Effect of providing near glasses on productivity among rural Indian tea workers with presbyopia (PROSPER): a randomised trial

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Summary

Background Presbyopia, age-related decline in near vision, is the most common cause of vision impairment globally, but no trials have assessed its workplace effects. We aimed to study the effect of near glasses on the productivity of tea workers with presbyopia.

Methods This randomised trial was done in tea pickers aged 40 years or older in Assam, India, with unaided near visual acuity (NVA) lower than 6/12 in both eyes, correctable to 6/7·5 with near glasses; unaided distance vision 6/7·5 or greater; and no eye disease. Participants were randomly assigned (1:1) to receive free glasses optimising NVA at working distance (cost including delivery US$10·20 per person), either immediately (intervention group) or at closeout (control group). Participants were stratified by age, sex, and productivity. The primary outcome (investigator-masked) was the difference between groups in the change in mean daily weight of tea picked (productivity), between the 4-week baseline period (June, 2017) and the 11-week evaluation period (July 24, 2017, to Oct 7, 2017). Workers' income was tied to their productivity. Compliance with study glasses was assessed at seven unannounced visits. Results were analysed on an intention-to-treat basis. This trial is registered with ClinicalTrials.gov, number NCT03228199.

Findings Between July 3, 2017, and July 15, 2017, 1297 (48·1%) of 2699 permanent workers met the age criteria and consented for eye examinations. 751 (57·9%) fulfilled vision criteria and were randomly assigned to the intervention (n=376) or control (n=375) groups. Groups did not differ substantially in baseline characteristics. No participants owned glasses at baseline, 707 (94·1%) received the allocated intervention, and all were followed up and analysed. Between the baseline and evaluation periods, mean productivity in the intervention group increased from 25·0 kg per day to 34·8 kg per day (an increase of 9·84 kg per day), a significantly higher increase than in the control group (from 26·0 kg per day to 30·6 kg per day; an increase of 4·59 kg per day), corresponding to a between-group difference of 5·25 kg per day (95% CI 4·50–5·99; 21·7% relative productivity increase; effect size 1·01 [95% CI 0·86–1·16]; p<0·0001). Intervention-group compliance with study glasses reached 84·5% by closeout. Regression model predictors of greater productivity increase included intervention group membership (5·25 kg per day [95% CI 4·60–5·91], p<0·0001) and, among intervention participants, older age (p=0·039) and better compliance with the intervention (p<0·0001).

Interpretation A substantial productivity increase was achieved in this rural cohort by providing glasses to correct presbyopia, with little cost and high intervention uptake.

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Introduction

Nobel Laureate Paul Krugman has said: "Productivity isn't everything, but in the long run it is almost everything. A country's ability to improve its standard of living over time depends almost entirely on... [raising] output per worker."[1] The Sustainable Development Goals (SDGs), central to the UN global development agenda, call for an end to poverty (SDG 1) and the promotion of health for all (SDG 3).[2] A basic tenet of global health policy is that good health and productive work are causally linked,[3] and yet the effects on labour productivity of only a few health interventions have been evaluated in randomised trials in low-income and middle-income countries.[4–9] Most such trials involve dietary supplementation to improve nutritional status,[4,6–9] and have generally shown uncertain or non-significant effect sizes.[4,6–9] Supplementation requires sustainable distribution pathways and long-term adherence, both of which are challenging in low-resource areas.

Low-cost, sustainable, and effective health interventions are needed to increase work productivity and reduce poverty in low-income and middle-income

Research in context

Evidence before this study

We reviewed the impact of presbyopia in low-income and middle-income countries by searching MEDLINE, Embase, and WHO Library databases from Nov 19, 2017, to Nov 26, 2017, for articles published in any language appearing after Jan 1, 1975, using the following combinations of terms together with a list of low-income and middle-income countries: "near vision" AND "impairment"; "prevalence" AND "presbyopia"; "presbyopia" OR "near vision" AND "correction"; "presbyopia" AND "correction" AND "productivity"; and "presbyopia" AND "correction" AND "quality of life" AND "activity". Population studies in rural China and Tanzania provided low-quality evidence of significantly increased difficulty with activities of daily living among individuals with presbyopia. A small study (n=187) in Zanzibar addressing the impact of presbyopia correction with glasses found moderate-quality evidence of large effects on work-related activities of daily living. We found no randomised trials. For our review of health interventions to improve work productivity in low-income and middle-income countries we searched MEDLINE, Embase, and Econlit databases on Nov 16, 2017, for studies published in any language since inception, using 53 terms (appendix). We found six trials, only one published after 2005, of which five concerned nutritional interventions and one mosquito nets. Only two had statistically significant effect sizes, both less than 15%. Together, these studies provided weak-to-moderate-quality evidence for a modest effect of iron, and possibly mosquito netting, on improving work productivity.

Added value of this study

Our investigator-masked, randomised trial on the effect of providing glasses to correct presbyopia among 751 tea workers aged 40 years or older in India found a significantly higher increase in mean productivity in the intervention group than in the control group. The intervention cost was low (US$10·20 per person), acceptance was high (>80% by closeout), presbyopia was common (>50%) among workers aged 40 years or older, and biological plausibility was increased by an observed greater effect of the intervention among older participants with this age-related condition.

Implications of all the available evidence

Our study adds to the evidence that correction of even modest presbyopia, which is common at age 40 years or older, can significantly improve work productivity at low cost in a visually demanding labour setting. This intervention can be sustained by workers themselves; 95% of workers in this study said they would pay for glasses. Our results are consistent with evidence from other studies (none of which were trials) suggesting that correction of presbyopia can improve performance of various economically important tasks.

countries. With the global population ageing rapidly, and labour participation rates in low-income and middle-income countries declining in individuals older than 45 years,[10] health strategies that support productive employment (SDG 8) among older workers are of particular interest. Gender equality (SDG 5) is also highly relevant to poverty alleviation, as increasing workforce participation and productivity among women results in faster economic growth.[11]

Presbyopia is the essentially universal decline in unaided near vision associated with ageing. Functionally apparent around the age of 40 years, and essentially complete by age 55 years,[12] presbyopia is prevalent during the working years.[13] The number of affected individuals globally exceeds 1 billion, making presbyopia the world's most common cause of vision impairment.[14] Although presbyopia is safely, effectively, and inexpensively treated with glasses, ownership rates in low-income and middle-income countries are as low as 10%.[15,16] Presbyopia causes an estimated US$25 billion in global productivity loss[17] and is associated with substantial impairment in activities of daily living.[18] However, to the best of our knowledge there are no published trials examining whether correcting presbyopia with glasses improves work productivity.

We aimed to do a randomised, investigator-masked trial to ascertain whether providing free glasses to tea workers with presbyopia in India could improve work productivity. Our hypothesis was that inclusion in the intervention group would lead to significantly greater increases in productivity than in the control group, measured as the group difference in the change in mean daily weight of tea picked before and after the intervention.

For the **study protocol** see https://www.qub.ac.uk/research-centres/CentreforPublicHealth/Research/PROSPER/

Methods

Study design and participants

The PROSPER (PROductivity Study of Presbyopia Elimination in Rural-dwellers) study was an investigator-masked, randomised trial carried out in Assam, India. The protocol was approved by ethics committees at Lions National Association of the Blind (NAB) Eye Hospital (Miraj, India) and Queen's University Belfast (Belfast, UK; approval for data analysis). The tenets of the Declaration of Helsinki were followed throughout. The study protocol is available online.

Unlike the rest of the year, the amount of tea picked during the high season in Assam (June to October) is limited by the worker, rather than by the rate of plant growth. Income is therefore tied to productivity as an incentive. All permanent workers aged 40 years or older as of Dec 31, 2017, at three tea estates in Assam (Kellyden, Nonoi, and Sagmootea) owned by Amalgamated

Plantation Private Ltd (APPL), and who had worked for APPL for at least 1 year and for 10 or more days in the previous month, were invited to undergo a free eye examination. Study personnel obtained oral informed consent from workers undergoing examinations. The study inclusion criterion based on this examination was the presence of presbyopia in both eyes, defined as habitual near visual acuity (NVA) of 6/12 or lower at 40 cm, correctable with spherical (non-astigmatic) near glasses to 6/7·5 or greater, as such glasses are cheap and quick to make. Exclusion criteria were: ownership of near glasses capable of improving NVA to 6/12 or greater, unaided distance vision lower than 6/7·5, visually significant eye disease, and low likelihood of completing follow-up. The latter was assessed by asking participants whether there was any reason why they might not be able to complete the study (eg, plans to move out of the region).

Randomisation and masking

Consenting participants eligible for the trial were divided into eight strata according to age (<50 years *vs* ≥50 years), sex, and work productivity during June, 2016 (<median *vs* ≥median). Participants in each stratum were randomly assigned (1:1) with a block size of six to the intervention or control groups. The intervention group immediately received free, spherical presbyopic glasses providing the best NVA in each eye at the participant's usual working distance. The control group received similar glasses after the 11-week evaluation period.

The randomisation sequence was generated by the study statistician at the Clinical Trials Unit of the Zhongshan Ophthalmic Center (Guangzhou, China) by use of an online random number generator (Randomization.com), and concealed until a worker was identified as being eligible and agreed to participate. The field team consisted of four experienced optometrists, three nurses, two data assistants, and a screening coordinator, all employed by VisionSpring, an eye health non-governmental organisation. This team had a list provided by APPL of potential participants and their current age and productivity in June, 2016. The team carried out eye examinations and distributed glasses to eligible participants in the intervention group from July 3, 2017, to July 15, 2017. Study personnel accessed the random assignment for each participant according to the correct age-sex-productivity stratum only at the time of enrolment.

Study personnel carrying out the eye examination and facilitating randomisation and distribution of glasses had no further contact with participants until glasses were distributed to the control group at trial closeout. Masking of study participants to their group assignment was impractical, but staff measuring the weight of tea picked were masked to workers' group assignments.

Procedures

Consenting workers meeting age and work criteria underwent measurement of distance visual acuity in each eye separately with a log of the Minimum Angle of Resolution (logMAR) chart in a well-lit area. Study optometrists measured unaided NVA (without near glasses) in each eye separately with a tumbling E Early Treatment Diabetic Retinopathy Study (ETDRS) chart[19] at a distance of 40 cm.

Workers meeting criteria for near and distance vision underwent assessment of refractive power by an optometrist. They were directed to stand in front of a tea bush and adopt their usual stance for picking tea. The distance from each eye to the top of the bush was measured, and lenses enabling the participant to identify two to three leaves and a bud appropriate for picking were prescribed. Glasses were provided to the intervention group immediately after the eye examination, with directions to begin wearing them on July 24, 2017, when the trial began.

Data were collected on potential determinants of productivity and compliance with glasses, including age, sex, marital status, baseline ownership of glasses, years working as a tea picker, and work attitudes. Participants' height was also measured as a potential determinant of productivity.

Workers with unaided distance visual acuity lower than 6/18 (ineligible for the study) underwent refraction tests and received free distance glasses if required. Those whose distance visual acuity did not improve with glasses underwent a detailed ocular examination with dilation of the pupil and examination of the ocular fundus. Workers with cataract were referred for free surgery and those with other conditions were referred to a local eye hospital (ERC Eye Care, Jorhat, Assam, India), with medical expenses assumed by APPL.

For the **online random number generator** see http://www.randomization.com

Outcomes

The main study outcome was the difference between randomised groups in the change in mean daily weight of tea picked between the baseline period (retrospective data from June, 2017) and the evaluation period. Secondary outcomes were visual quality of life, assessed once (Aug 2–8, 2017) with the National Eye Institute Visual Function Questionnaire-25 (VFQ-25)[20] during the evaluation period, and observed wear of glasses in the intervention group during seven regular, unannounced visits. Daily work attendance during the evaluation period was obtained from APPL records. Subjective usefulness of study glasses, likelihood of recommending them to other workers, and amount willing to pay for them if lost or broken were assessed for the intervention group, but these assessments were not prespecified.

Daily weight of tea picked by participants in both groups was assessed by masked APPL employees as follows during an 11-week evaluation period from

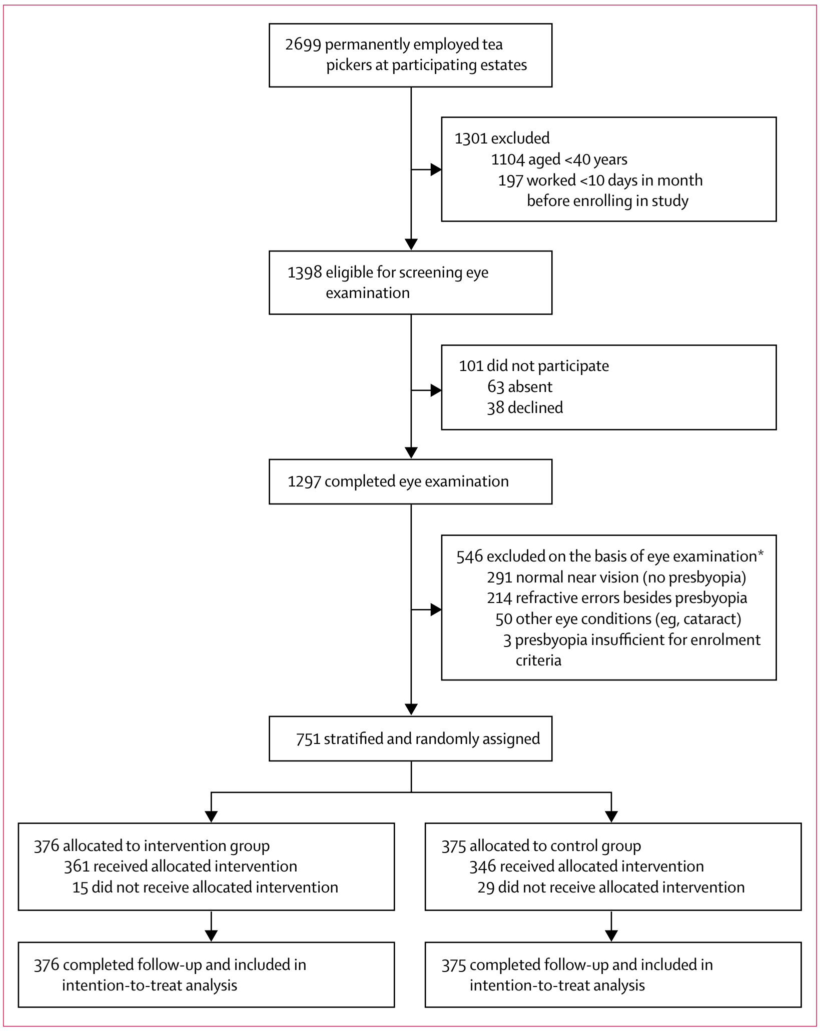

Figure 1: **Trial profile**

*12 participants had both refractive error and other conditions. For details of stratification by age, sex, and productivity, see the appendix.

See **Online** for appendix

July 24, 2017, to Oct 7, 2017. Intervention-group participants removed their glasses before proceeding to the weighing station. One employee received the sack of tea and suspended it on an electrical scale (Easyweigh, Applied Data Logix, Chennai, India), while a second, also masked to workers' group assignments, swiped the participant's work identification card. The scale automatically measured and recorded the weight in the APPL database.

Statistical analysis

With a two-sided significance level of p=0·05 and power of 80% to detect a 10% greater increase in the intervention group than in the control group from a baseline mean of 25·0 kg per day (SD 5·0) of tea picked (based on APPL records), and allowing for 20% loss to follow-up, we calculated that a sample size of 160 individuals (80 per group) would be required. To do adequately powered age-stratified analyses, we sought to recruit 700 participants in total.

The difference in productivity gains between study groups was assessed by intention to treat with the two-sample *t* test. Linear regression analyses were done on potential determinants of primary and secondary outcomes. The study group and all significant variables with p values less than 0·20 in simple regression analyses were included in multiple regression models. Histograms, normal quantile plots (QQ Plot), and the Jarque-Bera normality test were used to test the normality assumption in regression models. For the VFQ-25, a composite score (25 items) and near activities subscore (two items) were created on 0–100 scales. The percentage increase in productivity for each group, measured as the change in mean daily weight of tea picked between the baseline and evaluation period, divided by the group's baseline mean, was calculated. For multiple imputation of missing data in assessing primary and secondary outcomes, we created 20 copies of the data, in which missing values were imputed by chained equations, and the datasets were averaged. Statistical analyses were done in Stata, version 14.2.

This trial is registered with ClinicalTrials.gov, number NCT03228199.

Role of the funding source

The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Results

Among 2699 permanent tea pickers at the three estates, 1398 (51·8%) met the age and work criteria and were eligible for the screening eye examination (figure 1). For details of stratification by age, sex, and productivity, see the appendix. Among these, 1297 (92·8%) completed the examination. 63 (4·51%) were absent and 38 (2·72%) declined. Based on the examination, 751 (57·9%) workers were eligible for the trial and underwent stratification and randomisation, with 376 (50·1%) participants allocated to the intervention group and 375 (49·9%) to the control group. Among intervention participants, 361 (96·0%) received their allocated treatment, as did 346 (92·3%) of control participants. All participants completed follow-up and were analysed on an intention-to-treat basis.

Participants in both groups were primarily women, with a mean age of 47 years (table 1). No participants had glasses at baseline, and most had modest presbyopia, with less than 20% in both groups having NVA less than 6/18. Nearly all participants in both groups had normal NVA (6/6 at 40 cm) with study glasses, and all agreed that "It is important to maximise my income by picking as much tea as possible."

Baseline mean daily weight of tea picked (June, 2017) differed between control (26·0 kg per day) and intervention participants (25·0 kg per day; p=0·00055), as stratification on the most recently available data (June, 2016) did not fully balance the groups.

The daily weight of tea picked in the intervention group increased from 25·0 kg per day to 34·8 kg per day between the baseline and the evaluation periods. This increase of 9·84 kg per day (95% CI 9·27–10·4) was greater than that for the control group (from 26·0 kg per day to 30·6 kg per day, an increase of 4·59 kg per day [95% CI 4·10–5·07]; p<0·0001). The between-group difference (5·25 kg per day [95% CI 4·50–5·99]; p<0·0001) was equivalent to a 21·7% relative productivity increase, with an effect size (Cohen's *d*) of 1·01 (95% CI 0·86–1·16; table 2). In multiple regression models, variables significantly associated with greater productivity increase included intervention group membership, female sex, and work attendance during the evaluation period (table 3). Years working as a tea picker (p=0·042) and intervention-group compliance with glasses (p<0·0001) were significantly associated with greater productivity increases in univariate analyses, but were excluded from multivariate models because of collinearity with age and group assignment.

In multivariate models, the association between age and productivity increase was different between intervention and control groups: increasing age was associated with greater productivity increases (0·112 kg per day per year of age, p=0·039) in the intervention group, but negatively associated with productivity (–0·158 kg per day per year of age; p=0·00022) within the control group (table 3). Thus, the between-group difference in the change in productivity rose with increasing age (figure 2): 40–44 years (3·89 kg per day [95% CI 2·82–4·96], 15·8% of baseline); 45–49 years (4·79 kg per day [3·47–6·12], 18·9% of baseline), and 50 years or older (7·29 kg per day [5·90–8·68], 31·6% of baseline; p=0·0003, two-way ANOVA). Larger gains among older intervention-group participants were due to their lower baseline productivity than that of younger participants (40–44 years, 25·6 kg per day [95% CI 24·9–26·2]; ≥50 years, 23·9 kg per day [23·1–24·7]; p=0·0018]), a deficit that disappeared during the evaluation period (40–44 years, 35·4 kg per day [34·5–36·2]; ≥50 years, 35·1 kg per day [34·2–35·9]; p=0·607).

Intervention-group participants wore glasses during 1547 (69·5%) of 2227 unannounced visits. Compliance reached 84·5% (539 of 638) during the last month of the evaluation period. Productivity in the intervention group rose as compliance with study glasses increased (figure 2). No control-group participants had purchased glasses during compliance assessments.

Among those completing questionnaires (intervention group: 311 [82·7%] of 376; control group: 319 [85·1%] of 375), visual quality of life was significantly higher in the intervention group: the between-group difference in multiple regression models (same variables as for table 3) for VFQ-25 total score was 9·25 points (95% CI 8·47–10·0; p<0·0001) and 29·1 points (27·1–31·1; p<0·0001) for the near activities subscore (both 100-point scales). Older age was associated with a lower near activities subscore in the control group (–1·20 points per year [95% CI –1·59 to –0·814], p<0·0001), but not in the intervention group (p=0·663).

The cost of glasses per person, including delivery, was $10·20. Among the 362 (92·8%) recipients of glasses

	Control group (n=375)	Intervention group (n=376)
Age, years		
40–44	151 (40·3%)	132 (35·1%)
45–49	87 (23·2%)	108 (28·7%)
≥50	137 (36·5%)	136 (36·2%)
Mean age (range)	47·1 (40–61)	47·2 (40–59)
Sex		
Women	293 (78·1%)	293 (77·9%)
Men	82 (21·8%)	83 (22·0%)
Mean height, cm*	150 (7·79)	150 (8·17)
Marital status: married*	370 (98·7%)	371 (98·7%)
Wearing glasses at baseline	0 (0%)	0 (0%)
Uncorrected near vision <6/18 in better-seeing eye	73 (19·5%)	69 (18·4%)
Mean power of near correction in better-seeing eye, dioptres	1·62 (0·436)	1·61 (0·418)
Best corrected near vision 6/6 (normal) in better-seeing eye	362 (96·6%)	355 (94·4%)
Mean working distance		
40–59 cm	40 (10·7%)	52 (13·8%)
60 cm	122 (32·5%)	122 (32·5%)
61–70 cm	213 (56·8%)	202 (53·7%)
Mean time working as a tea picker, years*	27·4 (8·06)	26·2 (8·39)
Agree or strongly agree: Important to maximise income by picking as much tea as possible*	374 (100·0%)	375 (100·0%)
Agree or strongly agree: Picking tea is main source of family income during high season*	374 (100·0%)	375 (100·0%)

Data are n (%) or mean (SD), unless otherwise stated. *Two participants had missing values for each of these variables.

Table 1: **Baseline characteristics of participants by group**

	Baseline mean daily productivity over 4 weeks, kg per day (SD)	Post-intervention mean daily productivity over 11 weeks, kg per day (SD)	Change in productivity, kg per day (95% CI)	Between-group difference in change in productivity, kg per day (95% CI)
Control group (n=375)	26·0 (3·48)	30·6 (4·77)	4·59 (4·10–5·07)	..
Intervention group (n=376)	25·0 (4·25)	34·8 (5·11)	9·84 (9·27–10·4)	5·25 (4·50–5·99); p<0·0001

Table 2: **Effect of randomisation group on change in productivity (daily weight of tea picked) from baseline**

	Univariate analysis (n=751)		Full model* (n=751)	
	β (95% CI)	p value	β (95% CI)	p value
Intervention group (control group as reference)	5·25 (4·50 to 5·99)	<0·0001	5·25 (4·60 to 5·91)	<0·0001
Age, years (age effect in control group)	–0·00383 (–0·0841 to 0·0764)	0·925	–0·158 (–0·242 to –0·0745)	0·00022
Age, years (age effect in intervention group)	..	..	0·112 (0·00555 to 0·219)	0·039
Group × age interaction	..	..	0·271 (0·144 to 0·397)	<0·0001
Female sex	5·44 (4·80, 6·08)	<0·0001	4·61 (3·65 to 5·57)	<0·0001
Height, cm	–0·156 (–0·201 to –0·112)	<0·0001	–0·0339 (–0·0840 to 0·0162)	0·184
Observed compliance with study glasses (%)†	0·0640 (0·0473 to 0·0807)	<0·0001	..	..
Uncorrected near vision in better-seeing eye <6/18	1·11 (–0·0934 to 2·32)	0·071	1·00 (–0·126 to 2·13)	0·082
Working distance				
61–70 cm	Ref	..	Ref	..
60 cm	0·582 (–0·309 to 1·47)	0·200	–0·0235 (–0·741 to 0·694)	0·949
40–59 cm	–1·06 (–2·53 to 0·409)	0·157	–1·41 (–2·62 to –0·196)	0·023
Time working as tea picker, years	0·0543 (0·00189 to 0·107)	0·042	..	..
Work attendance rate during evaluation period (%)	0·106 (0·0777 to 0·134)	<0·0001	0·0367 (0·00978 to 0·0635)	0·008

*Including variables associated with change in productivity with significance of p<0·20 in the univariate analysis (time working as tea picker was excluded because of its collinearity with age; compliance with wearing of glasses was excluded because of collinearity with group assignment). Continuous variables were centred by subtracting the mean of the variable. †Expressed as a proportion: number of times glasses were worn during seven unannounced observations carried out at work during the 11-week evaluation period.

***Table 3:* Intention-to-treat analysis for linear regression model of potential predictors of change in productivity**

who responded to questionnaires, 356 (98·3%) found study glasses useful or very useful, 345 (95·3%) said they would recommend them to other tea pickers, and 343 (94·8%) said they would pay for new glasses if theirs were lost or broken. The mean amount willing to pay increased with age: $5·57 at age 40–44 years, $6·03 at age 45–49 years, and $6·64 at age 50 years or older (Kendall's tau bivariate correlation).

Discussion

In this randomised trial, we observed a significant increase in relative productivity of more than 20% among intervention-group members in this rural cohort of mostly female participants, with a low-cost and widely accepted intervention of near glasses for correction of presbyopia. The effect size of 1·01 fell between large (>0·8) and very large (>1·2).[21] Visual quality of life was also higher in the intervention group than in the control group, and almost all intervention-group participants found study glasses useful and said they would pay for them.

Presbyopia is strongly associated with ageing,[12] and we observed a significant interaction between age and study group for the main study outcome. Older participants in the intervention group had significantly greater productivity increases than younger participants, due to removal of their baseline deficit in productivity during the evaluation period, presumably because of the effects of corrective eyewear. Older participants in the control group, having more pronounced, uncorrected presbyopia, were less able than their younger peers to take advantage of higher tea yields during the peak high season, resulting in lower productivity increases. This strong interaction of age and productivity with study group adds to the biological plausibility of our results, as does the greater intervention-group productivity increase with improved study glasses compliance during the evaluation period.

We did two systematic reviews of studies done in low-income and middle-income countries: first, on the impact of presbyopia and second, on health interventions to improve work productivity. From the first systematic review, population studies of cohorts older than 40 years in rural China[22] and Tanzania[18] reported increased difficulty with near activities of daily living among individuals with presbyopia (increases of two times in China and eight times in Tanzania), although neither study assessed the effect of correction with glasses (low-quality data). Among 187 individuals aged 40 years or older in Zanzibar, most of whom had presbyopia, the effect size of giving glasses was substantial for various work-related activities of daily living (1·6–3·8, all p<0·001; moderate-quality data).[23] We identified no randomised trials in this review.

From our second systematic search, we found an iron supplementation trial among 199 tea workers with anaemia in Sri Lanka[4] that reported a significant effect on daily weight of tea picked for the intervention group only, but found no between-group difference. No significant difference between groups in weight of tea picked was reported in a trial of iron and anthelmintics among 553 Bangladeshi tea workers.[9] An Indonesian trial of iron supplementation involving 302 rubber plantation workers[8] reported a significant (14·5%) difference between study groups in productivity for tappers, but not for weeders. Among 80 Chinese mill

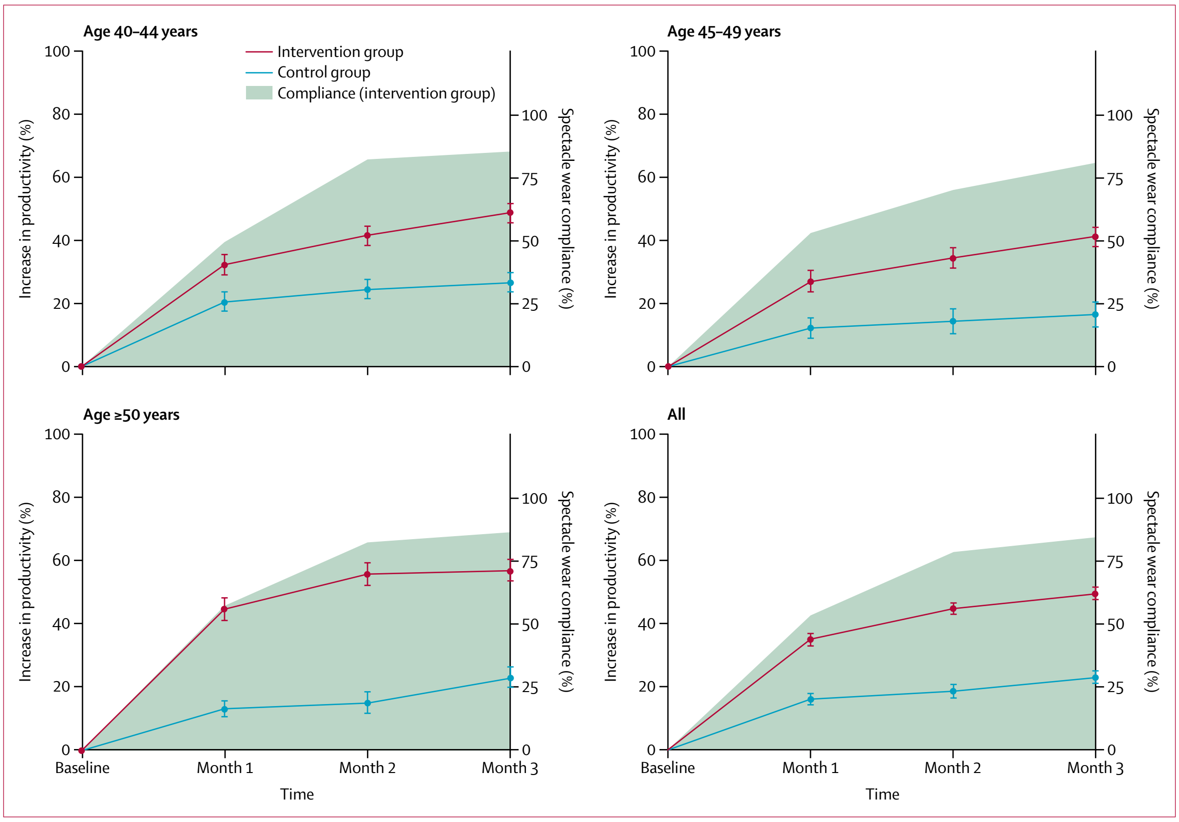

Figure 2: **Observed compliance with wearing of glasses (intervention group only) and percentage gain in productivity in the intervention and control groups during the evaluation period, stratified by age**

Error bars indicate 2 SD. Shaded area shows compliance.

workers receiving iron or placebo for 12 weeks,[6] a significant (5·2%) increase in productivity was observed in the intervention group, but there was no between-group difference. A Kenyan trial found no significant effect of caloric supplementation on productivity among 224 construction workers.[7] Provision of mosquito netting in a trial involving 516 farmers in a malarial area of Zambia[5] was associated with an improved harvest value of $76 (14·7%; p<0·05) compared with controls, although intervention-group farms were larger and more productive at baseline. In summary, few recent trials (only one since 2005) have assessed the impact of health interventions on productivity in low-income and middle-income countries. Only two studies[5,8] provide evidence for a modest effect of iron supplementation, and possibly mosquito netting, on work productivity.

The relative productivity increase in our intervention group was as large as or larger than that reported for other health intervention trials in low-income and middle-income countries.[4–9] Delivery of glasses to older workers could be a scalable and sustainable strategy for poverty alleviation. Our intervention was inexpensive and could potentially be sustained by employers benefiting from productivity increases, or by workers themselves: 95% of intervention-group participants said they would pay for glasses, consistent with other reports.[23] Medium-to-long-term retention of presbyopic glasses appears to be good, making provision logistically easy. Observed wear rates of our study glasses exceeded 80% by closeout, in accordance with other findings of high acceptance and retention of presbyopic glasses in low-income and middle-income countries.[23,24] Age-related decline in unaided near vision is essentially universal, so the pool of potential beneficiaries is large. Our data suggest that correction of even modest presbyopia (NVA ≤6/12), common in this setting, is associated with significant productivity gains. A study of Kenyan tea workers retiring for medical reasons[25] reported decreased productivity of 16–18% in the last 18 months of work, similar to the declines observed in workers with uncorrected presbyopia in our study. This finding suggests that productivity increases from provision of glasses might be sufficient to prevent older workers from leaving the labour force because of age-related vision loss.

Inferences about the applicability of our results to other work settings are limited by incomplete data. It is unclear what proportion of economically productive activity among older people in low-income and middle-income countries is sufficiently dependent on vision that correction of presbyopia would be useful. However, existing reports[22,23] from low-income and middle-income countries suggest that uncorrected presbyopia affects many economically important activities, including reading, writing, cooking, use of tools and mobile phones, sewing, weeding, and recognising money. Additional trials are needed in other work settings.

Other limitations of this study include the fact that, for practical and ethical reasons, participants were not masked to study group assignment, leaving open the possibility of placebo effects. The significant and biologically plausible interaction between age and study group makes a large placebo effect less plausible, although it cannot be excluded. Because of field team errors, 44 (5·85%) participants did not receive the allocated treatment, but the intention-to-treat analysis preserved the benefits of randomisation. Stratification of available data from 2016 rather than 2017 resulted in a modest but significant baseline difference in between-group productivity, although the difference-in-difference analysis reduced the impact on results. Study strengths, besides the randomised controlled design, included completeness of data for the main study outcome and its determinants, no losses to follow-up, and selection of a rural, low-income population highly relevant to assessment of poverty alleviation strategies in low-income and middle-income countries.

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Contributors

NC arranged financing for the study, supervised the study design and creation of forms, oversaw development and implementation of the protocol, directed statistical analysis, and wrote the draft of the manuscript. PAR drafted forms, supervised all field work and data entry, contributed to creation of the protocol, and offered criticism on manuscript drafts. GM arranged financing, contributed to the design of the study, protocol, and forms, carried out the presbyopia review with CJ, and offered input on statistical analysis and drafting of the manuscript. PG assisted with creation of the protocol and forms, contributed to field work, and offered criticism on the draft manuscript. QW helped design the forms, tables, and figures; carried out data cleaning and statistical analysis; drafted the statistical analysis section of the Methods; and offered criticisms of the draft manuscript. CJ assisted with design of forms, carried out the presbyopia review with GM, and offered criticism on the manuscript. MC contributed as an expert trial methodologist to the design and implementation of the study and drafting of the manuscript. JK assisted in arranging financing for the study, helped to identify the study site in Assam, offered input into the study design, and contributed to criticisms of the draft manuscript. EG helped to identify funding for the trial, contributed to field work by making arrangements for the field teams, and offered criticisms on the draft manuscript. CO'N oversaw health economics aspects of the study, principally the calculation of total study cost per beneficiary, supervised JT in carrying out the review of the literature on health-related productivity, and contributed to criticisms of the manuscript. LJ oversaw the process of randomisation and allocation with direction from MC, assisted QW in data analysis and creation of forms, and offered criticisms on the draft manuscript. JT carried out data analysis for the cost per beneficiary calculation, carried out the review of the literature on health-related productivity, and offered criticisms on the draft manuscript. KB helped in design of the study, protocol, and forms, and offered criticisms on the draft manuscript. DHC contributed to both the presbyopia and health-related productivity reviews, contributed suggestions to the data analysis, and offered criticisms on the draft manuscript. RA contributed to fieldwork with suggestions and examination protocols, and contributed criticisms to the draft manuscript. All authors gave final approval of the version of the manuscript to be published and agreed to be accountable for all aspects of the work.

Declaration of interests

GM reports personal fees for consulting on regulatory compliance in the UK, USA, and Japan for Adlens Ltd, a manufacturer of eyewear, outside the submitted work. JK and EG report personal fees from VisionSpring, a social enterprise engaged in the distribution and sale of eyewear, outside of the submitted work. PAR, NC, PG, QW, CJ, MC, CO'N, LJ, JT, KB, DHC, and RA declare no competing interests.

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