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Public Health

The Relationship Between Serum Biochemical Variables and Corneal Biomechanics Measured by Corvis ST Among Healthy Young Adults

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Received: August 21, 2024
Accepted: January 8, 2025
Published: February 14, 2025

Keywords: corneal biomechanics; corvis ST; alanine aminotransferase; uric acid

Citation: Li DL, Liu MX, Zheng YJ, Qin Y, Ma R, Liang G, Pan CW. The relationship between serum biochemical variables and corneal biomechanics measured by Corvis ST among healthy young adults. Transl Vis Sci Technol. 2025;14(2):19, https://doi.org/10.1167/tvst.14.2.19

Purpose: To investigate the relationship between serum biochemical variables and corneal biomechanics in healthy young adults.

Methods: A total of 1645 healthy university students were included. Every student underwent an ophthalmologic examination by Corvis ST to measure the corneal biomechanics and a blood examination to evaluate the alanine aminotransferase (ALT), aspartate aminotransferase (AST), urea, creatinine, and uric acid (UA) levels. Canonical correlation analysis (CCA) was conducted to assess their relationship.

Results: A significant relationship between serum biochemical variables and corneal biomechanics was found in both men and women. For men, the canonical correlation identified an association between the time of the first applanation (A1t), time of the second applanation (A2t), time of the highest concavity (HC-t), deflection amplitude of the highest concavity (HC-DeflA), and biomechanically corrected intraocular pressure (bIOP) with ALT, AST, urea, and UA ($r = 0.235$, $P = 0.03$). For women, a significant relationship between A1t, A2t, and bIOP with ALT and UA was found ($r = 0.187$, $P < 0.01$).

Conclusions: Elevated levels of ALT and UA were associated with softer corneas with greater elasticity and viscidity. The study provides novel evidence for the relationship between serum biochemical variables and ocular changes.

Translational Relevance: These findings may help clinicians perform adequate preoperative evaluations when performing corneal surgery on patients with liver or kidney disorders, as well as helping public health practitioners understand serum biochemical variables of corneal changes in healthy people.

Introduction

Corneal biomechanics is a primary property of the cornea, reflecting the ability to maintain the shape of the cornea under intraocular pressure (IOP) and to absorb and dissipate energy from external forces.[1] Corneal biomechanics can partly evaluate ocular health, as various ocular diseases are associated with corneal biomechanical alterations, such as glaucoma,[2] keratoconus,[3] and myopia.[4] Thus, corneal biomechanics measurements are widely utilized in clinical diagnosis and treatment.

Understanding corneal biomechanics can help interpret pathologies of related diseases and improve refractive surgeries. Previous studies have investigated various factors related to corneal biomechanics,[5] from corneal inherent structure to environmental

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factors, including extracellular matrix (ECM) components, corneal hydration, aging, smoking, and eye-rubbing. Systematic diseases have been reported to cause corneal biomechanical changes, such as diabetic mellitus, trisomy 21, and osteogenesis.

Both liver and kidney diseases have been reported to be correlated with ocular disorders. Infection with hepatitis B virus (HBV) is a risk factor for age-related macular degeneration (AMD), and infection with hepatitis C virus (HCV) is associated with Mooren's ulcer[6]; both of them show signs of dry eye. Chronic kidney disease (CKD) is associated with AMD, diabetic retinopathy (DR), glaucoma, and cataract,[7] and patients with end-stage renal disease show band keratopathy.[8] These associations indicate that there may be common pathologies of liver, kidney, and ocular diseases. Therefore, understanding the relationships among liver, kidney, and ocular changes can help to improve treatments and screening strategies for liver and kidney diseases.

Serum biochemical parameters are common measurements to evaluate kidney and liver functions, including alanine aminotransferase (ALT), aspartate aminotransferase (AST), urea, creatinine, and uric acid (UA). Although earlier studies have suggested that increased IOP is associated with elevated ALT and AST[9] and increased blood urea level is correlated with corneal endothelial changes,[10] few studies have investigated the association between serum biochemical parameters and corneal biomechanics. Therefore, we hypothesized that there is an association between corneal biomechanics and biochemical indicators of liver and kidney function in normal individuals. Moreover, because all of the serum biochemical parameters should be considered simultaneously and corneal biomechanical properties are multidimensional variables with interactions, the correlation between serum biochemical parameters and corneal biomechanics should be identified among groups of variables. Consequently, this study used canonical correlation analysis (CCA) to investigate the relationships between serum biochemical variables and corneal biomechanics. Linearly combining multiple factors into separate groups, CCA is a multidimensional statistical technique that systematically evaluates the relationships between two sets of variables.[11] This study aimed to investigate the association between serum biochemical variables and corneal biomechanics among healthy university students in China and to provide novel evidence and perspectives on the relationships among liver, kidney, and ocular changes.

Methods

Study Population

This study was derived from the Dali University Students Eye Health Study, which seeks to provide population-based data on the prevalence and risk factors for common ocular disorders among university students in Yunnan Province, a comparatively impoverished region of China. Detailed study protocols have been described in previous publications.[12,13] A total of 1645 of the 2698 first-year students accepted into the institution in 2021 were ultimately included in this study, excluding students over 26 years old, with eye disease (e.g., keratoconus, retinal detachment, acute infection), or with laser corneal refractive surgery history. Ethics approval was granted by the Affiliated Hospital of Yunnan University (No. 2021040), and the research was performed following the tenets of the Declaration of Helsinki. All participants provided informed consent.

Eye Examination

All participants underwent an ophthalmologic examination of corneal biomechanics by a dynamic Scheimpflug imaging technology system, the Corvis ST (CST; OCULUS, Wetzlar, Germany). The CST can visualize and record corneal movement during deformation caused by a rapid air puff; thus, CST can offer over 30 corneal biomechanical parameters. During the whole deformation, the corneal movement can be identified as three consecutive phases: the cornea bends inward from its resting shape through the first applanation (A1) into its highest concavity (HC), and then the cornea moves outward through the second applanation (A2) back to the primary shape.

To evaluate the corneal biomechanics, we selected seven relative parameters that basically describe corneal movement: (1) time of A1 (A1t), A2 (A2t), and HC (HC-t), or the time taken for corneal apex from the start to the A1, A2, and HC, respectively (a minus A2v value indicates its opposite direction against A1v as velocity is a vector quantity); (2) A1 deflection amplitude (A1 DeflA), HC deflection amplitude (HC-DeflA), and A2 deflection amplitude (A2 DeflA), or the vertical movement of the corneal apex at A1, HC, and A2, respectively; and (3) biomechanically corrected IOP (bIOP), a corrected IOP value taking corneal thickness, age, and other corneal biomechanical characteristics into account.[14]

The CST examinations were conducted in the examination room of the university hospital by a professional optometrist. Prior to the examination, the equipment was calibrated to ensure accuracy. During the examination, participants sat in front of the device and placed their lower jaw in the mandibular drag, forehead against the frontal rest. The subjects focused on the red fixation target inside the device, keeping their eyes open and fully exposing the pupil. The optometrist operated the joystick to align the cornea to automatically identify the parameter. Only the reliable measurements identified as "OK" by the CST monitor were selected.

Serum Biochemical Variables Measurement

Fasting venous blood samples collected from each participant were stored at −4°C and examined within 2 hours. The serum biochemical variable levels were measured by the laboratory department of The First Affiliated Hospital of Dali University using a Hitachi 7180 automatic analyzer (Hitachi, Tokyo, Japan), including ALT, AST, urea, creatinine, and UA.

Statistical Analysis

Statistical analyses were conducted on corneal biomechanical properties and serum biochemical variable levels, including mean, standard deviation (SD), quartile range, kurtosis, and skewness. The differences between men and women were evaluated by analysis of variance (ANOVA). The Pearson correlation coefficients between corneal biomechanical parameters and serum biochemical variables were calculated, and a heat map was drawn using Origin software.

CCA was performed to analyze the association between serum biochemical variables and corneal biomechanics. CCA can provide a prediction model that maximizes the linear relationship between two sets of data, offering clues to the weights of different predictor variables in the predicted outcome. Moreover, CCA can simplify the data into a set of orthogonal dimensions on which the variables are loaded; therefore, there can be several variables in each set of data in CCA. The sets of dimensions are referred to as canonical variates. CCA was performed using SAS 9.4 (SAS Institute, Cary, NC), and the other analyses were performed using SPSS Statistics 25.0 (IBM, Chicago, IL). $P < 0.05$ was defined as statistically significant.

Results

In this study, the average age of all participants was 19.0 ± 0.9 years; among the participants, 1132 were women (68.8%). Table 1 shows the distribution of corneal characteristics and serum biochemical variable levels of participants stratified by gender. A1t was significantly greater in women than in men (7.81 ± 0.48 ms for women and 7.74 ± 0.48 ms for men; $P = 0.003$). Compared with women, men showed significantly greater HC-DeflA but lower bIOP ($P < 0.05$ for all). There was no significant divergence between men and women in A2t, A1DeflA, or A2DeflA. All serum biochemical variables were significantly higher in men than in women. The Figure shows the correlations between each variable.

Table 2 shows the results of canonical analyses; there were five pairs of canonical variables in each group. The first set of canonical correlations in every group was statistically significant ($r = 0.188$ for the whole

Table 1. Distribution of Clinical Characteristics (Mean ± SD)

	Total	Men	Women	*P*
A1t (ms)	7.79 ± 0.48	7.74 ± 0.48	7.81 ± 0.48	0.003
A1DeflA (mm)	0.10 ± 0.01	0.10 ± 0.01	0.10 ± 0.01	0.87
A2t (ms)	21.30 ± 0.41	21.32 ± 0.43	21.30 ± 0.39	0.24
A2DeflA (mm)	0.11 ± 0.01	0.10 ± 0.01	0.11 ± 0.01	0.08
HC-t (ms)	16.31 ± 0.40	16.30 ± 0.40	16.31 ± 0.40	0.78
HC-DeflA (mm)	0.81 ± 0.09	0.83 ± 0.09	0.80 ± 0.08	<0.001
bIOP (mm Hg)	17.46 ± 2.67	17.18 ± 2.65	17.59 ± 2.67	0.004
ALT (IU/L)	15.92 ± 12.45	20.69 ± 15.77	13.76 ± 9.90	<0.001
AST (IU/L)	18.02 ± 6.49	20.06 ± 8.50	17.10 ± 5.08	<0.001
Urea (mmol/L)	4.22 ± 0.05	4.66 ± 0.14	4.01 ± 0.04	<0.001
Creatinine (μmol/L)	64.33 ± 0.35	79.64 ± 0.51	57.49 ± 0.26	<0.001
UA (μmol/L)	354.40 ± 2.21	431.79 ± 3.60	319.32 ± 2.05	<0.001

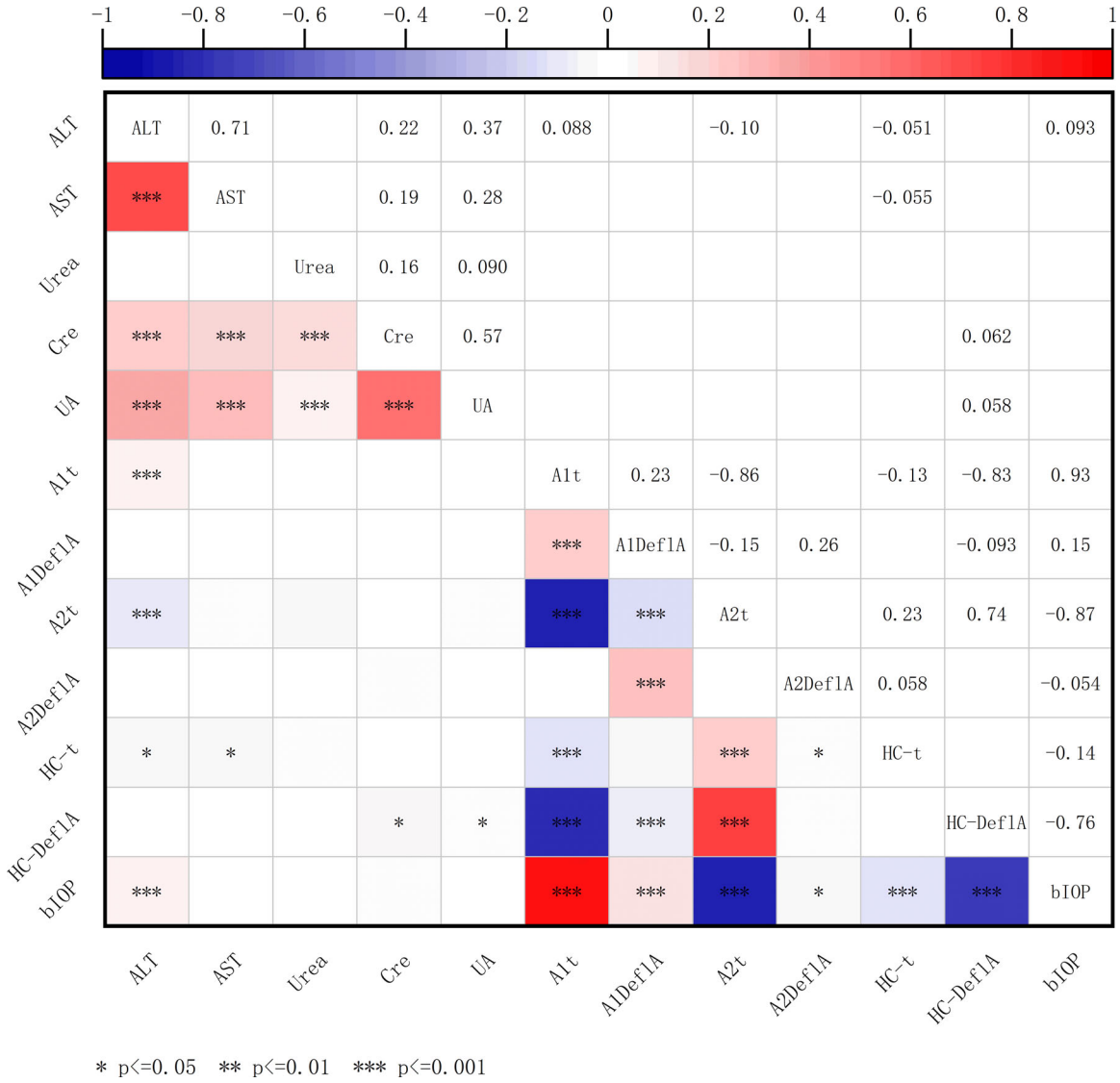

Figure. Correlations between corneal biomechanical parameters and serum biochemical variables.

population, $r = 0.235$ for men, $r = 0.187$ for women, $P < 0.05$ for all), whereas the second set showed significance only in the whole population ($r = 0.115$, $P < 0.05$). In populations with different myopia statuses, the results show that the canonical correlations in the myopic individuals were statistically significant for the first and second groups, with correlation coefficients of 0.214 and 0.133, respectively (both $P < 0.05$), whereas there was no statistical significance in the non-myopic group. Overall, further analyses were only performed in the first sets of canonical variables.

For the whole population, the contribution rate of the first pair of canonical variables was 61.1%, indicating that the eigenvalue of this canonical correlation can explain 61.1% of the variance. Table 3 shows the standardized canonical coefficients and structural coefficients of the first sets of canonical variables. W_1 refers to the first pair of canonical variables for corneal biomechanics and V_1 for serum biochemical variables. In the whole population, $W_1 = 1.296$ A1t $- 0.025$ A1DeflA $- 1.205$ A2t $- 0.035$ A2DeflA $- 0.260$ HC-t $+ 1.536$ HC-DeflA $- 0.681$ bIOP, and $V_1 = 0.964$ ALT $- 0.520$ AST $+ 0.054$ urea $+ 0.166$ creatinine $+ 0.422$ UA. The structural coefficients present the correlation between primary variables and canonical variables. The structural analysis of the first sets of canonical correlations is shown in Table 3. The higher the absolute value of the structural coefficient, the stronger the correlation. Structural coefficients with absolute values no less than 0.30 were considered to show significant associations between primary variables and canonical variables. W_1 was more significantly corre-

Table 2. Outcomes of Canonical Correlation Analysis

	Canonical Correlation	Proportion	Cumulative Proportion	*P*
Total				
1	0.188	0.611	0.611	<0.01
2	0.115	0.225	0.836	0.04
3	0.075	0.096	0.932	0.39
4	0.062	0.065	0.997	0.58
5	0.012	0.003	1.000	0.97
Men				
1	0.235	0.554	0.554	0.03
2	0.166	0.268	0.822	0.48
3	0.121	0.141	0.963	0.85
4	0.058	0.031	0.994	0.98
5	0.025	0.006	1.000	0.96
Women				
1	0.187	0.603	0.603	<0.01
2	0.109	0.202	0.804	0.32
3	0.082	0.114	0.916	0.59
4	0.065	0.072	0.990	0.70
5	0.024	0.010	1.000	0.88
Myopia				
1	0.214	0.631	0.631	<0.01
2	0.133	0.237	0.867	0.01
3	0.082	0.092	0.959	0.40
4	0.059	0.039	0.999	0.68
5	0.021	0.001	1.000	0.88
Non-myopia				
1	0.315	0.480	0.480	0.41
2	0.246	0.279	0.760	0.74
3	0.184	0.153	0.913	0.88
4	0.133	0.079	0.991	0.91
5	0.050	0.009	1.000	0.94

lated with A1t, A2t, and bIOP. ALT, AST, creatinine, and UA were more significantly associated with V_1. The variables whose structural coefficients were the opposite of canonical coefficients are referred to as suppressors. A1DeflA, A2DeflA, HC-t, bIOP, and AST were suppressors of the first pair of canonical variables in the whole population.

The first set of canonical correlations in men explained 55.4% of the variance: $W_1 = 0.781$ A1t $-$ 0.102 A1DeflA $-$ 1.293 A2t $-$ 0.076 A2DeflA $+$ 0.041 HC-t $+$ 0.754 HC-DeflA $-$ 0.564 bIOP, and $V_1 =$ 0.851 ALT $-$ 0.089 AST $+$ 0.398 urea $+$ 0.101 creatinine $+$ 0.242 UA. Structural analysis showed that W_1 was more significantly associated with A1t, A2t, HC-DeflA, and bIOP. V_1 was more significantly associated with ALT, AST, urea, and UA. A1DeflA, HC-t, HC-DeflA, bIOP, and AST were suppressors of the first canonical variables in men.

The first canonical correlation among women explained 60.3% of the variance: $W_1 = 1.443$ A1t $-$ 0.080 A1DeflA $-$ 0.894 A2t $+$ 0.223 A2DeflA $+$ 0.454 HC-t $+$ 1.356 HC-DeflA $-$ 0.482 bIOP, and $V_1 = 1.345$ ALT $-$ 1.243 AST $-$ 0.255 urea $-$ 0.017 creatinine $+$ 0.222 UA. As shown in Table 3, W_1 was more significantly associated with A1t, A2t, and bIOP. V_1 was significantly associated with ALT and UA but weakly with creatinine. Structural analysis showed that A1DeflA, HC-DeflA, bIOP, and creatinine were suppressors of the first canonical correlation in women.

The first canonical correlation in myopic individuals explained 63.1% of the variance. As shown in Table 3, $W_1 = -1.305$ A1t $+$ 0.139 A1DeflA $+$ 1.414 A2vt $-$ 0.008 A2DeflA $-$ 0.289 HC-t $-$ 1.516 HC-DeflA $+$ 0.964 bIOP, and V1 $= -0.789$ ALT $+$ 0.510 AST $-$ 0.047 urea $-$ 0.333 creatinine $-$ 0.465 UA. W_1 had

Table 3. Standardized Canonical Coefficients and Structural Coefficients of Canonical Variates

	Total		Men		Women		Myopia		Non-Myopia	
	Standardized Canonical Coefficient	Structural Coefficient	Standardized Canonical Coefficient	Structural Coefficient	Standardized Canonical Coefficient	Structural Coefficient	Standardized Canonical Coefficient	Structural Coefficient	Standardized Canonical Coefficient	Structural Coefficient
W_1										
A1t	1.296	0.385	0.781	0.738	1.443	0.556	−1.305	−0.300	−1.257	0.334
A1DeflA	−0.025	0.192	−0.102	0.089	−0.080	0.237	0.139	−0.079	−0.545	−0.386
A2t	−1.205	−0.526	−1.293	−0.898	−0.894	−0.570	1.414	0.487	0.225	−0.326
A2DeflA	−0.035	0.023	−0.076	−0.040	0.223	0.259	−0.008	−0.036	0.554	0.303
HC-t	0.260	−0.073	0.041	−0.237	0.454	0.147	−0.289	0.040	−0.498	−0.278
HC-DeflA	1.536	0.090	0.754	−0.424	1.356	−0.128	−1.516	−0.129	−1.424	−0.576
bIOP	−0.681	0.362	−0.564	0.714	−0.482	0.503	0.964	−0.263	0.512	0.307
V_1										
ALT	0.964	0.790	0.851	0.865	1.345	0.461	−0.789	−0.668	−0.723	−0.909
AST	−0.520	0.315	−0.089	0.511	−1.243	−0.187	0.510	−0.270	−0.035	−0.485
Urea	0.054	0.135	0.398	0.414	−0.255	−0.267	−0.047	−0.152	−0.051	−0.193
Creatinine	0.166	0.525	0.101	0.264	−0.017	0.005	−0.333	−0.690	−0.155	−0.507
UA	0.422	0.729	0.242	0.492	0.222	0.359	−0.465	−0.804	−0.332	−0.714

more significant correlations with A1t, A2t, and HC-DeflA. V_1 was significantly correlated with ALT and AST. Moreover, A1DeflA, HC-t, bIOP, and AST were suppressor factors in the first canonical correlation among myopic individuals.

Discussion

This study, from the perspective of early intervention, explored a particular relationship between serum biochemical variables and corneal biomechanics through CCA among a relatively healthy adult population. Consistent with the hypothesis, the most significant association identified by CCA was between the corneal biomechanical characteristics, including A1t, A2t, and bIOP, and serum biochemical variables, including ALT and UA. The results show that people with increased ALT and UA would have lower IOP and corneas with slower A1, faster A2, and greater deformity.

During the corneal biomechanical measurement by CST, the cornea deforms under an air puff, and its response depends on corneal biomechanics, including elasticity, viscidity, and stiffness. Elasticity refers to the ability of the cornea to deform under an external force and to return to its original shape. Viscidity evaluates the corneal ability to dissipate external energy, and stiffness describes the corneal resistance against elastic deformation. When the cornea is exposed to the air puff and bends inward, a portion of the energy from the air puff is converted to elastic potential energy, and the other is dissipated due to the corneal viscidity. In addition to the air puff, IOP is another external force on the cornea; hence, the corneal response at A1 depends on corneal stiffness, viscidity, and IOP. When the cornea reaches the HC and rebounds outward, the elastic potential energy is converted to kinetic energy and dissipated through corneal viscidity. Therefore, the corneal response at A2 depends on corneal elasticity, viscidity, and IOP. The effect of external forces on the cornea is minimized at the HC, and HC-DeflA can reflect corneal stiffness. The results suggest that people with increased ALT and UA would have softer corneas with greater elasticity and viscidity. Although the correlation coefficients are not high, their significance in healthy populations still aids in deepening our understanding of the association between liver and kidney diseases and ocular lesions, especially during the preclinical phase, which is crucial for implementing primary preventive measures. For example, regular monitoring of ocular health is necessary for patients with liver and kidney diseases.

Moreover, specific changes in eye diseases can also serve as an effective tool for risk stratification among individuals with liver and kidney dysfunction.

To the best of our knowledge, this study is the first to investigate the relationships between serum biochemical variables and corneal biomechanics. Previously, several studies have discussed the association between liver or kidney diseases and ocular disorders. Various congenital liver diseases have been reported to be associated with corneal changes,[15–17] especially those with cholestasis. Corneal ulcers and dry eye are common in chronic HBV and HCV patients.[6] CKD has been reported to be associated with AMD, DR, glaucoma, and cataract.[7] Patients with gout have been reported to have corneal endothelial changes.[18] Therefore, these studies indicate common pathologies of liver, kidney, and ocular changes. Moreover, Asaoka et al.[9] suggested that greater ALT and AST were associated with higher IOP, and Lee et al.[19] argued that an increasing AST/ALT ratio was one of the risk factors for the vertical cup-to-disc ratio. CKD patients with greater serum urea levels showed increased central corneal thickness and decreased endothelial cell density.[10] These studies demonstrate that existing liver or kidney diseases can lead to changes in the biomechanical properties of the cornea from a clinical perspective. Moreover, current study, focused on a relatively healthy population, also reveals a correlation between changes in corneal biomechanical indicators and serum biochemical markers for liver and kidney function. These findings hint at a potential link between the two systems in the early stages of disease, suggesting that alterations in one may reflect changes in the other, which could facilitate the early implementation of preventive and control measures.

Although the mechanism of the relationship between serum biochemical variables and corneal biomechanics remains unclear, it could be attributed to increasing oxidative stress. Glutathione (GSH) is an essential antioxidant that prevents cells from oxidative stress and maintains corneal hydration,[20] which is also vital for ocular tissues.[21] In the cornea, GSH is predominantly synthesized in corneal epithelium, whereas its accumulation in corneal endothelium largely depends on the uptake of GSH from the aqueous humor.[22] Although corneal biomechanics is mainly defined by the stroma, the corneal epithelium and endothelium can indirectly affect corneal biomechanics by regulating hydration.[5] ALT and AST play critical roles in producing glutamate, one of the precursor amino acids for GSH biosynthesis. Therefore, as the liver is the predominant source of GSH in plasma, liver diseases would influence corneal biomechanical properties by affecting the concentration of GSH.[23]

In terms of urea, increasing urea levels induces the production of intracellular reactive oxygen species.[24] The level of urea in aqueous humor would increase with serum urea,[25] leading to corneal endothelial dysfunction.[26] Similarly, accumulated UA aggregates inflammatory response and inhibits nitric oxide production, arousing corneal endothelial changes.[27]

Moreover, liver and kidney disorders are associated with increased levels of transforming growth factor β (TGF-β),[28] a kind of pro-inflammatory cytokines. Previous studies have suggested that TGF-β is increased in the aqueous humor of glaucoma patients, indicating a correlation between TGF-β and ocular changes.[29,30] TGF-β can promote the development of corneal fibroblasts into myofibroblasts. Corneal fibroblasts produce collagen and other ECM components that play critical roles in maintaining stromal integrity.[31] Because ECM components are determinants of corneal biomechanics, the relationship between serum biochemical variables and corneal biomechanics could be due to elevated TGF-β. Furthermore, TGF-β accumulated at the trabecular meshwork can contribute to the elevation of IOP,[32] in agreement with the association between bIOP and serum biochemical variables found in our study. Nevertheless, few studies have investigated the corneal biomechanical properties in patients with liver or kidney disorders, and further studies are necessary to clarify the relationship and underlying mechanisms.

Although the entire relationship was significant in both men and women, some nuances existed among the groups. HC-DelfA was only significantly associated with W_1 in men. Hormonal fluctuations could cause this divergence between genders. Previous studies have shown corneal biomechanical variations during the menstrual cycle,[33] indicating the influence of estrogen. Furthermore, AST and urea were slightly associated with V_1 in women, which could be attributed to the difference in corneal biochemical variables between genders.

The results identified A1DeflA and bIOP as suppressors in all groups, HC-t and AST as a suppressor in the whole population and men, HC-DeflA as a suppressor in women and men, and creatinine as a suppressor only in women. Although A1DeflA and bIOP were positively associated with W_1, their canonical coefficients were negative in the entire CCA model. This result suggests that A1DeflA and bIOP would be positively correlated with serum biochemical variables without consideration of other corneal biomechanical parameters. However, considering all of the canonical variables, the relationship between A1DeflA or bIOP and serum biochemical variables would be the opposite. Similarly, the other suppressors

can be interpreted in this way. These results indicate interactions among corneal biomechanical characteristics, but further research is required to determine the exact relationships. For AST, the seemingly paradoxical relationship could be due to the AST/ALT ratio, whose high or low levels indicate liver disorders.[34]

Through CCA, the results identified significant associations between serum biochemical variables and corneal biomechanics in both men and women, adding novel evidence of the relationship between liver or kidney disorders and ocular changes. Current study also pointed to a new direction for research on the pathophysiology and treatment of corneal biomechanical-related diseases.

There are several strengths of this study. First, we considered corneal biomechanics and serum biochemical variables as separate entities, which can help reveal the interactions between variables. Second, we included the basic dynamic corneal response parameters to avoid the bias introduced by other parameters calculated by algorithms, making the results easier to understand. However, the study still has some limitations. Because this was a cross-sectional study, we could not determine the sequence of changes in corneal biomechanics and serum biochemical variables. Furthermore, as the participants in the current study were enrolled from a single university with a limited age range, the results of the current study may not be extrapolated to other groups with different ethnicities or ages. Third, the study subjects were relatively healthy adults, but their serum indicators were not entirely within the normal range; however, these few deviations did not affect the purpose of the study but may have made the results more pronounced. Finally, this study took into account the effects of gender and refractive status and conducted subgroup analyses; however, it lacked consideration of other potential confounding factors such as age, lifestyle, and genetic predispositions, which should be controlled for in future studies.

In conclusion, this study suggests that greater ALT and UA are associated with softer corneas with greater elasticity and viscidity, providing new evidence for the relationship between serum biochemical variables and ocular changes. However, further studies are warranted to verify the relationship in other populations and to investigate the underlying mechanisms.

Acknowledgments

Supported by grants from the National Natural Science Foundation of China (82160204) and Nankai University Eye Institute (NKYKD202206).

Author Contributions: Conceptualization: Dan-Lin Li, Min-Xin Liu, Chen-Wei Pan; Methodology: Min-Xin Liu, Dan-Lin Li; Formal analysis and investigation: Min-Xin Liu, Dan-Lin Li, Ya-Jie Zheng, Yu Qin, Rong Ma, Gang Liang; Writing - original draft preparation: Min-Xin Liu, Dan-Lin Li; Writing - review and editing: Min-Xin Liu, Dan-Lin Li, Chen-Wei Pan; Funding acquisition: Gang Liang; Resources: Gang Liang; Supervision: Chen-Wei Pan, Gang Liang

Disclosure: **D.-L. Li**, None; **M.-X. Liu**, None; **Y.-J. Zheng**, None; **Y. Qin**, None; **R. Ma**, None; **G. Liang**, None; **C.-W. Pan**, None

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