Hand grip strength and ocular associations: the Ural Eye and Medical Study

Mukharram M Bikbov,[1] Rinat M Zainullin,[1] Timur R Gilmanshin,[1] Ellina M Iakupova,[1] Gyulli M Kazakbaeva,[1] Songhomitra Panda-Jonas,[2] Azaliia M Tuliakova,[1] Albina A Fakhretdinova,[1] Leisan I Gilemzianova,[1] Jost B Jonas [3]

[1]Ufa Eye Research Institute, Ufa, Russian Federation
[2]Department of Ophthalmology, Medical Faculty Mannheim of the Ruprecht Karls University Heidelberg, Mannheim, Germany
[3]Department of Ophthalmology, University Hospital Heidelberg, Heidelberg, Germany

Correspondence to
Dr Jost B Jonas, Department of Ophthalmology, University Hospital Heidelberg, Heidelberg 69120, Germany; jost.jonas@medma.uni-heidelberg.de

Received 3 March 2022
Accepted 31 July 2022
Published Online First 11 August 2022

To cite: Bikbov MM, Zainullin RM, Gilmanshin TR, *et al*. *Br J Ophthalmol* 2023;**107**:1567–1574.

ABSTRACT

Purpose To explore the associations between hand grip strength (HGS) and ocular parameters and diseases.

Design Population-based cohort study.

Methods Participants of the Ural Eye and Medical Study, including 5899 (80.5%) out of 7328 eligible individuals aged 40+ years, underwent systemic and ophthalmological examinations including dynamometric HGS measurement.

Results The study included 5381 (90.4%) individuals (age: 58.6±10.6 years; range: 40–94 years) with HGS measurements. Higher HGS (mean: 30.6±11.7 dekaNewton) correlated (multivariable analysis) with better visual acuity (beta: 0.02, p=0.02), longer ocular axial length (beta: 0.03, p=0.003), higher intraocular pressure (beta: 0.03, p=0.001), thicker peripapillary retinal nerve fibre layer (beta: 0.03, p=0.001) and lower prevalence of diabetic retinopathy (beta: −0.03, p=0.007), after adjusting for younger age, male sex, Russian ethnicity, higher body height and waist to hip ratio, higher educational level, higher physical total score, lower smoking package years, higher serum concentration of haemoglobin, higher prothrombin index, lower leucocyte cell count, lower prevalence of non-alcoholic fatty liver disease, lower depression score and lower prevalence of arthritis. In the model, HGS was not correlated with prevalence of nuclear cataract (p=0.38), cortical cataract (p=0.67), subcapsular posterior cataract (p=0.50), open-angle glaucoma (p=0.22) or angle-closure glaucoma (p=0.27).

Conclusions and relevance In addition to parameters such as lower physical activity, higher depression score and worse general health status, a reduced HGS is associated with visual impairment, shorter axial length, lower intraocular pressure, thinner peripapillary retinal nerve fibre layer and higher prevalence of diabetic retinopathy. HGS dynamometry or a handshake may provide the ophthalmologist additional clinical information about the general health and ocular parameters of the patient.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ A reduced hand grip strength has been known to be related to all-cause mortality, cardiovascular and non-cardiovascular mortality, and stroke, and to ocular parameters of low vision and age-related cataract.

WHAT THIS STUDY ADDS

⇒ In this population-based study including a large number of parameters and diseases in the multivariable analysis, a reduced hand grip strength was associated with visual impairment, shorter axial length, lower intraocular pressure, thinner peripapillary retinal nerve fibre layer and higher prevalence of diabetic retinopathy.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Measurement of hand grip strength or a handshake may provide the ophthalmologist additional clinical information about the general health and ocular parameters of the patient.

INTRODUCTION

A reduced hand grip strength (HGS) has been shown to be a prognostic factor for all-cause mortality, cardiovascular mortality, non-cardiovascular mortality, myocardial infarction, stroke and other disorders.[1–4] In the Prospective Urban Rural Epidemiology study on 140 000 individuals with a median follow-up of 4 years, HGS was a stronger predictor of all-cause and cardiovascular mortality than systolic blood pressure.[3] In a prospective population-based study in the setting of the UK Biobank of half a million participants aged 40–69 years, Celis-Morales and colleagues[4] found that lower HGS was associated with higher all-cause mortality and cause-specific mortality from cardiovascular disease, all respiratory diseases, chronic obstructive pulmonary disease (COPD), all cancers, colorectal cancer, lung cancer and breast cancer. The addition of HGS improved the prediction ability of an office-based risk score including the determinants of age, sex, diabetes, body mass index, systolic blood pressure and smoking for all-cause and cardiovascular mortality and the incidence of cardiovascular disease.

Besides studies which assessed the importance of HGS as a factor associated with the prevalence of and as a risk factor for the incidence of major internal medical diseases, other investigations have examined the correlations between HGS and the prevalence and degree of ocular parameters and diseases.[5–14] As also discussed in detail below, the population-based Beaver Dam Eye Study explored the relationships between HGS (as one of several measures of frailty) and visual function, age-related cataract and age-related macular degeneration

(AMD).[5–9] The Australian population-based Blue Mountains Eye Study examined the associations between vision, hearing and olfactory impairments and HGS.[9] Other studies addressed the relationships between visual function and HGS in various populations including Koreans and Irish.[10–14] The limitations of these studies were that they usually did not include the full panoply of systemic parameters which influenced HGS so that there was a risk of bias due to confounding factors; they did not include the whole array of major ocular parameters and disorders which are correlated with each other so that again there was a risk of a bias; and some of the studies had a relatively small study sample or had not recruited their study population in a population-based manner. We therefore conducted this study to examine the relationship of HGS with a whole list of ocular parameters, such as intraocular pressure (IOP) and ocular axial length, and ocular diseases, such as cataract, glaucoma, AMD and diabetic retinopathy, after adjusting for a large number of non-ocular conditions. Including a large number of parameters potentially influencing HGS and including a relatively large number of ocular parameters may reduce the risk of bias by taking into account interrelationships between these parameters. In addition, to reduce the effect of a potential referral-associated bias, we recruited the study participants in a population-based manner. We addressed the hypothesis whether a lower HGS, after adjusting for systemic parameters such as age, sex, physical activity and systemic diseases, is associated with a higher prevalence and degree of major ocular disorders. The basis of the hypothesis was that ocular parameters and ophthalmological diseases are correlated with systemic parameters which have been shown to be related to HGS in previous studies.[1–14] Knowledge of the associations between HGS and ocular parameters and diseases could be helpful in screening individuals with respect to their general health and ophthalmological disorders, and could be of help in the daily routine of ophthalmic clinics and offices since a handshake with the patient could already provide the ophthalmologist with some initial information about the patient's conditions.

METHODS

The Ural Eye and Medical Study (UEMS) is a population-based investigation which was performed in a rural region and an urban area in the Russian republic of Bashkortostan at the southwestern end of the Ural Mountains in the study period from 2015 to 2017.[15 16] The inclusion criteria for the study were living in the study regions and age 40 years or older. All participants gave an informed written consent. As described in detail recently, out of a total of 7328 eligible individuals, 5899 (80.5%) (3319 (56.3%) women) with a mean age of 59.0±10.7 years (range: 40–94 years) participated in the study.[5 6] Some of the reasons for non-participation were absence from the region (such as in the case of seasonal workers), feeling too old or sick, or simply no interest in participating. The study population did not differ significantly in the distribution of gender and age from the total Russian population, as explored in the census carried out in 2010.[17]

Using a bus, the study participants were brought from their homes to the Ufa Eye Institute, where a team of about 20 trained medical doctors and technicians performed all examinations. As described in detail previously, the series of examinations started with a detailed interview consisting of more than 250 standardised questions on socioeconomic background, including self-reported ethnicity, level of education, occupation, family income and family estate (ownership of a house and a second house, telephone, smartphone, laptop, television, bicycle and car), and size and structure of the family; diet (number of meals per day, frequency and amount of intake of vegetables, fruits, whole grain and meat, consumption of tea and coffee, use of animal fat or cooking oil); smoking (since when or has stopped, cigarettes or other types of tobacco products, symptoms of smoking cessation); alcohol consumption (since when or has stopped, alcohol consumption-related wrongdoing); physical activity (frequency and intensity of daily work, leisure time activities, sitting or reclining); quality of life and quality of vision; symptoms of COPD, asthma, kidney disease and orthopaedic disorders; history of any type of injuries and interpersonal violence; and health assessment questions.[15 16] The questionnaire additionally included questions on medical history, including known diagnosis and therapy of major disorders such as diabetes mellitus, arterial hypertension, cardiovascular diseases, headache, neck pain, thoracic spine and low back pain; questions on previous neurological attacks, including stroke, epilepsy, polyneuropathy and unconsciousness; and questions on cognitive function and hearing loss. All questions during the interview were taken from standardised interviews published in the literature, such as the National Eye Institute Visual Functioning Questionnaire-25, the Questionnaire for Verifying Stroke-Free Status from the American Heart Association, and the Michigan Neuropathy Screening Instrument.[15 16] Cognitive function was assessed applying Folstein's Mini-Mental State Examination, with a maximal score of 30 points.

Examinations further included anthropometry, blood pressure measurement, spirometry and biochemical analysis of blood samples taken under fasting conditions. We defined arterial hypertension according to the criteria published by the American Heart Association. The criteria for diagnosis of diabetes mellitus were a fasting glucose concentration of ≥7.0 mmol/L or a self-reported history of physician diagnosis of diabetes mellitus or a history of drug treatment for diabetes (insulin or oral hypoglycaemic agents). Anaemia was defined by a haemoglobin concentration of <140 g/L for men and <130 g/L for women. Estimated glomerular filtration rate was calculated using the Chronic Kidney Disease Epidemiology Collaboration equation. Depression was assessed using the Center for Epidemiologic Studies Depression Scale scoresheet. We examined anxiety using the State-Trait Anxiety Inventory Test. Using the definition of the International Diabetes Federation, metabolic syndrome was defined by a waist circumference of ≥94 cm in men and ≥80 cm in women, and at least two of the following four conditions: blood glucose concentration of >5.6 mmol/L or diagnosis of diabetes mellitus; serum concentration of high-density cholesterol of <1.0 mmol/L in men and <1.3 mmol/L in women or a specific drug treatment for hyperlipidaemia; serum triglyceride concentration of >1.7 mmol/L or a specific drug treatment for hyperlipidaemia; and arterial blood pressure of >130/85 mm Hg or a specific drug treatment for arterial hypertension. We applied a spirometry-based definition to characterise COPD, with a cut-off value for forced expiratory volume in 1 s to forced vital capacity ratio of less than 0.7. Non-alcoholic fatty liver disease (NAFLD) was characterised by absence of alcohol consumption on a regular basis and by abnormally high serum concentrations of alanine aminotransferase (ALT) and aspartate aminotransferase (AST) or by an AST to ALT ratio of >1.0. Hearing loss was assessed by a series of 11 standardised questions, 10 of which were derived from the 'Hearing Handicap Inventory for the Elderly Screening Version (HHIE-S)'. The questions could be answered by 'no' (0 points), 'sometimes' (2 points) and 'yes' (4 points). The total hearing loss score was the sum of all points and could range between 0 and 44 points. The study design has been described recently.[15 16]

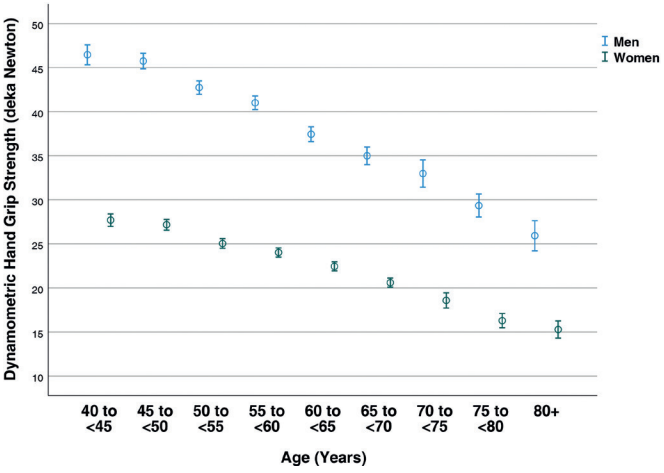

Figure 1 Graph showing the distribution of the hand grip force stratified by age and sex.

HGS was measured using a portable handheld dynamometer (Dynamometer DK 140, Silarukov Company, Moscow, Russia). In a standardised manner, we first measured the HGS of the right hand, followed by measurement of the HGS of the left eye followed by measurement of the HGS of the left hand, with the study participants sitting on a chair.

Ophthalmological examinations included assessment of the best corrected visual acuity (BCVA), expressed in logMAR units (logarithm of the minimal angle of resolution), slit lamp-based biomicroscopy of the anterior and posterior ocular segment, including assessment of pseudoexfoliation of the lens in medical mydriasis, digital photography of the cornea, lens, optic nerve head and macula, and spectral-domain optical coherence tomography of the macula and the optic nerve head. As described previously, we differentiated nuclear lens opacities into six grades using the classification scheme for cataract of the Age-Related Eye Disease Study.[15 16] We defined moderate to severe vision impairment by a visual acuity in the better eye or binocularly of <6/18 but ≥3/60, and blindness by a visual acuity in the better eye or binocularly of <3/20. We defined the presence of nuclear cataract as a nuclear cataract grade of 3+. Cortical lens opacities were assessed using photographs taken by retroillumination. Using optical coherence tomography (OCT) scans, we determined the peripapillary retinal nerve fibre layer thickness, the width and shape of the neuroretinal rim and the depth of the optic cup, and the thickness of the retina as a whole and stratified into various retinal layers in the foveola and the perifoveal region. Glaucoma was defined by the morphological criteria described by Foster and colleagues.[18] As recommended by the Beckman Initiative for Macular Research Classification Committee, we defined AMD using fundus photographs.[19] Dry eye disease was defined by a dry eye symptom score of ≥3, with a Schirmer's test for measurement of tear production of ≤5 mm.

The inclusion criteria for the present study were availability of HGS measurements. Using a statistical software package (SPSS for Windows, V.27.0), we assessed the distribution and mean values (mean±SD) of the main outcome parameter, that is, HGS, and searched for the associations between HGS and other parameters, first in single regression analyses with adjustments made for age and sex, followed by multivariable regression analyses. The latter included HGS as the dependent variable and as independent parameters all those variables which were associated with HGS in the univariable analysis with a p value of ≤0.10. In a step-by-step manner, we dropped those parameters out of the list of independent parameters that were no longer significantly associated with HGS. We then added again to the model those parameters which were previously dropped out to retest the significance of their potential association with HGS. We calculated standardised regression coefficient beta and non-standardised regression coefficient B and its 95% CI. All p values were two-sided and values less than 0.05 were considered statistically significant.

RESULTS

Out of the 5899 participants of the UEMS, the present investigation included 5381 (90.4%) individuals (2940 (54.6%) women) with HGS measurements. The mean age was 58.6±10.6 years (median: 58 years; range: 40–94 years). The group of study participants as compared with the group of individuals without HGS measurements was significantly younger (58.6±10.6 years vs 62.9±11.2 years; p<0.001) and included a higher proportion of men versus women (men/women: 45.4%/54.6% vs 73.2%/26.8%; p<0.001).

The mean HGS was significantly (p<0.001) higher for the right hand than for the left hand (30.6±11.7 dekaNewton (dN), median: 30 dN, range: 0–72 vs 30.0±11.3 dN, median: 25, range: 0–70). Since HGS was strongly associated with sex and age (figure 1), the primary assessment of the associations between HGS and parameters other than age and sex was adjusted for both parameters (table 1). In the analysis, a higher HGS (right hand) was associated with a multitude of systemic parameters and with ocular parameters such as better BCVA, lower prevalence of dry eye feeling, longer axial length, higher IOP, thicker peripapillary retinal nerve fibre layer, lower prevalence of diabetic retinopathy and subcapsular posterior cataract, and lower prevalence and lower stage of chronic open-angle glaucoma (table 1). In the multivariable analysis with HGS as the dependent variable, we dropped out of the list of independent variables those parameters which either showed high collinearity or which were no longer significantly associated with HGS.

In the final model, a higher HGS correlated with better visual acuity, longer ocular axial length, higher IOP, thicker peripapillary retinal nerve fibre layer and lower prevalence of diabetic retinopathy, in addition to younger age, male sex, Russian ethnicity, higher body height and higher body waist to hip ratio, higher level of education, lower number of smoking pack years, lower self-reported salt consumption, higher degree of processing meat, higher physical activity score, higher serum concentration of haemoglobin and higher prothrombin index, lower leucocyte cell count, lower prevalence of NAFLD, lower depression score, and lower prevalence of arthritis (table 2). When we added to the model the parameters of dry eye disease (P=0.23) and of any cataract (P=0.65), degree (P=0.12) and prevalence (P=0.38) of nuclear cataract, degree (P=0.33) and prevalence (P=0.67) of cortical cataract, degree (P=0.72) and prevalence (P=0.50) of subcapsular posterior cataract, prevalence of any glaucoma (P=0.12), degree (P=0.26) and prevalence (P=0.22) of open-angle glaucoma, or degree (P=0.13) and prevalence (P=0.27) of angle-closure glaucoma, these associations were not statistically significant. If the parameter of visual acuity was replaced by the prevalence of moderate to severe vision impairment or blindness, the latter parameters correlated significantly with lower HGS (beta: −0.02, B: −1.91, 95% CI −3.50 to −0.33, p=0.01).

If the HGS of the left hand was taken as the independent variable, a higher HGS was associated with a similar range of parameters.

Table 1 Associations between hand grip strength (right hand) and other parameters in the Ural Eye and Medical Study with adjustment for sex and age

	Standardised regression coefficient beta	Non-standardised regression coefficient B	95% CI of B	P value
Age (years)	−0.37	−0.41	−0.43 to −0.39	<0.001
Sex (female/male)	−0.69	16.3	15.9 to 16.6	<0.001
Region of habitation (rural/urban)	0.06	1.48	1.09 to 1.88	<0.001
Ethnicity (non-Russian/Russian)	0.06	1.80	1.35 to 2.26	<0.001
Body height (cm)	0.19	0.26	0.23 to 0.29	<0.001
Body weight (kg)	0.13	0.10	0.09 to 0.12	<0.001
Body mass index (kg/m^2)	0.07	0.17	0.13 to 0.21	<0.001
Waist circumference (cm)	0.07	0.07	0.05 to 0.08	<0.001
Hip circumference (cm)	0.06	0.06	0.04 to 0.07	<0.001
Waist to hip circumference ratio	0.03	3.95	1.76 to 6.14	<0.001
Waist to height ratio	0.04	5.33	2.98 to 7.68	<0.001
Level of education (1–8)	0.08	0.65	0.51 to 0.79	<0.001
Socioeconomic score	0.05	0.43	0.30 to 0.56	<0.001
Smoking, currently (no/yes)	−0.03	−1.11	−1.72 to −0.50	<0.001
Smoking package years	−0.04	−0.03	−0.05 to −0.02	<0.001
Alcohol consumption, any (no/yes)	0.02	0.49	0.02 to 0.96	0.04
Number of daily meals	0.002	0.04	−0.21 to 0.28	0.77
In a week, how many days do you eat fruits?	0.03	0.20	0.10 to 0.30	<0.001
In a week, how many days do you eat vegetables?	0.01	0.10	−0.04 to 0.23	0.16
Type of oil for cooking used: vegetable cooking oil, animal fat (butter)	−0.01	−0.64	−1.80 to 0.52	0.28
Food containing whole grains (no/yes)	0.02	0.47	−0.004 to 0.93	0.05
Salt consumed per day (g)	−0.04	−0.18	−0.26 to −0.10	<0.001
Degree of processing meat (weak, medium, strong)	0.02	0.44	0.08 to 0.79	0.02
Length of working day (hours)	0.03	0.001	0.000 to 0.002	0.004
Mostly sit and walk less than 10 min (no/yes)	0.004	0.09	−0.36 to 0.54	0.68
Work with moderate to vigorous physical activity (no/yes)	−0.01	−0.26	−0.67 to 0.16	0.23
Days per week with vigorous physical work	−0.03	−0.24	−0.42 to −0.07	0.006
Amount of time spent with vigorous physical work per day	0.03	0.001	0.001 to 0.002	0.001
Work with moderate physical activity (no/yes)	0.01	0.23	−0.22 to 0.67	0.32
Days per week with moderate physical activity at work	−0.02	−0.15	−0.31 to 0.02	0.09
Amount of time spent with moderate physical activity at work per day	0.03	0.001	0.001 to 0.002	0.001
Walking or biking for at least 10 min per day (no/yes)	0.02	0.81	0.13 to 0.149	0.02
Days per week with walking or biking for at least 10 min per day	0.01	0.13	−0.02 to 0.27	0.10
Recreation and leisure time spent mostly with sitting (no/yes)	−0.004	0.000	−0.002 to 0.001	0.63
In your leisure time, do you do any physically vigorous activities like running, strenuous sports or weightlifting for at least 10 min at a time? (no/yes)	0.003	0.08	−0.31 to 0.48	0.68
In your leisure time, do you do any moderate-intensity activities like brisk walking, cycling or swimming for at least 10 min at a time? (no/yes)	0.02	0.36	−0.03 to 0.74	0.07
Over the past 7 days, how much time did you spend sitting or reclining on a typical day? (hours)	−0.01	0.000	0.000 to 0000	0.10
Physical activity score	0.04	0.05	0.03 to 0.08	<0.001
History of angina pectoris	−0.01	−0.26	−0.94 to 0.41	0.44
History of asthma	−0.003	−0.21	−1.39 to 0.99	0.74
History of arterial hypertension	0.02	0.56	0.15 to 0.97	0.007
History of arthritis	−0.01	−0.38	−0.82 to 0.06	0.09
History of bone fractures	−0.01	−0.31	−0.73 to 0.10	0.14
History of low back pain	0.01	0.19	−0.19 to 0.57	0.33
History of thoracic spine pain	0.01	0.31	−0.15 to 0.76	0.19
History of neck pain	−0.01	−0.36	−0.77 to 0.07	0.10
History of headache	−0.02	−0.55	−0.93 to −0.16	0.006
History of cancer	0.01	0.56	−0.60 to 1.71	0.34
History of cardiovascular disorders including stroke	0.01	0.17	−0.28 to 0.61	0.46
History of heart attack	−0.01	−0.74	−1.61 to 0.13	0.09
History of dementia	−0.02	−2.77	−5.07 to −0.48	0.02
History of diabetes mellitus	−0.003	−0.13	−0.82 to 0.57	0.72
History of diarrhoea	−0.002	−0.41	−3.08 to 2.27	0.77
History of iron deficiency anaemia	−0.01	−0.56	−1.39 to 0.27	0.19
History of low blood pressure and hospital admittance	−0.002	−0.13	−1.19 to 0.93	0.81

Continued

Table 1 Continued

	Standardised regression coefficient beta	Non-standardised regression coefficient B	95% CI of B	P value
History of osteoarthritis	−0.01	−0.29	−0.79 to 0.20	0.25
History of skin disease	0.002	0.11	−0.73 to 0.95	0.80
History of thyroid disease	0.01	0.20	−0.46 to 0.86	0.55
History of falls	−0.03	−0.85	−1.33 to −0.37	<0.001
History of unconsciousness	−0.02	−0.79	−1.48 to −0.10	0.02
History of menopause	−0.001	−0.03	−0.68 to 0.63	0.94
Age of the last regular menstrual bleeding (years)	0.01	0.01	−0.04 to 0.06	0.60
Age of the last menstrual bleeding (years)	0.01	0.01	−0.04 to 0.06	0.61
Alanine aminotransferase (IU/L)	0.02	0.02	0.000 to 0.03	0.06
Aspartate aminotransferase (IU/L)	0.01	0.01	−0.01 to 0.03	0.29
Aspartate aminotransferase to alanine aminotransferase ratio	0.001	0.02	−0.35 to 0.40	0.90
Bilirubin, total (µmol/L)	0.01	0.01	−0.01 to 0.03	0.18
High-density lipoprotein (mmol/L)	0.003	0.05	−0.17 to 0.26	0.68
Low-density lipoprotein (mmol/L)	0.03	0.25	0.09 to 0.41	0.002
Cholesterol (mmol/L)	0.03	0.19	0.08 to 0.30	0.001
Triglycerides (mmol/L)	0.02	0.36	0.10 to 0.61	0.006
Rheumatoid factor (IU/mL)	0.002	0.03	−0.19 to 0.25	0.78
Erythrocyte sedimentation rate (mm/hour)	−0.03	−0.03	−0.05 to −0.01	<0.001
Glucose (mmol/L)	0.004	0.03	−0.09 to 0.14	0.62
Creatinine (µmol/L)	−0.003	−0.002	−0.01 to 0.01	0.70
Estimated glomerular filtration rate (mL/min/1.73 m^2)	−0.01	−0.01	−0.02 to 0.003	0.16
Chronic kidney disease stage	0.01	0.02	−0.01 to 0.05	0.13
Urea (mmol/L)	−0.01	−0.11	−0.24 to 0.02	0.11
Residual nitrogen (g/L)	−0.01	−1.84	−4.43 to 0.75	0.16
Total protein (g/L)	0.01	0.02	−0.01 to 0.05	0.20
International normalised ratio	−0.02	−1.73	−3.01 to −0.44	0.009
Blood clotting time (min)	−0.02	−0.49	−0.87 to −0.11	0.01
Prothrombin time (%)	0.03	0.03	0.01 to 0.05	0.003
Haemoglobin (g/L)	0.06	0.05	0.03 to 0.06	<0.001
Erythrocyte count (10^6 cells/µL)	0.06	1.84	1.28 to 2.40	<0.001
Leucocyte cell count (×10^9/L)	−0.02	−0.19	−0.32 to −0.05	0.006
Rod-core granulocyte (% of leucocytes)	−0.02	−0.13	−0.27 to 0.01	0.07
Segment nuclear granulocyte (% of leucocytes)	0.02	0.02	−0.003 to 0.05	0.09
Eosinophil granulocytes (% of leucocytes)	−0.02	−0.19	−0.38 to 0.000	0.05
Lymphocytes (% of leucocytes)	−0.001	−0.002	−0.03 to 0.03	0.92
Monocytes (% of leucocytes)	−0.02	−0.08	−0.16 to 0.01	0.07
Prevalence of diabetes mellitus	−0.01	−0.27	−0.88 to 0.34	0.39
Anaemia (serum haemoglobin concentration <140 g/L in men and <130 g/L in women)	−0.04	−0.97	−1.42 to −0.52	<0.001
Blood pressure, systolic (mm Hg)	0.02	0.01	0.000 to 0.02	0.046
Blood pressure, diastolic (mm Hg)	0.02	0.03	0.01 to 0.04	0.008
Blood pressure, mean (mm Hg)	0.02	0.02	0.01 to 0.04	0.01
Arterial hypertension (no/yes)	0.02	0.70	0.16 to 1.23	0.01
Arterial hypertension, stages	0.03	0.28	0.09 to 0.47	0.004
Ankle–brachial index, right	−0.01	−0.45	−1.86 to 0.96	0.53
Ankle–brachial index, left	−0.01	−0.63	−2.04 to 0.78	0.38
Prevalence of chronic obstructive pulmonary disease (no/yes)	0.02	3.27	0.35 to 6.19	0.03
Metabolic syndrome, prevalence (no/yes)	0.03	0.81	0.37 to 0.124	<0.001
Non-alcoholic fatty liver disease, prevalence (no/yes)	−0.01	−0.32	−0.71 to 0.07	0.10
State-Trait Anxiety Inventory Test	−0.05	−0.17	−0.23 to −0.12	<0.001
Depression score	−0.06	−0.18	−0.23 to −0.13	<0.001
Hearing loss score	−0.03	−0.03	−0.04 to −0.01	0.004
Ocular parameters				
Visual acuity (best corrected; better eye) (logMAR)	−0.08	−4.21	−5.17 to −3.25	<0.001
Dry eye, prevalence (no/yes)	−0.02	−1.10	−1.97 to −0.4	0.01
Ocular axial length (mm)	0.05	0.50	0.33 to 0.68	<0.001
Intraocular pressure (mm Hg)	0.04	0.11	0.06 to 0.15	<0.001
Retinal nerve fibre layer thickness peripapillary (µm)	0.02	0.02	0.004 to 0.03	0.006

Continued

Table 1 Continued

	Standardised regression coefficient beta	Non-standardised regression coefficient B	95% CI of B	P value
Diabetic retinopathy, prevalence	−0.03	−2.21	−3.65 to −0.77	0.003
Cataract, nuclear (prevalence)	−0.004	−0.10	−0.55 to 0.35	0.67
Cataract, nuclear (degree)	−0.01	−0.15	−0.38 to 0.07	0.18
Cataract, cortical (prevalence)	−0.01	−0.41	−0.99 to 0.17	0.17
Cataract, cortical (degree)	0.001	0.001	−0.02 to 0.02	0.95
Cataract, subcapsular posterior (prevalence)	−0.02	−2.51	−5.01 to −0.02	0.048
Cataract, subcapsular posterior (degree)	−0.01	−0.05	−0.14 to 0.05	0.33
Cataract, any (prevalence)	0.002	0.05	−0.36 to 0.46	0.82
Age-related macular degeneration, any (prevalence)	0.005	0.19	−0.50 to 0.88	0.59
Age-related macular degeneration, early stage (prevalence)	0.003	0.15	−0.68 to 0.97	0.73
Age-related macular degeneration, intermediate stage (prevalence)	−0.001	−0.09	−1.33 to 1.14	0.88
Age-related macular degeneration, late stage (prevalence)	−0.001	−0.20	−2.89 to 2.49	0.88
Glaucoma, open-angle, prevalence	−0.02	−1.32	−2.56 to −0.08	0.037
Glaucoma, open-angle, stage	−0.02	−0.57	−1.08 to −0.07	0.03
Glaucoma, angle-closure, prevalence	−0.01	−0.68	−2.55 to 1.19	0.47
Glaucoma, angle-closure, stage	−0.01	−0.36	−1.18 to 0.45	0.38
Glaucoma, any, prevalence	−0.02	−1.17	−2.22 to −0.12	0.03
Glaucoma, any, stage	−0.02	−0.54	−0.97 to −0.10	0.02

logMAR, logarithm of the minimal angle of resolution.

DISCUSSION

In our population-based study from Russia, a higher HGS correlated with better visual acuity (beta: 0.02, p=0.02), longer ocular axial length (beta: 0.03, p=0.003), higher IOP (beta: 0.03, p=0.001), thicker peripapillary retinal nerve fibre layer thickness (beta: 0.03, p=0.001) and lower prevalence of diabetic retinopathy (beta: −0.03, p=0.003), after adjusting for potential systemic confounding factors (table 2). In the model, HGS was not correlated with the prevalence of other major ocular disorders, such as any cataract, nuclear cataract, cortical cataract, subcapsular posterior cataract, any glaucoma, open-angle glaucoma or angle-closure glaucoma, and dry eye disorder. The findings suggest that HGS dynamometry, or a handshake as surrogate, may provide the ophthalmologist some additional clinical information about the general health and some ocular parameters of the patient.

Table 2 Associations (multivariable analysis) between hand grip strength (right hand) and other parameters in the Ural Eye and Medical Study (correlation coefficient r^2=0.67)

	Standardised regression coefficient beta	Non-standardised regression coefficient B	95% CI of B, lower limit	95% CI of B, upper limit	P value	Variance inflation factor
Visual acuity, binocular or better eye, best corrected (logMAR)	−0.02	−1.14	−2.07	−0.20	0.02	1.15
Ocular axial length (mm)	0.03	0.31	0.11	0.51	0.003	1.16
Intraocular pressure (mm Hg)	0.03	0.10	0.04	0.16	0.001	1.05
Retinal nerve fibre layer thickness, peripapillary (µm)	0.03	0.02	0.01	0.03	0.001	1.19
Diabetic retinopathy, prevalence	−0.03	−2.35	−3.93	−0.77	0.003	1.02
Systemic parameters						
Age (years)	−0.27	−0.31	−0.33	−0.28	<0.001	1.46
Sex (female/male)	0.55	12.9	12.3	13.6	<0.001	2.46
Russian ethnicity (no/yes)	0.04	1.23	0.72	1.74	<0.001	1.06
Body height (cm)	0.16	0.21	0.18	0.25	<0.001	2.05
Body waist to hip circumference ratio	0.04	4.52	2.15	6.89	<0.001	1.16
Level of education (1–8)	0.05	0.40	0.24	0.56	<0.001	1.15
Smoking package years	−0.03	−0.03	−0.04	−0.01	0.006	1.17
Salt consumption, self-reported (g)	−0.04	−0.20	−0.29	−0.11	<0.001	1.01
Degree of processing meat (weak, medium, well done)	0.02	0.51	0.13	0.89	0.009	1.01
Physical activity score	0.04	0.05	0.02	0.08	<0.001	1.15
Serum concentration haemoglobin (g/L)	0.06	0.04	0.03	0.06	<0.001	1.29
Prothrombin index	0.02	0.03	0.01	0.04	0.01	1.02
Leucocyte cell count	−0.03	−0.20	−0.35	−0.06	0.006	1.01
Non-alcoholic fatty liver disease, prevalence	−0.02	−0.48	−0.90	−0.06	0.03	1.04
Depression score	−0.05	−0.15	−0.20	−0.09	<0.001	1.09
History of arthritis	−0.02	−0.54	−1.02	−0.07	0.03	1.07

logMAR, logarithm of the minimal angle of resolution.

The findings of our study agree with observations obtained in previous investigations. The association between higher HGS and better visual acuity found in our study population confirms the observations made by Klein and colleagues[5 6] in the Beaver Dam Eye Study, in which poorer visual functions were associated with greater frailty as measured by HGS and other methods. Our findings are also in agreement with the findings made by Gopinath and associates[9] in the Blue Mountains Eye Study. Since the present study was only a cross-sectional investigation, conclusions about the causality of lower vision and lower HGS cannot be drawn. It may be likely that visually impaired individuals have a lower chance for physical activity and, according to previous studies, a higher risk for depression.[20 21] Both lower physical activity and higher depression score were associated with lower HGS in our study population (tables 1 and 2). Since a low HGS is a risk factor for all-cause mortality, the association between lower HGS and vision impairment may be an additional argument to improve low vision, in particular in the elderly population, by measures such as providing glasses that correct refractive errors including presbyopia and providing cataract surgery, with cataract and undercorrection of refractive errors being by far the most common causes of vision impairment worldwide.[22] The prevalence of most of the common ocular disorders, such as any cataract and the various types of cataract, any glaucoma as a whole and differentiated between open-angle glaucoma and angle-closure glaucoma, dry eye disorder, and AMD, was not correlated with HGS in the multivariable analysis of our study population (table 2). Klein and colleagues[7 8] reported that cortical cataract correlated in men with weaker HGS (p=0.02), while cortical cataract in women and nuclear cataract in both sexes were not significantly associated with HGS after controlling for age, comorbidity index, smoking package years, sedentary lifestyle, level of education and visual acuity. In the Beaver Dam Eye Study by Klein and associates,[8] cataract was associated with frailty indicators other than HGS. Klein and colleagues also found a weak correlation between HGS and AMD in men. The reasons for the discrepancies between the studies may in particular be differences in the multivariable analysis, that is, which systemic and other ocular parameters were included in the analysis as independent variables.

Interestingly, a higher prevalence of diabetic retinopathy correlated with a lower HGS in our study population (table 2). It is paralleled by a tendency of a lower HGS correlating with a higher prevalence of diabetes (beta: −0.01, p=0.11) in the multivariable model in our study. A higher HGS was associated with a thicker peripapillary retinal nerve fibre layer, longer axial length and higher IOP. The correlation with thicker retinal nerve fibre layer may correspond to the association between higher HGS and general good health. The correlation with longer axial length or myopia may be due to an association between myopia and higher socioeconomic background in the population, with a higher socioeconomic status usually correlating with lower body mass index and better general health.[23] The correlation between higher HGS and higher IOP may be due to an association between higher intraocular and higher arterial blood pressure, with the prevalence of arterial hypertension showing a borderline significant association with higher HGS in our study population (beta: 0.02, p=0.05).[24] It was also noteworthy that a lower HGS correlated with lower visual acuity, but not with the hearing loss score. It may suggest that vision loss as compared with hearing loss played a more important role in HGS and its associated factors.

It may be interesting why ophthalmological diseases other than diabetic retinopathy were not significantly associated with HGS. The reason may be that, after adjusting only for age and sex, a higher HGS indeed correlated with a lower prevalence of dry eye, open-angle glaucoma and of any glaucoma, in addition to better visual acuity, longer axial length, higher IOP, higher prevalence of diabetic retinopathy and thicker peripapillary retinal nerve fibre layer (table 1). The prevalence of any cataract and AMD was not related to HGS with adjustments for age and sex. If the multivariable analysis additionally included the independent parameters as listed in table 2 (eg, visual acuity, axial length, IOP, body height and depression score), the associations between HGS and the prevalence of dry eye and open-angle glaucoma and of any glaucoma were no longer statistically significant. One may discuss that the parameters included in the multivariable analysis were proxies for dry eye and glaucoma. The observation that the prevalence of AMD and cataract was independent of HGS after adjusting for sex and age may suggest that these two disorders were less dependent on systemic parameters or on general health.

When the observations made in our study are discussed, the limitations of our investigation have to be considered. First, when the findings of investigations on different study populations are compared with each other, differences in the composition of the study populations with respect to the factors associated with HGS should be taken into account. Second, the techniques to measure HGS vary between investigations.[2] Third, although the correlation coefficient for the whole analysis was relatively high (r^2=0.67), one may have to take into account that the correlation coefficients for the single ocular parameters were relatively low (table 2). It indicates that the major parameters for HGS were age and sex, while the ocular parameters played a minor role. The strengths of our project were that it is the first study where the associations of HGS with ocular parameters and diseases were assessed, in particular in a population-based manner; the study included a large number of parameters and diseases which were examined and then assessed for their associations with HGS (it may have reduced the risk of bias due to confounding factors); the study recruited its study population in a population-based manner; the study is the first to explore the associations between HGS and sensory functions other than vision; and HGS has not yet been examined for a population residing in Russia, Eastern Europe and Central Asia.

In conclusion, in addition to parameters such as lower physical activity, higher depression score and worse general health status, a reduced HGS is associated with visual impairment, shorter axial length, thinner peripapillary retinal nerve fibre layer, lower IOP and higher prevalence of diabetic retinopathy. HGS dynamometry or a handshake may provide the ophthalmologist additional clinical information about the general health and some ocular parameters of the patient.

Contributors Design: MMB, JBJ. Examination of participants: MMB, RMZ, TRG, EMI, GMK, SP-J, AMT, AAF, LIG, JBJ. Funding: MMB. Statistical analysis: SPJ, JBJ. Writing of the first draft: SP-J, JBJ. Revision and final approval: MMB, RMZ, TRG, EMI, GMK, SP-J, AMT, AAF, LIG, JBJ. Guarantor: MMB and JBJ.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient consent for publication Not required.

Ethics approval This study involves human participants. The Ethics Committee of the Academic Council of the Ufa Eye Research Institute approved the study design and confirmed that the study adhered to the Declaration of Helsinki (date of approval: 16 March 2015). Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request.

ORCID iD
Jost B Jonas http://orcid.org/0000-0003-2972-5227

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