African Vision and Eye Health
ISSN: (Online) 2410-1516, (Print) 2413-3183

The effect of water consumption on the aqueous layer of the tear film

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Dates:
Received: 10 May 2024
Accepted: 25 Nov. 2024
Published: 28 Jan. 2025

How to cite this article:
Nirghin U, Dlamini SE, Mkhize N, Munsami T, Nzama N, Pillay R. The effect of water consumption on the aqueous layer of the tear film. Afr Vision Eye Health. 2025,84(1), a944. https://doi.org/10.4102/aveh.v84i1.944

Background: Tear deficient dry eye is a condition of insufficient tear production and may cause discomfort and visual disturbances, and if untreated, may cause ocular surface damage. While various treatment options have been explored and are available, these are usually costly and invasive.

Aim: This study aimed to investigate the effect of water consumption on the aqueous layer of the tear film.

Setting: University of KwaZulu-Natal Eye Clinic.

Methods: A quantitative experimental design was implemented on 85 healthy participants of both genders aged between 18 and 34 years old. Pre-screening procedures, followed by baseline Schirmer 1 readings were obtained on all participants. The participants thereafter consumed water in relation to their body mass. Schirmer 1 test was re-administered at time intervals of 15, 30, 45 and 60 min after water consumption.

Results: The mean baseline Schirmer 1 result prior to water consumption was 9.95 mm ± 4.52 mm. The mean Schirmer 1 results, at 15, 30, 45 and 60 min, following water consumption were 14.56 ± 5.82, 16.82 ± 5.44, 13.49 ± 4.82 and 11.54 mm ± 4.22 mm, respectively with a *P*-value of 0.000.

Conclusion: This study showed that water consumption has a statistically significant increase on the aqueous tear volume.

Contribution: Water consumption has been shown to increase aqueous tear production and may serve as a more affordable option to reduce dry eye symptoms.

Keywords: water consumption; tear film; dry eye; aqueous deficient dry eye; Schirmer test.

Introduction

The human body is comprised of approximately 75% of water, and it is widely known that increasing one's dietary water intake positively affects bodily functions.[1] An important constituent of the precorneal tear film is also water and is crucial to the health of the ocular surface. The tear film is comprised of three layers, namely, mucin, aqueous and lipid layers, with the aqueous layer, produced by the lacrimal system, being the thickest of all three layers and comprising 98% water.[2] A dysfunction of this system results in an aqueous deficient dry eye (ADDE).[3] Dry eye disease (DED) is defined as a 'multifactorial disease of the tears and ocular surface', resulting in tear film instability and hyperosmolality, causing symptoms of discomfort and visual disturbance. This in turn may result in inflammation with the potential to further damage the ocular surface.[3] Despite variation observed across age, gender and geographical location, DED has become increasingly prevalent, affecting up to 50% of the global population,[4] and is one of the most commonly reported eye conditions in clinical practice.[5]

The treatment of DED largely depends on its aetiology and severity.[3] Aqueous deficient dry eye is primarily managed with artificial tear supplements of varying viscosity, therapeutic contact lenses and moisture chamber goggles.[6] In more severe cases, invasive therapy is recommended with the use of topical and/or systemic medication such as pilocarpine, corticosteroids or anti-inflammatory drugs, punctal occlusion, and surgery. Furthermore, with the rise in DED and cost implications considering its long-term management, recent research has suggested that increasing the dietary content of macro and micronutrients yields positive outcomes for DED patients and provides symptomatic relief.[7,8]

While the effect of various constituents on the tear film, such as omega-3-fatty acids, Vitamins A and B6, potassium, zinc and caffeine, has been explored, with positive outcomes,[8,9,10] excess of dietary fats, salts, cholesterol and alcohol were associated with tear dysfunction.[9] This provides evidence that a link does exist between what we consume and the stability of tear film. As the aforementioned studies include water as a solvent in their procedure, and with water being the key constituent of the aqueous layer of the tear film,[2] the independent role of water on the tear layer has not been explored. The purpose of this study therefore was to investigate the effect of water consumption on the aqueous layer of the tear film. The results of this study may prove a cost-effective and accessible treatment for ADDE, particularly benefiting underserved populations where affordability and accessibility to other treatments are significantly challenged.

Materials and method

The study design was quantitative and experimental with the baseline Schirmer 1 test serving as the control to evaluate the intervention of water consumption. Schirmer 1 test was repeated post-water consumption, and the numerical data was compared.

Study sampling

The study population constituted students and staff from a tertiary institution and was selected through convenience sampling. With the assistance of a statistician and using the Powering Sample Size statistical software, a sample size of 85 was calculated based on an effect size of 0.5, a significance level of 0.05 and 80% power.[11] Participants aged between 18 and 34 years old, male and female, and of all race groups were invited to participate in the study.

A pre-screening assessment included the completion of a questionnaire to obtain demographic details and case history, slit lamp examination to rule out ocular pathologies, tear break-up time (TBUT) and baseline Schirmer 1 test to exclude dry eyes. Furthermore, great care was taken to ensure the validity of the results by eliminating confounding variables that may impact tear functioning. These included caffeine or water consumption 2 h before the commencement of the study as caffeine is known to affect the tear film,[10] while water consumption was the variable being studied. Smokers, those on medications, presenting with systemic diseases that affect the lacrimal gland, pathologies of the eyelids, eyelashes and conjunctiva, pregnant or with a tear break up time of less than 10 s or baseline Schirmer of less than 10 mm,[9,10,12,13] were excluded from the study considering these contribute to a non-optimal ocular surface. Participants with known hypersensitivity reactions and a history of anaphylaxis were also excluded as they may develop negative reactions to the fluorescein dye or the Oxybuprocain (0.4%) used.[14] Lastly, patients were not allowed to wear contact lenses during the study as previous research indicates contact lenses negatively impact the tear film.[15]

Procedure for data collection

All techniques performed were within the scope of optometric practice in South Africa. Only the right eye was used during the study as no statistical difference between data obtained from the right and left eye has been reported.[16] The data collection procedure consisted of a pre-screening evaluation to identify eligible participants, followed by body mass measurement, using a measuring scale, aimed to determine the required amount of water to consume per kilogram of mass and equivalent to 10 mL of water/kilogram of body mass.[10]

The experimental data collection commenced with an assessment of the baseline aqueous volume, using the Schirmer strips as the primary data-gathering instrument. While there are various tests available to assess dry eye, there is no single gold standard to date, and considering that the Schirmer test is readily available and most commonly used to assess tear volume,[5,13] this was the chosen data instrument for this study. The procedure for the Schirmer 1 test (with topical anaesthetic) was conducted as follows: one drop of topical anaesthetic, Oxybuprocain (0.4%), was instilled into the participant's right eye. Oxybuprocain is frequently used during the Schirmer 1 test to ensure patient comfort and minimise reflex tearing. Punctum occlusion was performed to reduce systemic absorption of the Oxybuprocain, and participants were informed to avoid rubbing their eyes for approximately 15 min after instillation of the drop. This was to minimise the risk of accidental corneal epithelial erosion.[17] Thirty seconds after the instillation of the drop, the cotton wisp sensitivity test was performed to ensure that the participants' anterior ocular surface was anesthetised.

The Schirmer strip was thereafter placed in the inferior temporal cul-de-sac of the lower eyelid. The participants were instructed to keep their eyes closed for 5 min to increase the reliability of the reading,[13] and to notify the researcher should they experience any discomfort. The Schirmer strip was then removed, and the length of wetting on the strip, which indicates the tear volume, was measured using the graticules printed onto the strip and recorded in mL. Within 5 min, the subjects consumed water, equivalent to 10 mL of water/kilogram of body mass,[10] dispensed using a measuring jug to ensure accuracy. The Schirmer 1 test was then reassessed and recorded at times 15 (T1), 30 (T2), 45 (T3) and 60 (T4) minutes following water consumption. A stopwatch was used to monitor time intervals for the duration of the study. Finally, a post-staining evaluation using fluorescein dye was performed to ensure that the integrity of the cornea and conjunctiva were not compromised following the use of the Schirmer strips. One drop of ocular lubricant, sodium carboxymethylcellulose (1%) was instilled into the right eye for patient comfort.

The Statistical Package for Social Sciences version 24.0 (SPSS, Inc., Chicago, IL, United States [US]) was used for all statistical analysis. Descriptive, *post hoc* multiple comparison, and paired *t*-test analyses were performed in which baseline Schirmer 1 test results were compared to the experimental

results. The Spearman correlation test was used to observe any relationships that may have existed between the grouped variables. A 95-percentile confidence index and a *P*-value of < 0.05 was considered statistically significant.

Ethical considerations

Approval to conduct this study was obtained from the institution's Ethics Committees (BE240/17) and the registrar. All the guidelines of the committee were adhered to before, during, and after the research study. This study followed the tenets of the Declaration of Helsinki with written informed consent obtained from the participants after an explanation of the nature and possible consequences of the study.

Results

The study comprised of 85 healthy participants with the demographic profile depicted in Figure 1. The participants were aged between 18 and 34 years (mean 21.06 ± 2.40 years); 51.8% (n = 44) were males and 48.2% (n = 41) were female; the majority being of African descent (61.8%, n = 52), and mass ranging from 39 kg to greater than 81 kg (mean 65.69 kg ± 13.94 kg) with a mean water consumption of 646.86 mL ± 147.68 mL.

The mean baseline Schirmer 1 test was 9.95 mm ± 4.52 mm being higher for males (10.32 mm ± 3.80 mm) and Indian (10.05 mm ± 5.20 mm) with $P < 0.05$ (Figure 2). No statistical difference existed between the different age groups nor mass to the baseline Schirmer 1 results ($P > 0.05$) (Figure 1).

Following water consumption, the mean Schirmer 1 results at T1, T2, T3 and T4 were 14.56 ± 5.82, 16.82 ± 5.44, 13.49 ± 4.82 and 11.54 mm ± 4.22 mm, respectively (Table 1).

When compared to baseline, a statistical difference was found across time points T1, T2, T3 and T4 ($P = 0.00$). Further analysis revealed that for males, the Schirmer 1 results increased from baseline to mean values of 15.43 mm ± 5.58 mm (T1), 17.80 mm ± 5.17 mm (T2), 14.95 mm ± 4.87 mm (T3) and 12.82 mm ± 4.16 mm (T4). A similar trend was observed on females, of 13.63 mm ± 6.00 mm (T1), 15.78 mm ± 5.59 mm (T2), 11.92 ± 4.28 (T3) and 10.17 mm ± 3.87 mm (T4). With respect to race, African participants presented with Schirmer 1 results of 14.62 mm ± 5.61 mm, 16.88 mm ± 5.48 mm, 12.92 mm ± 4.874 mm and 10.85 mm ± 4.01 mm, while Indian participants were 14.61 mm ± 6.29 mm, 16.58 ± 6.34, 12.80 mm ± 5.76 mm and 10.97 mm ± 4.72 mm for T1, T2 T3 and T4, respectively. Statistical differences ($P = 0.00$) were established when baseline Schirmer 1 results were compared to results at T1, T2, T3 and T4 for both gender and race, with males and Indians being statistically higher than females and African participants ($P = 0.00$) (Figure 2).

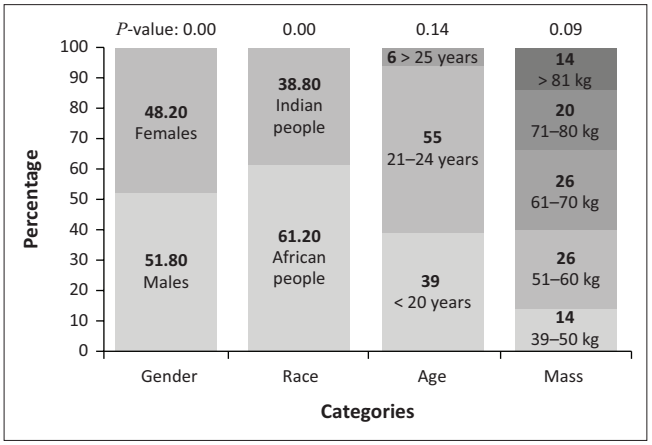
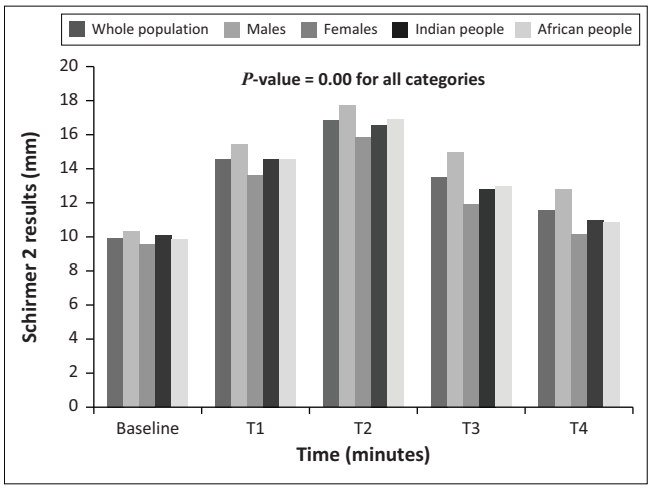


FIGURE 1: Distribution of gender, race, age and mass of the population (in %).

Discussion

The purpose of the study was to investigate the effect of water consumption on the aqueous layer of the tear film by administering and analysing the Schirmer 1 test before and after water consumption. Schirmer 1 test may be administered with or without topical anaesthesia, with the former assessing basal and reflex tearing while the latter reflecting basal tear secretion with minimal influence from reflex tearing and was thus selected for this study.[5,13,18] While studies have been conducted to assess various constituents on the tear film, to our knowledge, a study of this nature has not been undertaken before.

Participants included in the study presented with a mass ranging from 39 kg to 100 kg and were required to consume 10 mL per kilogram of body mass of water;[10] thus each participant consumed between 390 mL and 1000 mL of water within 5 min. The results showed a statistically significant increase in tear volume at times T1, T2, T3 and T4 underscoring the reliability of the results and the potential implications for understanding ADDE, its associated symptoms and management thereof. In addition to artificial tears, and patient advice as 'Step 1' in the management of DED, dietary advice is also recommended.[6] These results therefore provide evidence of an informed recommendation to hydrate in cases of ADDE. A peak



T1 - 15 minutes; T2 - 30 minutes; T3 - 45 minutes; T4 - 60 minutes.

FIGURE 2: Change in average Schirmer 2 results over time.

TABLE 1: Mean change in Schirmer 1 scores after water consumption at baseline, T1, T2, T3 and T4.

Variable	Schirmer 1 test results										*P*
	Baseline		T1		T2		T3		T4		
	Mean (mm)	s.d.	Mean (mm)	s.d.	Mean (mm)	s.d.	Mean (mm)	s.d.	Mean (mm)	s.d.	
Mean (mm)	9.95	4.52	14.56	5.82	16.82	5.44	13.49	4.82	11.54	4.22	0.00
Male	10.32	3.80	15.43	5.58	17.80	5.17	14.95	4.870	12.82	4.16	-
Female	9.55	5.20	13.63	6.00	15.78	5.59	11.92	4.28	10.17	3.87	-
African people	9.86	4.17	14.62	5.61	16.88	5.48	12.92	4.87	10.85	4.01	-
Indian people	10.05	5.20	14.61	6.29	16.58	6.37	12.80	5.764	10.97	4.72	-

T1 - 15 minutes; T2 - 30 minutes; T3 - 45 minutes; T4 - 60 minutes; s.d., standard deviation.

increase in aqueous tear volume was noted at T2 (30 min) after water consumption; thereafter, the tear volume appeared to have decreased. This could be because of the water metabolism rate in the body being approximately 25 min followed by tissue absorption.[19] It is worth noting, however, that the average tear volume at the end of the study was significantly higher than that of the baseline reading. This proves that there is a link between water consumption and the aqueous tear film reflecting a positive effect of hydration on tear volume.

Upon further analysis of the data, it was noted that male participants had statistically significant higher average baseline Schirmer 1 values compared to females. This is consistent with a study suggesting that males in general possess a higher average tear volume when compared to their female counterparts.[4] In addition, males presented with a consistently higher average change in tear volume throughout the study period (T1 to T4). This may be because of males having a higher total body water content than females,[20] possibly having a greater influence on the aqueous layer of the tear film. While studies found that females are at a greater risk of tear dysfunction compared to males,[4,5] one study specifically stated the greater incidence of ADDE in females.[21] The gender disparity in the current study could be attributed to differences in the sex-steroid hormones and hormonal changes during the menstrual cycle.[22] This may explain why greater change to the aqueous tear layer was observed in males than in females.

Indians were found to have a statistically higher baseline Schirmer 1 value compared to those of African descent implying greater tear volume. The study findings correlate with a previous study conducted in a similar setting with black participants having a higher prevalence of ADDE compared to Indians.[23] Contrary to these findings, racial variations are more likely reported in cases of evaporative dry eye (EDE) than ADDE because of geographical, climate and environmental factors.[21] The authors also stated that individuals with a compromised health status are more likely to present with ADDE than EDE. The current study, however, only included participants in good health; hence, the observed racial variation could not be attributed to associated comorbidities, highlighting the need for further studies exploring race as a risk factor for ADDE.

The relationship between age and mass to tear volume displayed a *P*-value greater than 0.05, suggesting that no correlation exists between these variables and tear volume as was similarly reported in a previous study.[24] While increased prevalence of DED with age has been reported,[4] this study ensured that there were no physiological differences in the tear film apparatus within the sample participants and that mass incorporated into the basal metabolic rate was accounted for; hence, no correlation was to be expected.

This study provides quantitative data on the Schirmer test following water consumption and at regular intervals. It further offers clear and objective results without the interference of confounding variables such as underlying health and ocular conditions that could impact tear production as were informed in previous studies.[6,18] Furthermore, the assessment of its effect at multiple intervals yields insight into the benefit of timed hydration on tear volume, serving as a recommended baseline guide for water intake in addition to daily activities. The limitation of the present study included only African and Indian participants, with no response from other race groups; hence, affecting generalisation of the results. Budget and time constraints restricted the use to the Schirmer test only, whereas a combination of other tests to assess tear volume could have added more value to this study. While this study has proven that water consumption has a statistically significant increase on tear volume, it is recommended that future studies be conducted on patients with DED to determine a possible clinical significance to symptomatic relief. Finally, despite excluding confounding variables, a randomised controlled design can further reduce bias from undisclosed variables, enhancing the reliability of the results independent of external factors.

Conclusion

This study provided evidence that water consumption increases aqueous tear volume, reaching a peak at 30 min post-consumption, followed by a steady decline, with tear volume still being statistically greater than baseline even at 60 min. The method of increasing water intake is simple and practical, making it a potential first-line recommendation for individuals experiencing ADDE. With a statistical increase in tear volume noted across gender and race, males and Indians had a statistically higher tear volume compared to females and Africans respectively, while age and mass showed no relationship with the change in aqueous tear volume.

Acknowledgements

The authors would like to acknowledge the University of KwaZulu-Natal as this article was adapted from an undergraduate research study.

This article is based on the authors thesis entitled 'The effect of water consumption on the aqueous layer of the tear film' towards the degree of Bachelor of Optometry, Department of Optometry, University of KwaZulu-Natal, South Africa, December 2017, with supervisor Dr U. Nirghin. It is available using this link: https://library.ukzn.ac.za/.

Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

Authors' contributions

U.N., S.E.D., N.M., T.M., N.N. and R.P. contributed to the design and implementation of the research, analysis of the results, data collection, and writing of the article.

Funding information

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Data availability

The data that support the findings of this study are available from the corresponding author, U.N., upon reasonable request.

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