RBSO Revista Brasileira de Saúde Ocupacional
ISSN: 2317-6369 (online)
http://dx.doi.org/10.1590/2317-6369/24319EN2022v47e5

Research article

Job stress and glycated hemoglobin levels: the role of educational attainment. Baseline data from the Longitudinal Study of Adult Health (ELSA-Brasil)

Estresse no trabalho e níveis de hemoglobina glicada: o papel da escolaridade. Dados da linha de base do Estudo Longitudinal de Saúde do Adulto (ELSA-Brasil)

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The authors inform in Acknowledgments about the support received for the study and declare no conflict of interest.

The authors inform that this study was not presented at scientific events.

The authors inform that the work is based on the master thesis "Associação entre estresse psicossocial no trabalho e alteração dos níveis glicêmicos em servidores públicos: resultados do Estudo Longitudinal de Saúde do Adulto (ELSA-Brasil)" (Association between psychosocial stress at work and changes in glycemic levels in public servants: results of the Longitudinal Study of Adult Health), by Raíla de Souza Santos, defended in 2018 with the Graduate Program in Public Health Epidemiology, of the Sergio Arouca National School of Public Health, Fundação Oswaldo Cruz.

Received: October 17, 2019
Reviewed: May 8, 2020
Approved: July 28, 2020

Abstract

Introduction: stressful work conditions are associated to increased glycemic levels, but little is known about the role of educational attainment in this association. *Objectives*: to analyze the association between psychosocial stress at work, levels of glycated hemoglobin (HbA1c), and the role of educational attainment as an effect modifier. *Methods*: a cross-sectional study with baseline data from 11,922 active workers who participated in the Brazilian Longitudinal Study of Adult Health (ELSA-Brasil). Psychosocial stress at work was measured via the Demand-Control model. Multinomial logistic regression and multiplicative interactions were performed. *Results*: among female workers with low educational attainment, there was an association of low skill discretion and elevated HbA1c (OR 1.56; 95% CI 1.09-2.24). Low decision authority was associated to borderline (OR 1.21; 95% CI 1.01-1.45) and high (OR 1.73; 95% CI 1.19-2.51) HbA1c. Among male workers with low educational attainment, high strain (OR 1.94; 95% CI 1.18-3.21), low skill discretion (OR 2.0; 95% CI 1.41-2.83), and low decision authority (OR 1.58; 95% CI 1.13-2.21) were associated to high HbA1c. *Conclusion*: Stress at work was associated to high and borderline levels of HbAlc in workers from both genders with low educational attainment. Actions to modify work relations and to prevent chronic diseases should be prioritized for this group.

Keywords: glycated hemoglobin A; occupational stress; educational status; cross-sectional studies; occupational health.

Resumo

Introdução: *as condições estressantes do trabalho estão associadas ao aumento dos níveis glicêmicos, mas pouco se conhece sobre o papel da escolaridade neste contexto.* Objetivos: *analisar a associação entre o estresse psicossocial no trabalho e os níveis de hemoglobina glicada (HbA1c) e a influência da escolaridade como modificador de efeito.* Métodos: *estudo transversal com dados de 11.922 trabalhadores ativos da linha de base do Estudo Longitudinal de Saúde do Adulto (ELSA-Brasil). O estresse psicossocial no trabalho foi avaliado pelo modelo demanda-controle. Foram empregadas a regressão logística multinomial e interações multiplicativas.* Resultados: *em trabalhadoras do sexo feminino com baixa escolaridade, observou-se associação entre baixo uso de habilidades no trabalho (OR 1,56; IC95% 1,09-2,24) e HbA1c elevada. A baixa autonomia no trabalho foi relacionada à HbA1c limítrofe (OR 1,21; IC95% 1,01-1,45) e elevada (OR 1,73; IC95% 1,19-2,51). Entre trabalhadores do sexo masculino com baixa escolaridade, o trabalho de alto desgaste (OR 1,94; IC95% 1,18-3,21), o baixo uso de habilidades (OR 2,00; IC95% 1,41-2,83) e a baixa autonomia no trabalho (OR 1,58; IC95% 1,13-2,21) foram associados à HbA1c elevada.* Conclusão: *o estresse psicossocial no trabalho foi associado a níveis limítrofes e elevados de HbAlc para trabalhadores com baixa escolaridade de ambos os sexos. Assim, ações para modificar as relações de trabalho e prevenir doenças crônicas devem ser priorizadas.*

Palavras-chave*: hemoglobina A glicada; estresse ocupacional; escolaridade; estudos transversais; saúde do trabalhador.*

Introduction

Psychosocial stress has been identified as an important risk factor for chronic diseases such as diabetes[1,2]. The hypothesis that psychosocial stress directly affects glycemic levels finds biological plausibility in neuroendocrinology (catecholamines, glucocorticoids, and biomarkers of inflammation), resulting in changes in the production of hepatic glucose, and insulin secretion and sensibility[1]. Psychosocial stress can also trigger behaviors considered risk factors for increasing glycemic levels[1,2].

However, little attention has yet been given in the international literature to the identification of psychosocial risk factors that can increase glycemic levels[3]. The multiple etiology of stress, and time spent in adult life with work activities, demand the identification of mechanisms by which the work environment affects the health of workers[3].

Various studies pointed out that work characteristics directly or indirectly influence the effects of stress on glycaemia, such as work shifts, weekly workload, interpersonal relations, and the type of position or function[4-9]. Likewise, educational attainment can enhance or reduce effects of this type on glycemic changes[5,7]. Despite being yet little explored, educational attainment, in addition to determining the type of occupation, can interfere with strategies for coping with stress and even modify the effects of work conditions on health[7].

One of the most used theoretical models to evaluate the deleterious effects of work-related stress on health is the Demand-Control (DC) model, developed by Karasek-Theorell, which is based on situational matters of the psychosocial work environment, more specifically on the way work is organized and the characteristics of the tasks carried out[10]. The effects of occupational stress measured by this model are well established for cardiovascular diseases[11-13]. It is possible that this association may involve changes in glycemic levels, one of the main risk factors for cardiovascular disease[14]. However, evidence of the effects of occupational stress on glycemic levels and the development of glycemic changes and diabetes is still contradictory.

In recent years, despite evidence of how occupational stress affects the development of different patterns of glycemic changes, measured by glycated hemoglobin (HbA1c), Cesana et al. reported that HbA1c concentrations were higher in workers exposed to a stressful working environment[15]. Netterstrom and Sjol's cross-sectional study observed the association between high job strain and higher concentrations of HbA1c[16]. High job strain and low social support at work have also been associated with higher HbA1c concentrations[6].

There is more evidence for diabetes. Sectional studies[17,18]; case-controls[19]; and longitudinal cohorts in Europe[20], Sweden[21], England[7,22], Germany[23], and Canada[24] showed that work stress has been positively associated to diabetes. However, there are some studies that did not confirm this association, e.g., those from the USA[8,25], Japan[6], and Israel[4]; one study with three cohorts [French (GAZEL Study), Swedish (Slosh Study), and British (British Whitehall II Study)][9]; and two meta-analyses[26,27].

As seen, the association of psychosocial stress at work and the increase of glycemic levels measured by HbA1c is still little explored. For diabetes, there is a greater number of studies conducted in developed countries, especially in Europe and the USA. However, there are divergences between these study findings. Moreover, no studies that explored educational attainment as a potential effect modifier in this relation have been identified. Thus, this study aims to evaluate the association of psychosocial work stress and glycemic levels, using glycated hemoglobin (HbA1c) values as a marker, and to analyze the influence of educational attainment as an effect modifier of this association in both genders.

Methods

Study design and participants

This cross-sectional study uses baseline data from the Longitudinal Study of Adult Health (ELSA – Brasil), a multicentric study that aims to investigate the occurrence and progression of chronic diseases, particularly cardiovascular ones, and diabetes. The ELSA study population consisted of 15,105 public workers, with ages varying from 35 to 74 years old, from five universities and one research institute in six Brazilian state capitals[28]. A detailed description of the methodological aspects of that study, such as data collection, clinical and laboratorial measurements, and quality control measures are found in other publications[28].

Only baseline active participants were selected for this study. Retired workers, those with untested HbA1c levels, and those who failed to answer all questions related to occupational stress or showed missing data on the covariates used in this study were excluded.

Exposure variable: psychosocial stress at work

The explanatory variable of interest was work stress, measured via the Brazilian version[29] of the Swedish Demand-Control questionnaire, developed by Theorell[13] based on the Job Content Questionnaire[10]. This questionnaire encompasses two dimensions: *psychological demands*, which involve workload and the psychological demands of performing tasks, and *decision latitude*, composed of two sub-dimensions: *decision authority*, i.e., autonomy to decide how to perform the job, and *skill discretion*, i.e., the intellectual skills appropriate for the job[10].

The scores obtained for the psychological demand (5-20 points) and decision latitude (6-24 points) domains were dichotomized into low and high, via a median cut-off point. Decision latitude was analyzed by two ungrouped sub-dimensions, as proposed in other studies indicating better adjustments[30,31]. Work psychosocial stress was categorized into four quadrants: "*high job strain*" (characterized by workers with high psychological demands and low decision latitude; the sub-group most prone to stress), "*low job strain*" (low demands and high decision latitude in the work process), "*passive work*" (composed of low demands and low decision latitude; circumstance in which there are skill limitations and discouragement) and "*active work*" (which associates high demands and high decision latitude and consists of less harmful circumstances to workers even in the presence of high demands)[10].

For the construction of the indicators for each component of the model, the scores generated by summing the answers to psychological demands (median = 14), skill discretion (median = 12), and decision authority (median = 6) items were dichotomized. For psychological demands, the reference category was "low," and for all decision latitude sub-dimensions the reference category was "high."

Dependent variable: glycemic levels

Glycated hemoglobin (HbA1c) was calibrated via high-performance liquid chromatography. Analyses were carried out in a central laboratory to ensure uniformity in exam analyses[30]. HbA1c was classified into three categories: "normal" HbA1c < 5.7% (< 39 mmol/mol), "borderline" HbA1c 5.7% – 6.4% (39 mmol/mol – 47 mmol/mol), and "high" HbA1c ≥ 6.5% (≥ 48 mmol/mol)[14].

HbA1c is a trustworthy glycemic level marker, reflecting these levels in the last three to four months preceding its measurement[14,32]. It adequately correlates to the long-run risk of diabetes complications and shows technical advantages in pre-analytical (not necessarily fast) and analytical (less day-by-day disturbances during stress and disease) assessments, when compared to the glycaemia laboratorial measurements used today[14,32].

Covariates

The following sociodemographic characteristics were included: gender (male or female), age (continuous), educational attainment (up to complete high school and complete under-graduation). The labor domain variables encompassed: weekly workload (up to 40 hours/week or more than 40 hours/week) and work shift (daytime, nighttime, and ex-nighttime, for workers who, at some time, had worked nightshifts).

Variables related to health habits were also assessed: smoking (never smoked, ex-smoker, and smoker), and physical activities, evaluated by the International Physical Activity Questionnaire (IPAQ), translated to Portuguese and validated, which contemplates the type of activity and its intensity, classified posteriorly as strong, mild, and weak. The body mass index (BMI), representing adiposity, was estimated as a continuous variable, from the ratio between weight (kg) and squared height (kg/m^2), and categorized for descriptive analysis as "underweight or normal" (BMI below 24.9), "overweight" (BMI between 25 and 29.9), and "obese" (BMI equal to or above 30).

Data analysis

All analyses were stratified by gender since both occupational stress and the occurrence of glycemic changes differed for male and female workers[17,21,23,25]. The Pearson's chi-squared test, with Yates' correction, was used for variables with only two categories. The level of significance used in the tests was 5%.

The strength of the association of stress at work and glycemic levels was evaluated by odds ratios, and their respective 95% confidence intervals (95% CI), via a multinomial logistic regression analysis. Odds ratios (OR) were estimated for the crude model (model 1), and subsequent models were progressively adjusted to a set of variables to control for confounding sociodemographic factors: age (model 2); educational attainment (model 3); and characteristics related to work, life habits, and adiposity (model 4). Only the variables significant ($p < 0.05$) in the ANOVA test remained in the final model. To evaluate the modifying effect

of educational attainment on the association of interest in the multiplicative scale, the measure of its effect and its respective 95% confidence intervals were estimated. The presence of multiplicative interaction between each component of the Demand-Control model and educational attainment was tested in the final models. Analyses were carried out in R, version 3.3.1.

Ethical aspects

The ELSA study was approved by the Ethic Committees of each institution involved and by the National Ethics Council in Research (CONEP). This study was approved on April 10, 2017, by the Research Ethics Committee of the Oswaldo Cruz Foundation (Fiocruz) and the National School of Public Health (CAAE 656716.0.0000.5240). All participants signed an informed consent form.

Results

From the ELSA study population, consisting of 15,105, this study excluded 3,059 retired workers. Among the 12,046 baseline active participants we selected, we excluded 124 for either having their glycated hemoglobin (HbA1c) untested, failing to answer all questions related to occupational stress or lacking data on the covariates used. Thus, our final sample contained 11,922 workers (6,229 women and 5,693 men).

The proportion of high and borderline HbA1c were, respectively, 6% and 21% among women, and 8% and 19% among men. The mean age of the study population was 48.8 (SD = 7.0) years for women and 49.5 (SD = 7.0) years for men, and around 50% of participants showed high educational attainment. Concerning work-related factors, women worked more night shifts and men reported a higher weekly workload. Similar proportions of men (14,8%) and women (12,6%) reported being smokers, whereas men worked in more intense physical activities and obesity was more frequent among women (**Table 1 and 2**).

In general, for all HbA1c subgroups, the prevalence of borderline and high HbA1c increased with age, a pattern inversely proportional to the increase in educational attainment. For both genders, borderline and high HbA1c values were more frequent among those who work up to 40 weekly hours and among night and ex-night workers. Concerning health behavior, borderline and high HbA1c values were concentrated among obese participants, those who practiced low-intensity physical activities (moderate and low), smokers, and ex-smokers (**Tables 1 and 2**).

Concerning job strain, participants of both genders showed a higher frequency of passive work (**Tables 1 and 2**). In general, we observed borderline and high HbA1c values among women with passive work, and low psychological demands, skill discretion, and decision authority (**Table 1**). Among men, a higher frequency of altered HbA1c values occured on those with high job strain and passive work, and among those classified with low psychological demands, skill discretion, and decision authority (**Table 2**).

Comparing crude models between genders, women exposed to passive work (low control and low demand) show odds of high HbA1c (OR 1.79; 95% CI 1.35-2.38) compared to women exposed to low job strain (**Table 3**). Among men, the odds were higher among those exposed to passive work (OR 1.56 95% CI 1.24-1.97) and high job strain (OR 1.56; 95% CI 1.60-2.08), both with low decision authority (**Table 3**). Women with high psychological demands at work showed lower odds of high HbA1c (OR 0.73; 95% CI 0.59-0.91) (**Table 3**).

Among women, low skill discretion was associated with changes in HbA1c at borderline and elevated levels (OR 1.18; 95% CI 1.04-1.33 and OR 1.61; 95% CI 1.30-2.00, respectively). Among men, it was associated with elevated HbA1c (OR 1.62; 95% CI 1.34-1.95). Likewise, female and male workers with low decision authority showed around 30% increased odds of elevated HbA1c in relation to those with high decision authority (**Table 3**).

After adjustment, the association of interest for both job strain and isolated stress domains was strongly affected by age, which increased the magnitude of the associations, but the same pattern was not observed for educational attainment; some strata were no longer significant, and magnitudes diminished (**Table 3**).

We observed an interaction between educational attainment, job strain, low skill discretion, and low decision authority in men (p-values 0.023, < 0.001 and 0.004 respectively). Among women, we only found an interaction between educational attainment and the sub-dimensions of decision latitude (p-value 0.019) (**Table 3**).

Table 1 Characterization of female participants according to glycemic levels, active workers from the ELSA-Brasil, 2008-2010 baseline

WOMEN	*HbA1c*§			
	Total	*Normal*	*Borderline*	*High*
	n = 6,229	*n = 4,546*	*n = 1,297*	*n = 386*
Age	*Mean (SD)*	*Mean (SD)*	*Mean (SD)*	*Mean (SD)*
	48.8 (7.0)	48.0 (6.9)	50.7 (7.0)	52.9 (6.5)
	n (%)	*n (%)*	*n (%)*	*n (%)*
Educational attainment				
Up to complete high school	2,762 (44.3)	1,834 (66.4)**	674 (24.4)**	254 (9.2)**
Complete under-graduation	3,467 (55.7)	2,711 (78.2)	624 (18.0)	132 (3.8)
Weekly workload				
Up to 40 hours a week	4,477 (71.9)	3,192 (71.3)**	976 (21.8)**	309 (6.9)**
More than 40 hours a week	1,752 (28.1)	1,354 (77.3)	323 (18.4)	75 (4.3)
Shiftwork				
Daytime	3,911 (62.8)	2,945 (75.3)**	763 (19.5)**	203 (5.2)**
Nighttime	1,117 (17.9)	765 (68.5)	266 (23.8)	86 (7.7)
Ex-nighttime	1,201 (19.3)	836 (69.6)	267 (22.2)	98 (8.2)
Smoking habit				
Never smoked	3,926 (63.0)	2,964 (75.5)**	754 (19.2)**	204 (5.2)**
Ex-smoker	1,520 (24.4)	1,076 (70.8)	336 (22.1)	108 (7.1)
Smoker	783 (12.6)	504 (64.4)	207 (26.4)	72 (9.2)
Physical activities				
Strong	322 (5.3)	262 (81.4)**	52 (16.1)**	8 (2.5)**
Moderate	805 (13.1)	593 (73.7)	162 (20.1)	50 (6.2)
Weak	5,003 (81.6)	3,612 (72.2)	1,066 (21.3)	325 (6.5)
Body mass index				
Underweight/normal	2,553 (41.0)	2,064 (80.8)**	417 (16.3)**	72 (2.8)**
Overweight	2,183 (35.0)	1,589 (72.8)	463 (21.2)	131 (6.0)
Obese	1,493 (24.0)	891 (59.7)	418 (28.0)	184 (12.3)
Job Strain†				
Low strain ‡	1,453 (23.3)	1,090 (75.0)**	292 (20.1)**	71 (4.9)**
Active	1,204 (19.3)	926 (76.9)	226 (18.8)	52 (4.3)
Passive	2,252 (36.2)	1,576 (70.1)	491 (21.8)	185 (8.2)
High strain	1,320 (21.2)	952 (72.1)	289 (21.9)	79 (6.0)
Psychological Demands				
Low ‡	3,705 (59.5)	2,667 (72.0)*	782 (21.1)*	256 (6.9)*
High	2,524 (40.5)	1,878 (74.4)	515 (20.4)	131 (5.2)
Skill Discretion				
High ‡	2,846 (45.7)	2,148 (75.5)**	561 (19.7)**	137 (4.8)**
Low	3,383 (54.3)	2,399 (70.9)	737 (21.8)	247 (7.3)
Decision Authority				
High ‡	2,142 (34.4)	1,598 (74.6)*	433 (20.2)*	111 (5.2)*
Low	4,087 (65.6)	2,947 (72.1)	866 (21.2)	274 (6.7)

§HbA1c: normal HbA1c <5.7% (< 39 mmol/mol), borderline HbA1c 5.7% – 6.4% (39 mmol/mol – 47 mmol/mol), and high HbA1c ≥ 6.5% (≥ 48 mmol/mol); †Job Strain: low strain work (low demand and high control); active work (high demand and high control); passive work (low demand and low control); and high strain work (high demand and low control); ‡Reference categories; *$p < 0.05$; **$p < 0.01$ in Pearson chi-squared test with Yates' correction for glycemic level. SD: Standard Deviantion.

Table 2 Characterization of male participants according to glycemic levels, active workers from the ELSA-Brasil, 2008-2010 baseline

MEN	*HbA1c*§			
	Total	*Normal*	*Borderline*	*High*
	n = 5,693	*n = 4,051*	*n = 1,138*	*n = 504*
Age	*Mean (SD)*	*Mean (SD)*	*Mean (SD)*	*Mean (SD)*
	49.5 (7.4)	49.1 (7.5)	50.1 (7.2)	52.1 (6.7)
	n (%)	*n (%)*	*n (%)*	*n (%)*
Educational attainment				
Up to complete high school	2,872 (50.4)	1,884 (65.6)**	643 (22.4)**	345 (12.0)**
Complete under-graduation	2,821 (49.6)	2,167 (76.8)	496 (17.6)	158 (5.6)
Weekly workload				
Up to 40 hours a week	3,529 (62.0)	2,446 (69.3)**	731 (20.7)**	352 (10.0)**
More than 40 hours a week	2,164 (38.0)	1,604 (74.1)	409 (18.9)	151 (7.0)
Shiftwork				
Daytime	3,652 (64.1)	2,650 (72.6)**	714 (19.6)**	288 (7.9)**
Nighttime	714 (12.5)	504 (70.6)	131 (18.3)	79 (11.1)
Ex-nighttime	1,327 (23.3)	897 (67.6)	292 (22.0)	138 (10.4)
Smoking habit				
Never smoked	2,981(52.4)	2,250 (75.5)**	540 (18.1)**	191 (6.4)**
Ex-smoker	1,868 (32.8)	1,262 (67.6)	387 (20.7)	219 (11.7)
Smoker	844 (14.8)	536 (63.5)	213 (25.2)	95 (11.3)
Physical activities				
Strong	521 (9.3)	401 (77.0)*	90 (17.3)*	30 (5.8)*
Moderate	887 (15.8)	633 (71.4)	179 (20.2)	75 (8.5)
Weak	4,197 (74.9)	2,946 (70.2)	852 (20.3)	399 (9.5)
Body mass index				
Underweight/normal	1,952 (34.3)	1,495 (76.6)**	359 (18.4)**	98 (5.0)**
Overweight	2,567 (45.1)	1,843 (71.8)	501 (19.5)	223 (8.7)
Obese	1,174 (20.6)	711 (60.6)	279 (23.8)	183 (15.6)
Job Strain †				
Low strain ‡	1,736 (30.5)	1,257 (72.4)**	356 (20.5)**	123 (7.1)**
Active	1,047 (18.4)	792 (75.6)	183 (17.5)	72 (6.9)
Passive	2,081 (36.6)	1,442 (69.3)	416 (20.0)	223 (10.7)
High strain	829 (14.6)	560 (67.6)	183 (22.1)	86 (10.4)
Psychological Demands				
Low ‡	3,817 (67.0)	2,699 (70.7)	771 (20.2)	347 (9.1)
High	1,876 (33.0)	1,352 (72.1)	366 (19.5)	158 (8.4)
Skill Discretion				
High ‡	3,030 (53.2)	2,206 (72.8)**	609 (20.1)**	215 (7.1)**
Low	2,663 (46.8)	1,845 (69.3)	527 (19.8)	291 (10.9)
Decision Authority				
High ‡	2,124 (37.3)	1,559 (73.4)**	399 (18.8)**	166 (7.7)**
Low	3,569 (62.7)	2,491 (69.8)	739 (20.7)	339 (9.5)

§HbA1c: normal HbA1c < 5.7% (< 39 mmol/mol), borderline HbA1c 5.7% – 6.4% (39 mmol/mol – 47 mmol/mol), and high HbA1c ≥ 6.5% (≥ 48 mmol/mol); †Job Strain: low strain work (low demand and high control); active work (high demand and high control); passive work (low demand and low control); and high strain work (high demand and low control); ‡Reference categories; *$p < 0.05$; **$p < 0.01$ in Pearson chi-squared test with Yates' correction for glycemic level. SD: Standard Deviation.

Table 3 Multinomial logistic regression with odds ratio (OR) and 95% confidence intervals of the association of psychosocial stress at work (quadrants and isolated dimensions) and glycemic levels, adjusted by selected variables, in active female and male workers of the ELSA-Brasil 2008-2010 baseline

Models	*Women (n = 6,229)*		*Men (n = 5,693)*	
	*HbA1c**		*HbA1c**	
	Borderline	*High*	*Borderline*	*High*
Job Strain †	*OR (95% CI)*	*OR (95% CI)*	*OR (95% CI)*	*OR (95% CI)*
Crude model 1[a]				
Low strain	1.00	1.00	1.00	1.00
Active	0.91 (0.75-1.11)	0.86 (0.60-1.25)	0.82 (0.67-0.99)	0.92 (0.68-1.25)
Passive	1.16 (0.98-1.37)	1.79 (1.35-2.38)	1.02 (0.87-1.19)	1.56 (1.24-1.97)
High strain	1.13 (0.94-1.36)	1.27 (0.91-1.77)	1.15 (0.94-1.41)	1.56 (1.16-2.08)
Model 2[b]				
Low strain	1.00	1.00	1.00	1.00
Active	0.91 (0.75-1.11)	0.87 (0.60-1.26)	0.83 (0.68-1.01)	0.98 (0.72-1.33)
Passive	1.17 (0.99-1.38)	1.83 (1.37-2.45)	1.04 (0.88-1.22)	1.67 (1.32-2.11)
High strain	1.22 (1.02-1.48)	1.50 (1.07-2.11)	1.19 (0.97-1.46)	1.72 (1.28-2.31)
Model 3[c]				
Low strain	1.00	1.00	1.00	1.00
Active	0.93 (0.77-1.14)	0.92 (0.64-1.34)	0.85 (0.70-1.04)	1.04 (0.76-1.41)
Passive	1.00 (0.84-1.19)	1.28 (0.95-1.74)	0.87 (0.73-1.03)	1.14 (0.88-1.46)
High strain	1.07 (0.88-1.30)	1.12 (0.79-1.59)	1.02 (0.82-1.26)	1.23 (0.90-1.67)
Model 4[d]				
Low strain	1.00	1.00	1.00	1.00
Active	0.91 (0.74-1.11)	0.85 (0.58-1.24)	0.86 (0.70-1.05)	1.05 (0.77-1.44)
Passive	0.99 (0.83-1.18)	1.27 (0.94-1.73)	0.88 (0.74-1.05)	1.15 (0.89-1.49)
High strain	1.02 (0.84-1.24)	1.05 (0.73-1.49)	1.01 (0.82-1.26)	1.19 (0.87-1.62)
educational attainment interactions	*p = 0.4273*		*p = 0.0231*	
Dimensions				
High Psychological Demands				
Crude model 1[a]	0.94 (0.82-1.06)	0.73(0.59-0.91)	0.95 (0.82-1.09)	0.91 (0.75-1.11)
Model 2[b]	0.97 (0.85-1.10)	0.79(0.63-0.98)	0.96 (0.83-1.10)	0.95 (0.77-1.16)
Model 3[c]	1.01 (0.89-1.15)	0.88 (0.70-1.10)	1.00 (0.87-1.15)	1.05 (0.85-1.28)
Model 4[d]	0.97 (0.85-1.11)	0.81 (0.65-1.03)	0.99 (0.86-1.15)	1.03 (0.84-1.26)
educational attainment interactions	*p = 0.745*		*p = 0.579*	
Low Skill Discretion				
Crude model 1[a]	1.18 (1.04-1.33)	1.61 (1.30-2.00)	1.03 (0.91-1.18)	1.62 (1.34-1.95)
Model 2[b]	1.19 (1.05-1.35)	1.65 (1.32-2.05)	1.05 (0.92-1.19)	1.69 (1.40-2.04)
Model 3[c]	1.01 (0.89-1.16)	1.15 (0.90-1.46)	0.86 (0.74-0.99)	1.15 (0.93-1.42)
Model 4[d]	1.01 (0.88-1.16)	1.15 (0.90-1.46)	0.86 (0.74-1.00)	1.16 (0.93-1.43)
educational attainment interactions	*p = 0.058*		*p < 0.00001*	
Low Decision Authority				
Crude model 1[a]	1.09 (0.95-1.24)	1.33 (1.06-1.67)	1.16 (1.01-1.33)	1.30 (1.07-1.58)
Model 2[b]	1.18 (1.04-1.35)	1.56 (1.23-1.97)	1.18 (1.03-1.36)	1.40 (1.15-1.71)
Model 3[c]	1.08 (0.94-1.24)	1.25 (0.99-1.59)	1.06 (0.92-1.22)	1.07 (0.87-1.32)
Model 4[d]	1.07 (0.93-1.23)	1.27 (1.00-1.63)	1.06 (0.92-1.22)	1.04 (0.84-1.28)
educational attainment interactions	*p = 0.019*		*p = 0.004*	

*HbA1c: borderline HbA1c 5.7% – 6.4% (39 mmol/mol – 45 mmol/mol); high HbA1c ≥ 6.5% (≥48 mmol/mol); 95% CI: 95% confidence interval; OR: odds ratio; † Job Strain: low strain work (low demand and high control); active work (high demand and high control); passive work (low demand and low control), and high strain work (high demand and low control).

[a] Crude model 1; [b] Crude model 1 + adjusted by age; [c] Model 2 + adjusted by educational attainment; [d] Model 3 + adjusted by work shift, smoking habit, and body mass index.

Educational attainment showed a change in the association of interest with confirmed statistical significance in the multiplicative scale (**Table 4**) when compared to the categories of low (until complete high school) versus high educational attainment (complete high school and undergraduate education).

In the adjusted final model, after controlling for potential confounders, the association of interest remained only among women with low educational attainment (**Table 4**). For men, we found an association both among those with high and low educational attainment, although in reverse. The odds of high HbA1c between women with low educational attainment, submitted to low skill discretion, is higher (OR 1.56; 95% CI 1.09-2.24). We observed an equivalent pattern for low decision authority, which is associated both to borderline (OR 1.21; 95% CI 1.01-1.45) and high HbA1c (OR 1.73; 95% CI 1.19-2.51) (**Table 4**).

Among men with low educational attainment, and a high job strain that combines high demands and low decision latitude, odds were higher for high HbA1c (OR 1.94; 95% CI 1.18-3.21), compared to men exposed to low job strain. Similarly, the following decision latitude subdimensions are associated to high HbA1c: low skill discretion (OR 2.00; 95% CI 1.41-2.83) and low decision authority (OR 1.58; 95% CI 1.13-2.21) for men with low educational attainment (**Table 4**). Moreover, for men with high educational attainment, the observed effect was the opposite, passive work and skill discretion have an inverse association to the occurrence of borderline HbA1c (OR 0.77; 95% CI 0.62-0.98 and OR 0.78; 95% CI 0.54-0.95).

Table 4 Multinomial logistic regression with odds ratio (OR) and 95% confidence intervals of the association of psychosocial stress at work (quadrants and isolated dimensions) and glycemic levels, adjusted by selected variables and interaction with educational attainment, active female and male workers of the ELSA-Brasil 2008-2010 baseline

Models Interaction Schooling	*Women (n = 3,467)*		*Men(n = 2,821)*		*Women (n = 2,762)*		*Men (n = 2,872)*	
	*HbA1c**				*HbA1c**			
	Borderline	*High*	*Borderline*	*High*	*Borderline*	*High*	*Borderline*	*High*
	OR (95% CI)	*OR (95% CI)*	*OR (95% CI)*	*OR (95% CI)*	*OR (95% CI)*	*OR (95% CI)*	*OR (95% CI)*	*OR (95% CI)*
	LOW EDUCATIONAL ATTAINMENT				*HIGH EDUCATIONAL ATTAINMENT*			
†**Job Strain** ‡								
Low strain			1.00	1.00			1.00	1.00
Active			0.87 (0.68-1.11)	0.83 (0.54-1.28)			0.87 (0.60-1.26)	1.45 (0.92-2.31)
Passive			1.04 (0.80-1.36)	1.35 (0.87-2.10)			0.77 (0.61-0.98)	1.06 (0.76-1.47)
High strain			1.14 (0.80-1.61)	1.94 (1.18-3.21)			0.90 (0.68-1.20)	0.97 (0.65-1.44)
Control Dimensions ‡								
High Skill Discretion	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Low Skill Discretion	0.97 (0.81-1.17)	1.56 (1.09-2.24)	0.98 (0.77-1.23)	2.00 (1.41-2.83)	1.06 (0.86-1.30)	0.92 (0.67-1.25)	0.78 (0.65-0.95)	0.87 (0.68-1.12)
High Decision Authority	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Low Decision Authority	1.21 (1.01-1.45)	1.73 (1.19-2.51)	1.13 (0.92-1.37)	1.58 (1.13-2.21)	0.91 (0.73-1.12)	0.98 (0.71-1.35)	0.97 (0.79-1.20)	0.78 (0.60-1.02)

*HbA1c: borderline HbA1c 5.7% – 6.4% (39 mmol/mol – 45 mmol/mol); high HbA1c ≥ 6.5% (≥ 48 mmol/mol); 95% CI: confidence interval 95%; OR: odds ratio; †Job Strain: low strain work (low demand and high control); active work (high demand and high control); passive work (low demand and low control) and high strain work (high demand and low control); ‡model adjusted by age, educational attainment, work shift, smoking habit, body mass index + interaction with educational attainment.

Discussion

Our results showed that the odds of high and borderline HbAlc levels increase in the presence of psychosocial stress at work for people with low educational attainment. This covariate consisted in an effect modifier in the investigated association. The effect of stress at work on glycated hemoglobin values is reduced with increased educational attainment. Women with low educational attainment, submitted to passive work, of low decision authority or with low skill discretion showed higher odds of high and borderline glycated hemoglobin values. Men with low educational attainment, high job strain, low skill discretion, and low decision authority showed an association with high HbA1c.

Stress is one the most relevant psychosocial risk factors in the development of diabetes. Different neuroendocrine mechanisms can directly affect blood glucose via alterations in the production of hepatic glucose, and insulin sensibility and secretion[1,22,23]. Moreover, stress maintains an indirect action related to negative coping via disease risk behaviors[1,23]. In the perspective that stress has multiple etiologies, emphasis was placed on the work environment, often considered stressful.

Several aspects of work have been highlighted as enlarging the risk of diabetes, such as night work shifts[33], long hours and high workload[5,6,34], quality of interpersonal relations at work[4,9] and the type of position or function[7,8]. Moreover, the risk of diabetes can be modified by workers' educational attainment[5,8] and gender, which play a determining role in its prevalence[18,19,21-23,25,27,35].

Studies with different populations of workers show the effect of educational attainment on work stress in relation to other health problems, such as cardiovascular disease, depression, and poor self-rated health[36-38]. Studies show that educational attainment determines type of occupation; thus, workers with positions of high educational attainment are better protected against the harmful effects of stress[36,39]. For high HbA1c, it was shown that, even in the presence of high work demands and high workload, risk was reduced among those with high educational attainment.

Other findings confirmed that individuals with low educational attainment have less control over work and, consequently, lower skill discretion and authority. As a result, they are often deprived of satisfactory experiences at work[38]. It is important to consider that people with low educational attainment have limited resources to deal with stressful workloads, in part as a result of multiple competing risk factors that can overwhelm their efforts and result in less effective coping skills[36,38,39].

Even though the association of occupational stress and diabetes is more frequently observed among women[17,19,21-23,25], this study found relevant associations of psychosocial stress at work and variations in glycated hemoglobin values in both genders. Similar findings were seen on European longitudinal studies[20] and in Leynen's[18] sectional study. Even so, there are differences in the type of work developed and glycemic variation for both groups.

Passive work, low skill discretion and, mainly, low decision authority at work are more associated to glycemic variations among women with low educational attainment. Our findings confirm the available results related to the isolated impact of low labor control in the occurrence of high HbA1c among women, unobserved for high psychological demands[17-19,21,24]. Likewise, we observed high job strain work associated with high glycated hemoglobin values only among men, contradicting studies that show an association for this type of work – high demands combined with low control – and diabetes among women[18-21,23].

According to Karasek et al.[10], stress is generated by long-term environmental restrictions. Therefore, in some cases, effects of stress at work could only be explained by low control. Such hypothesis would explain the low control magnitude, regardless of psychological demands, in women, who showed lower decision authority at work compared to men[10]. Moreover, studies that used components of the scale in isolation found similar results for diabetes; Agardh et al.[17] and Smith et al.[24] point out that high demands at work have no influence in the occurrence of diabetes. Eriksson et al.[21] also reinforce the need for separate analyses for demand and control, as they do not find an association with high psychological demands at work in isolation.

Currently, other studies[30,31,40] have analyzed the sub-dimensions of decision latitude. Hökerberg et al.[30] indicated that the best adjustment model for the Brazilian context was achieved using the sub-dimensions of control in an ungrouped manner. Such method is justified as the distinct aspects[30] of control measure sub-dimensions. In this study, low skill discretion and decision authority were associated to variations in HbA1c levels for men and women. However, the magnitude of associations related to variations in glycated hemoglobin values were different. In women with low educational attainment, there was a stronger

association for low decision authority at work. Conversely, in men with lower educational attainment, there was a higher impact for low skill discretion at work.

Relevant points of this study include methodological rigor at all stages of data collection and the fact that this is the first Brazilian national study to test the hypothesis of interaction of psychosocial stress at work and educational attainment, which is an important measure of social context for changes in glycemic levels. Thus, educational attainment was more than a confounder in this relation and showed itself as an effect modifier for groups with low levels of it, which should be priority groups for actions to prevent illnesses triggered by stress in the work environment.

It should be considered that the results reported may not represent the real magnitude of the problem in the country since distribution of educational attainment in the sample might not adequately represent the general educational attainment pattern of Brazilian workers. Likewise, estimates of glycemic change are probably underestimated as a result of the use of a single marker (glycated hemoglobin) for the evaluation of glucose metabolism. Yet, other studies show that glycated hemoglobin has been the most adequate marker to evaluate psychosocial stress at work[6,15,16]. It is necessary to highlight that multinomial models do not enable the analysis of other types of interactions, as, for example, the additive interaction that would probably be present in the analyses. Finally, the sectional nature of analyses limits interpretations in relation to the directionality of observed associations, and reverse causality cannot be ruled out. Likewise, the perception of workers on stress is probably dynamic and, therefore, impossible to be the same over long periods.

Conclusion

In conclusion, our study points out that low educational attainment potentiates the effect observed in the association of stress at work and values of glycated hemoglobin. Control at work (decision latitude) was a determinant factor of occupational stress associated to values of glycated hemoglobin among workers with low educational attainment in both genders. Thus, changes in work relationships that promote greater use of personal skills and greater autonomy for decision making to reduce occupational stress may have an impact on this marker. Although educational attainment partially explains the association of interest, the promotion of strategies aimed at improving working conditions offers a positive effect in principle, which is more feasible than changing the level of educational attainment in adulthood. Therefore, actions that reduce occupational stress may represent the preferential target of intervention for the development of preventions strategies including chronic diseases, such as diabetes.

Acknowledgments

The ELSA-Brasil baseline study was supported by the Science and Technology Department of Brazil's Ministry of Health and by the Ministry of Science and Technology (the Brazilian Innovation Agency-FINEP and the National Research Council-CNPq) (grants 01 06 0010.00 RS, 01 06 0212.00 BA, 01 06 0300.00 ES, 01 06 0278.00 MG, 01 06 0115.00 SP, 01 06 0071.00 RJ). R.H.G is an award recipient from National Council for Scientific and Technological Development (CNPq) (number 301807/2016-7) and State Scientists (Faperj). The funders played no role in the study design, collection, analysis and interpretation of the data, writing of the report, and decision to submit the paper for publication.

Authors' contributions

Santos RS, Griep RH, Fonseca MJM, Chor D, Santos IS and Melo ECP contributed substantially to the conception and design of the study, to the collection, analysis and interpretation of data, to the elaboration and critical revisions of the manuscript and to the approval of the final published version. All authors assume full responsibility for the study and for the published content.

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