captured the two most accessible of these constructs—the overall magnitude of constriction and the time to reach minimum diameter—but expressed them in uncalibrated pixels rather than millimeters. Consequently, the absolute values reported here are specific to the camera, distance, and resolution used and cannot be compared directly with published normative pupillometry data. What can be compared is the qualitative behavior: the direction, consistency, and proportionality of the response. The observation that constriction scales with baseline size, for instance, is a relationship that should hold regardless of measurement

units and therefore offers a unit-independent feature on which future calibrated work can build.

The practical appeal of a video-based approach lies in its accessibility. Clinical pupillometers cost hundreds to thousands of dollars and are concentrated in hospitals and well-resourced athletic programs, whereas a smartphone capable of high-frame-rate video is already carried by most coaches, parents, and athletic trainers. A method that extracts meaningful PLR features from such a device could, in principle, bring an objective neurological measure to the settings that currently rely almost entirely on subjective judgment—youth leagues, school teams, and rural or community programs. Prior smartphone-pupillometry systems have demonstrated that this is technically achievable (14, 15), and the present results contribute baseline reference behavior obtained with nothing more than a consumer phone and a simple light source. Such a tool would not replace clinical evaluation, but it could lower the threshold for flagging an athlete who warrants further assessment, helping to close the gap between the moment of injury and any objective measurement.

Set against its limitations, the study also has a notable strength: it shows that a fully manual, low-cost pipeline—a consumer smartphone, a simple light source, and free measurement software—can produce internally consistent PLR data. This lowers the barrier both for independent replication and for testing the approach in new populations and settings, which is itself a meaningful step for an accessibility-focused method.

Several limitations should be noted. First, all participants were healthy, so these data establish baseline behavior only and do not test whether the method can detect concussion-related changes. Second, measurements were made manually and reported in pixels rather than calibrated physical units, which limits direct comparison across cameras, viewing distances, and devices; manual frame-by-frame measurement is also labor-intensive and subject to observer variability. Third, the sample was small (ten participants, 30 trials) and spanned a wide age range, which the present analysis did not account for. Fourth, the temporal resolution of the time-to-minimum-diameter measurements is bounded by the recording frame rate; at 120 frames per second, each frame spans about 8 milliseconds, so reported times are finely resolved but still approximate. Finally, testing was performed indoors under controlled lighting and did not assess performance under the variable conditions of an actual sports sideline, nor did it include oculomotor measures such as saccades. Several additional factors may have influenced the measurements. Because the recording smartphone applied automatic exposure, focus, and gain adjustments, the captured frames reflect device-specific processing that was not controlled; the reported pixel values are therefore specific to the particular camera, viewing distance, resolution, zoom, lighting, and manual measurement workflow used here, and should be interpreted as setup-specific values rather than general reference norms. The intensity of the LED stimulus at the eye was not calibrated, and accommodation and gaze direction were not fixed, both of which can alter measured pupil size. Repeated light exposure across the three trials may have induced light adaptation, and trial order or participant fatigue could have contributed systematic effects that the present design cannot separate. Measurements were made by a single, non-blinded operator, and the method has not been validated against a reference clinical pupillometer, so the reported repeatability reflects internal consistency rather than clinical accuracy. The use of a single operator, a single device, and a convenience sample of volunteers further limits how far the present findings can be generalized.

These limitations point toward clear next steps. Replacing manual measurement with automated computer-vision detection would improve speed and reproducibility and remove observer variability, and calibrating pixel measurements to physical units would allow comparison across devices. Future versions could also extend beyond the two metrics measured here to capture constriction velocity, dilation recovery, and the latency between stimulus onset and the start of constriction—parameters that automated pupillometers already track and that may prove more sensitive to subtle injury than overall magnitude alone (10). Subsequent work could test the method under variable lighting and integrate the camera and LED stimulus into a single portable, handheld unit that performs on-device analysis and outputs a simple risk indicator—an accessible neuro-optical scanner intended for sideline use. Such a device would need to be validated against clinical pupillometry and tested in concussed versus control populations before any screening application. The present baseline study establishes the measurement feasibility on which that development depends.

CONCLUSION

This study demonstrates that key characteristics of the pupillary light reflex—baseline diameter, constriction magnitude, and time to minimum diameter—can

be measured consistently in healthy participants using a smartphone camera and a simple white-LED stimulus, without specialized clinical equipment. The measurements were stable and repeatable across trials, and constriction was found to scale with baseline pupil size. These findings provide preliminary evidence of within-study repeatability under the specific device, lighting, distance, and manual-analysis conditions used and support the feasibility of accessible, video-based PLR measurement as a foundation for developing a portable concussion-screening tool. Translating this approach into a diagnostic device will require automated measurement, calibration to physical units, and validation in clinical and concussed populations. More broadly, the study illustrates that careful measurement with widely available tools can generate usable physiological data, and that establishing how a signal behaves in healthy individuals is a necessary foundation before that signal can be relied upon to detect deviation from normal.

CONFLICT OF INTEREST

The author declares no conflicts of interest related to this work.

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