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RESEARCH ARTICLE

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# Predictors of elevated capillary blood glucose in overweight railway French employees: a cross-sectional analysis

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## Abstract

**Background:** Hyperglycaemia is a risk factor of cardiovascular disease and a high risk state for progression to type 2 diabetes. Moreover, overweight, defined as a body mass index (BMI) between 25 and 29.9 kg/m<sup>2</sup>, increases the risk of diabetes. Information about the feasibility of measuring, during routine occupational health examinations, predictors of elevated capillary blood glucose in overweight individuals is scarce. This study aims to identify factors that are associated with elevated capillary blood glucose and can be routinely measured in French overweight employees to develop targeted preventive strategies in the workplace.

**Methods:** Cross-sectional study based on data collected during a workplace health promotion programme of the French National Railways Company (SNCF) from January 2011 to March 2015. A self-administered questionnaire was completed by overweight volunteers during the routine occupational health examination. Data collected included health, anthropometric, sociodemographic, occupational, and lifestyle characteristics. Elevated capillary blood glucose was defined as capillary blood glucose equal to or higher than 7 mmol/L. Multivariate logistic regression analysis was used to examine factors associated with elevated capillary blood glucose and results were described with odds ratios (OR) and 95% confidence intervals (CI).

**Results:** The analysis concerned 2248 overweight employees (mean age: 43 years) with complete data (total population: 7724). The prevalence of elevated capillary blood glucose was 20.0%. In the multivariate analysis, significant predictors of elevated capillary blood glucose were: male sex (OR 1.66, 95% CI 1.21–2.28), age  $\geq$  50 years (OR 1.61, 95% CI 1.01–2.55), high blood pressure (OR 1.35, 95% CI 1.07–1.69), and daily intake of sugary food (OR 1.53, 95% CI 1.17–2.00). No association with occupational characteristics (work schedule, job seniority, professional grade, and job sector) was found possibly due to lack of statistical power.

**Conclusions:** Our findings provide information for setting up specific diabetes prevention strategies in the workplace. Overweight men, aged 50 and older, with high blood pressure and daily sugary food intake should be considered for capillary blood glucose measurements during their occupational medical surveillance. Hypertension screening and management as well as health policy measures to target sugary food consumption could be included in workplace prevention strategies.

**Keywords:** Elevated capillary blood glucose, Type 2 diabetes, Overweight, Body mass index, Employees, Workplace

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## Background

Diabetes affects approximately 422 million adults worldwide, among whom 300 million working-age adults (20–64 years) [1, 2]. Type 2 diabetes has a negative impact on the working population's employment and productivity by reducing the ability to work [3]. Indeed, diabetes contributes to work disability, early retirement, unemployment, and premature death [4–7]. Type 2 diabetes also represents an important cause of sickness absence with a growing economic burden for employers [8, 9].

Type 2 diabetes is a chronic disease characterised by elevated levels of blood glucose as a result of pancreatic cell dysfunction or insulin resistance [10]. Frequently, diabetes remains undetected for many years because of the slow onset and progression of symptoms. During its prolonged asymptomatic phase, elevated blood glucose leads to the development of long-term chronic and invalidating complications, such as visual impairment, renal failure, coronary heart disease, stroke, neuropathy and peripheral vascular disease [11]. These complications may contribute to premature mortality and will have a negative impact on the quality of life. Moreover, hyperglycaemia is defined as a condition characterised by abnormally high level of blood glucose and it is recognised as a risk state in the progression for type 2 diabetes and a risk factor for other chronic conditions, such as cardiovascular disease (even below the threshold for diabetes diagnosis) [12].

Currently, a large proportion of adults with type 2 diabetes are undiagnosed and this represents a major public health issue [11]. Therefore, there is an urgent need to find strategies to improve the early identification of individuals at high risk of diabetes because the management of modifiable risk factors could stop or delay its appearance. Moreover, if started early, blood glucose level management with specific measures, such as changes in lifestyle behaviours and medications, can delay the progression of complications [13–15].

Many different risk factors contribute to increase the risk of diabetes, such as overweight and obesity, physical inactivity, unhealthy diet, smoking, hypertension, and also environmental and socioeconomic factors [12, 15, 16]. Moreover, several studies have shown that chronic conditions, such as obstructive sleep apnoea, are associated with higher incidence of type 2 diabetes [17, 18]. Occupational characteristics also have been related to type 2 diabetes. For instance, shift work, where eating and sleep patterns are significantly modified, seems to contribute to insulin resistance, and has been associated with higher risk of diabetes [19, 20]. Similarly, long working hours and occupational stress have been associated with diabetes risk [21–23]. Other studies reported an association between occupational class and the risk of diabetes, suggesting a higher risk for people who belong to the lower occupational classes [24].

Workplace has been identified as an ideal setting for disease prevention and health promotion strategies [25–27]. Screening initiatives carried out in the workplace during routine occupational health examinations can easily target the whole working population. Moreover, these initiatives could be particularly useful to reach specific populations, such as disadvantaged individuals, people with obesity, physically inactive individuals or with poor dietary habits, and smokers, who usually do not participate in health screening programmes carried out in primary care settings [28, 29].

Overweight (body mass index, BMI, between 25 and 29.9 kg/m<sup>2</sup>) is strongly associated with the risk of diabetes [30]. In France, the prevalence of type 2 diabetes is estimated at 6% and being treated for diabetes is three times more frequent among overweight adults compared with individuals with a BMI ≤ 25 kg/m<sup>2</sup> [31, 32]. However, despite the number of scientific publications about the determinants of type 2 diabetes, information about the feasibility of measuring, during routine occupational health examinations, predictors of elevated capillary blood glucose in overweight individuals is still scarce.

This study on overweight employees from the French National Railways Company (SNCF) aimed to identify factors (health, anthropometric, sociodemographic, occupational and lifestyle characteristics) that are associated with elevated capillary blood glucose and that can be routinely measured in order to develop targeted preventive strategies in the workplace setting.

## Methods

### Population and study design

This cross-sectional study was based on data collected from overweight employees (BMI 25–29.9 kg/m<sup>2</sup>) who accepted to participate in a health screening during their occupational health examination as a part of a workplace health promotion programme carried out at the SNCF, between January 2011 and March 2015. SNCF is a national public-sector company and therefore, its employees cover a large diversity of occupations (train drivers, manual workers, administrative staff, health professionals, lawyers, etc.) classified in seven job sectors by the company: freight, infrastructure, material (maintenance, distribution), traction (train operators), transportation (station and on-board personnel), security and administrative staff. During the health screening, anthropometric measurements (weight, height, waist circumference, BMI) and health data (capillary blood glucose and blood pressure) were measured and collected by trained health professionals using standardised methods (i.e., same methods/equipment in all medical centres). Participants were asked to complete a self-administered questionnaire on sociodemographic,

occupational and lifestyle characteristics (diet and physical activity), and the risk of sleep apnoea. Individuals with BMI  $\geq 30$  kg/m<sup>2</sup> were referred to a specialist and were excluded from the study. A total of 7724 overweight employees agreed to take part in the health screening. After exclusion of participants with missing data, the study population consisted of 2248 overweight employees for whom complete data were available. All participants gave their written informed consent. The study protocol and data collection were approved by the Data Protection Officer of the French National Railways Company (Ref. D14.022.V.M00).

#### Data collection

##### Outcome variable

Capillary blood glucose was based on measurements obtained by fingerprick and using a calibrated glucometer (BeneCheck, model BK-G-M001). Capillary blood glucose measurement is recommended as an alternative option in settings where venous plasma glucose measurement is not available or feasible for diabetes screening [21]. The outcome of interest, elevated capillary blood glucose, was defined on the basis of a threshold for random plasma glucose  $\geq 7$  mmol/L [33]. Capillary blood glucose was then categorised in normal ( $< 7$  mmol/L) and elevated ( $\geq 7$  mmol/L).

##### Sociodemographic and occupational characteristics

The self-administered questionnaire included sociodemographic information (sex, age, and marital status). Occupational characteristics included job seniority, which was divided in four categories (less than 10 years, 11–20 years, 21–30 years and  $\geq 30$  years), and work schedule (day only, night only, shift work, and rotating shift work). Moreover, the employees' professional grade (low, intermediate and high, according to the company three-level scale) was also recorded, as well as the occupation, according to the main job sectors of the company previously described in the population and study design section.

##### Anthropometric and health data

Height (cm), weight (kg) and waist circumference (cm) were measured by trained occupational health nurses during the occupational health examination. The waist circumference was measured in the horizontal plane of the superior border of the iliac crest with the individual in standing position after a full expiration. Waist circumference was dichotomised in normal ( $< 88$  cm for women and  $< 102$  cm for men) and elevated ( $\geq 88$  cm for women and  $\geq 102$  for men) [34, 35]. BMI was calculated as weight (kilograms) divided by the square of height (metres) and included in the analysis in two categories (BMI  $> 27.5$  kg/m<sup>2</sup> and BMI  $\leq 27.5$  kg/m<sup>2</sup>)

according to the additional cut-off points proposed by the World Health Organization (WHO) [36, 37]. Blood pressure was assessed using an electronic upper-arm sphygmomanometer with the subject in seated position after 5 min of rest. Blood pressure was then categorised in normal (systolic blood pressure  $< 140$  mmHg and diastolic blood pressure  $< 90$  mmHg) and high (systolic blood pressure  $\geq 140$  mmHg and/or diastolic blood pressure  $\geq 90$  mmHg) according to the WHO recommended cut-off values [38–40].

##### Lifestyle characteristics

Lifestyle characteristics included information on diet and physical activity. Participants were questioned about their dietary habits during a working day: intake frequency of specific foods (fruits and vegetables, cereals and starchy carbohydrates, dairy products, meat and poultry, eggs, fish, ready-to-eat food and sugary food), addition of salt to meals at the table, and consumption of sugary drinks and alcoholic beverages.

Information on physical activity was collected using an adapted version of the General Practice Physical Activity Questionnaire (GPPAQ) translated from English to French. The GPPAQ assesses the physical activity in adults in the context of primary care services using a four level-physical activity index (active, moderately active, moderately inactive and inactive) [41].

##### Risk level of sleep apnoea

The Berlin sleep questionnaire that includes ten items covering three different domains (snoring, daytime sleepiness and risk factors) was used to evaluate the risk level of sleep apnoea (low and high risk) [42].

##### Statistical analysis

All statistical analyses were conducted using the SAS software version 9.3 (SAS Institute, Cary, North Carolina, USA). Descriptive analysis was performed and frequencies and percentages were reported for categorical variables. Percentages were compared using the chi-square test. Logistic regression analysis was used to determine predictors of elevated capillary blood glucose in terms of odds ratios (OR) and 95% confidence intervals (CI). All variables associated with elevated capillary blood glucose with  $p < 0.10$  in the univariate logistic regression analysis were retained for the multivariate analysis. For multivariate logistic regression analysis, a stepwise variable selection method was used. A  $p$  value less than 0.05 was considered statistically significant.

Additionally, the impact of missing data was assessed by performing all the analyses in the whole study population (i.e., including all the individuals with missing data,  $n = 7724$ ). Sensitivity analyses were also conducted to assess the impact of missing data. The multiple

imputation method for categorical variables based on a cumulative logistic regression model was applied using PROC MI in SAS. The multiple imputation model was constructed based on the BMI category and all the variables retained in the multivariate logistic regression model from the complete-case analysis. Five imputed datasets were created and each dataset was analysed. Then, results were combined using PROC MIANALYZE in SAS.

## Results

### Population characteristics

The study population included 1832 men (81.5%) and 416 women (18.5%) with a mean age of 43 years (age range: 19–62). Table 1 shows the characteristics of the study participants. The prevalence of elevated capillary blood glucose was 20.0% ( $n = 450$ ), 21.7% and 12.7% in men and women respectively. A large majority of the respondents belonged to the low professional grade (42.1%,  $n = 946$ ), followed by the intermediate grade (30.9%,  $n = 695$ ), and the high grade (27.0%,  $n = 607$ ). About two thirds of participants had a day work schedule ( $n = 1359$ , 60.5%). High blood pressure was detected in 28.6% ( $n = 642$ ) of participants, and high current risk level of sleep apnoea in 16.9% ( $n = 380$ ). A body mass index between 25.0 and 27.4 kg/m<sup>2</sup> was found in 49.4% ( $n = 1111$ ) of respondents, and elevated waist circumference in 35.8% ( $n = 804$ ). Concerning the diet characteristics, daily intake of sugary foods (once per day or more) was reported by 23.7% ( $n = 534$ ) of participants. Overall, 30% ( $n = 674$ ) of respondents consumed sugary drinks once or twice per day and 32.7% ( $n = 735$ ) drunk alcoholic beverages  $\geq 3$  times/week. Finally, 31.8% of participants ( $n = 715$ ) were classified in the inactive category for physical activity and only 22.2% ( $n = 499$ ) in the active category.

### Logistic regression analysis

The potential association of all the variables presented in Table 1 with the outcome variable (elevated capillary blood glucose) was assessed in the univariate logistic regression analysis (Table 2).

Overweight employees who were on night work (OR 1.44, 95% CI 0.66–3.12;  $p = 0.36$ ) or rotating shift work (OR 1.12, 95% CI 0.84–1.49;  $p = 0.44$ ) as well as those with elevated waist circumference (OR 1.06, 95% CI 0.86–1.32;  $p = 0.58$ ), and high risk of sleep apnoea (OR 1.23, 95% CI 0.94–1.60;  $p = 0.12$ ) were more likely to present elevated capillary blood glucose. However, these results did not reach statistical significance (Table 2). In addition, overweight employees with high professional grade (OR 0.82, 95% CI 0.64–1.06;  $p = 0.14$ ), daily intake of dairy products (3 times per day) (OR 0.82, 95% CI 0.51–1.31;  $p = 0.40$ ), and daily intake of fruits and vegetables (3 times per day) (OR 0.67, 95% CI 0.41–1.13;  $p = 0.13$ )

were less likely to have elevated capillary blood glucose, but these results were not statistically significant.

On the other hand, sex, age, job seniority, BMI, blood pressure, consumption of meat, poultry, eggs and fish, ready-to-eat food, sugary foods intake, consumption of sugary drinks and alcoholic beverages were significantly associated with elevated capillary blood glucose ( $p < 0.10$ ) (Table 2). All variables significantly associated with elevated capillary blood glucose in univariate analyses were retained for the multivariate logistic regression analysis using a stepwise variable selection method.

Multivariate analysis revealed that men (OR 1.66, 95% CI 1.21–2.28) and older employees (age  $\geq 50$  years: OR 1.61, 95% CI 1.01–2.55) had a higher likelihood of elevated capillary blood glucose. Similarly, individuals with high blood pressure were significantly more likely to have elevated capillary blood glucose than those with normal blood pressure (OR 1.35, 95% CI 1.07–1.69). Finally, participants reporting a daily sugary food intake (once per day or more) had a higher likelihood for elevated capillary blood glucose compared with participants reporting a sugary food intake of less than 3 times per week (OR 1.53, 95% CI 1.17–2.00). The adjusted ORs with 95% CI for elevated capillary blood glucose predictors in overweight employees are shown in Table 2.

In addition, the impact of the missing data was tested by performing all the analyses in the whole population ( $n = 7724$ ). Similar results were obtained with the two datasets, with a similar proportion of people with elevated capillary blood glucose (17.7%,  $n = 1367/7724$ ). Moreover, no significance change was observed when the analysis of the whole population ( $n = 7724$ ) was restricted to the five variables selected in the multivariate analysis (Table 2). Actually, all the point estimates of the adjusted ORs were found within the confidence intervals presented in Table 2. Results are presented in Additional file 1: Table S1. Additionally, results obtained from analyses performed in the multiple imputed data showed that all the associations were in the same direction (see Additional file 2: Table S2).

## Discussion

The present study investigated the predictors of elevated capillary blood glucose in a sample of French overweight employees of a large public-sector company. To our knowledge, this is the first study carried out to investigate which factors proved to be measurable and associated with elevated capillary blood glucose among overweight individuals in order to develop targeted preventive strategies in the workplace setting in France. Our findings show that 20% ( $n = 450$ ) of the overweight employees included in the study had elevated capillary blood glucose levels and this condition was significantly associated with male sex, older age ( $\geq 50$  years), high



**Table 1** Characteristics of the study population

Characteristics	Total  ( <i>n</i> = 2248)	Capillary blood glucose		<i>p</i> value
		Normal (< 7 mmol/L) <i>n</i> (%)	Elevated ( $\geq$ 7 mmol/L) <i>n</i> (%)	
Sex				
Women	416 (18.5)	363 (87.3)	53 (12.7)	< 0.001
Men	1832 (81.5)	1435 (78.3)	397 (21.7)	
Age (years)				
< 30	163 (7.2)	137 (84.0)	26 (16.0)	< 0.001
31–39	657 (29.2)	562 (85.5)	95 (14.5)	
40–49	716 (31.9)	561 (78.3)	155 (21.7)	
$\geq$ 50	712 (31.7)	538 (75.6)	174 (24.4)	
Marital status				
Married/living with a partner	1916 (85.2)	1535 (80.1)	381 (19.9)	0.71
Single	332 (14.8)	263 (79.2)	69 (20.8)	
Professional grade				
Low	946 (42.1)	742 (78.4)	204 (21.6)	0.28
Intermediate	695 (30.9)	561 (80.7)	134 (19.3)	
High	607 (27.0)	495 (81.6)	112 (18.4)	
Job sector				
Administrative staff	281 (12.5)	231 (82.2)	50 (17.8)	0.76
Freight	117 (5.2)	96 (82.0)	21 (18.0)	
Infrastructure	785 (34.9)	625 (79.6)	160 (20.4)	
Material	340 (15.1)	263 (75.4)	77 (22.6)	
Traction	238 (10.6)	195 (81.9)	43 (18.1)	
Transportation	450 (20.0)	358 (79.6)	92 (20.4)	
Security	37 (1.7)	30 (81.1)	7 (18.9)	
Job seniority (years)				
$\leq$ 10	465 (20.7)	391 (84.1)	74 (15.9)	< 0.01
11–20	704 (31.3)	577 (82.0)	127 (18.0)	
21–30	596 (26.5)	465 (78.0)	131 (22.0)	
$\geq$ 30	483 (21.5)	365 (75.6)	118 (24.4)	
Work schedule				
Day only	1359 (60.5)	1087 (80.0)	272 (20.0)	0.48
Shift work	517 (23.0)	422 (81.6)	95 (18.4)	
Rotating shift work	338 (15.0)	264 (78.1)	74 (21.9)	
Night only	34 (1.5)	25 (73.5)	9 (26.5)	
BMI (kg/m <sup>2</sup> )				
25 to 27.4	1111 (49.4)	906 (81.6)	205 (18.4)	0.07
27.5 to 29.9	1137 (50.6)	892 (78.5)	245 (21.6)	
Waist circumference				
Normal	1444 (64.2)	1160 (80.3)	284 (19.7)	0.58
Elevated	804 (35.8)	638 (79.4)	166 (20.7)	

**Table 1** Characteristics of the study population (*Continued*)

Characteristics	Total  ( <i>n</i> = 2248)	Capillary blood glucose		<i>p</i> value
		Normal (< 7 mmol/L) <i>n</i> (%)	Elevated ( $\geq$ 7 mmol/L) <i>n</i> (%)	
Blood pressure				
Normal	1606 (71.4)	1318 (82.1)	288 (17.9)	< 0.001
High	642 (28.6)	480 (74.8)	162 (25.2)	
Risk of sleep apnoea				
Low	1868 (83.1)	1505 (80.6)	363 (19.4)	0.12
High	380 (16.9)	293 (77.1)	87 (22.9)	
Physical activity				
Inactive	715 (31.8)	577 (80.7)	138 (19.3)	0.72
Moderately inactive	468 (20.8)	367 (78.4)	101 (21.6)	
Moderately active	566 (25.2)	450 (79.5)	116 (20.5)	
Active	499 (22.2)	404 (81.0)	95 (19.0)	
Diet				
Cereals/bread				
Never or less than 3 times per week	172 (7.6)	135 (78.5)	37 (21.5)	0.69
3 to 6 times per week	350 (15.6)	287 (82.0)	63 (18.0)	
1 or 2 times per day	1119 (49.8)	896 (80.1)	223 (19.9)	
At least, three times per day	607 (27.0)	480 (79.1)	127 (20.9)	
Rice/pasta				
Never or less than 3 times per week	282 (12.5)	224 (79.4)	58 (20.6)	0.79
3 to 6 times per week	1350 (60.1)	1083 (80.2)	267 (19.8)	
1 or 2 times per day	599 (26.6)	479 (80.0)	120 (20.0)	
At least, three times per day	17 (0.8)	12 (70.6)	5 (29.4)	
Dairy products				
Never or less than 3 times per week	216 (9.6)	172 (79.6)	44 (20.4)	0.65
3 to 6 times per week	530 (23.6)	427 (80.6)	103 (19.4)	
1 or 2 times per day	1254 (55.8)	994 (79.3)	260 (20.7)	
At least, three times per day	248 (11.0)	205 (82.7)	43 (17.3)	
Fruits and vegetables				
Never or less than 3 times per week	192 (8.5)	149 (77.6)	43 (22.4)	0.24
3 to 6 times per week	923 (41.1)	725 (78.6)	198 (21.4)	
1 or 2 times per day	943 (41.9)	765 (81.1)	178 (18.9)	
At least, three times per day	190 (8.5)	159 (83.7)	31 (16.3)	
Meat and poultry, eggs and fish				
Never or less than 3 times per week	125 (5.5)	93 (74.4)	32 (25.6)	0.33
3 to 6 times per week	822 (36.6)	652 (79.3)	170 (20.7)	
1 or 2 times per day	1261 (56.1)	1021 (81.0)	240 (19.0)	
At least, three times per day	40 (1.8)	32 (80.0)	8 (20.0)	
Ready-to-eat food				
Never or less than 3 times per week	1797 (79.9)	1437 (80.0)	360 (20.0)	0.12
3 to 6 times per week	395 (17.6)	322 (81.5)	73 (18.5)	
1 or 2 times per day	56 (2.5)	39 (69.6)	17 (30.4)	

**Table 1** Characteristics of the study population (*Continued*)

Table 1 Characteristics of the study population (continued)				
Characteristics	Total	Capillary blood glucose		<i>p</i> value
		Normal (< 7 mmol/L) <i>n</i> (%)	Elevated (≥ 7 mmol/L) <i>n</i> (%)	
	( <i>n</i> = 2248)	1798 (80.0)	450 (20.0)	
Sugary food				
Never or less than 3 times per week	874 (38.9)	719 (82.3)	155 (17.7)	< 0.05
3 to 6 times per week	840 (37.4)	674 (80.2)	166 (19.8)	
Once per day or more	534 (23.7)	405 (75.8)	129 (24.2)	
<i>You add to your meals...</i>				
Salt				
Never/sometimes	1316 (58.5)	1052 (79.9)	264 (20.1)	0.95
Often/always	932 (41.5)	746 (80.0)	186 (20.0)	
<i>You drink...</i>				
Sugary drinks				
Never or less than 3 times per week	718 (31.9)	590 (82.2)	128 (17.8)	< 0.05
3 to 6 times per week	458 (20.4)	367 (80.1)	91 (19.9)	
1 or 2 times per day	674 (30.0)	544 (80.7)	130 (19.3)	
At least, three times per day	398 (17.7)	297 (74.6)	101 (25.4)	
Alcoholic beverages				
Never or less than 3 times per week	1513 (67.3)	1231 (81.4)	282 (18.6)	< 0.05
3 times or more per week	735 (32.7)	567 (77.1)	168 (22.9)	

blood pressure and regular sugary food consumption (once per day or more). In France, the prevalence of overweight is progressively increasing, and therefore these findings are particularly relevant in terms of diabetes prevention strategies in workplace settings, because of the deleterious impact of high blood glucose levels on health.

Our study reveals a higher likelihood of elevated capillary blood glucose among men. According with previous studies, men generally tend to have higher levels of blood glucose compared with women [43] and type 2 diabetes is more prevalent in men [1, 31]. Moreover, this finding is in line with a previous study carried out in the USA in which screening for impaired glucose tolerance using random blood glucose measurements showed higher risk of elevated blood glucose among men [33]. Our study also shows a higher likelihood of having elevated capillary blood glucose among  $\geq 50$ -year-old participants, in agreement with previous studies on working populations that reported an increased diabetes prevalence with age among overweight individuals [44]. Moreover, alterations of the glucose metabolism and glucose intolerance are frequently observed during aging [45]. Additionally, the significant association between high blood pressure and elevated capillary blood glucose is in line with the existing literature indicating that hyperglycaemia can induce arterial damage and facilitate the development of atherosclerosis [46, 47]. Moreover,

high blood glucose levels, but still below the threshold for diabetes diagnosis, are strongly correlated with mortality by stroke and ischemic heart disease [48], two conditions that imply arterial damage [49]. As diabetes and vascular disease share important pathophysiological pathways, these two conditions often affect the same individuals.

Substantial literature supports the association between unhealthy diet and chronic diseases, such as diabetes mellitus and hypertension [50]. Our findings highlight that regular sugary food intake (once or more per day) increases the probability of elevated capillary blood glucose among overweight individuals. Although a large number of studies have highlighted the controversial association between sugary food intake and risk of chronic diseases [51–53], other works showed that sugary food intake can be associated with diabetes through different pathways [54].

On the other hand, it has been suggested that regular consumption of fruits and vegetables and of dairy products is inversely associated with the risk of diabetes [55, 56]. Moreover, high intake of fruits/vegetables and consumption of dairy products have been related to better glycaemic control and lower incidence of hyperglycaemia, respectively [57–59]. The occupational characteristics (night work and rotating shift work) and the presence of chronic disorders, such as obstructive sleep apnoea, also have been linked to impaired glucose



**Table 2** Unadjusted and adjusted ORs for predictors of elevated capillary blood glucose in overweight employees

Variables	Unadjusted ORs (95% CI)	<i>p</i> value	Adjusted ORs (95% CI)	<i>p</i> value
Sex				
Women	1 (reference)		1 (reference)	
Men	1.89 (1.39–2.58)	< 0.001	1.66 (1.21–2.28)	< 0.01
Age (years)				
< 30	1 (reference)		1 (reference)	
31–39	0.89 (0.56–1.43)	0.63	0.89 (0.55–1.43)	0.62
40–49	1.46 (0.92–2.30)	0.11	1.42 (0.89–2.25)	0.14
≥ 50	1.70 (1.08–2.68)	< 0.05	1.61 (1.01–2.55)	< 0.05
Marital status				
Married/living with a partner	1 (reference)	0.70		
Single	1.06 (0.79–1.41)			
Professional grade				
Low	1 (reference)			
Intermediate	0.87 (0.68–1.11)	0.26		
High	0.82 (0.64–1.06)	0.14		
Job sector				
Administrative staff	1 (reference)			
Freight	1.01 (0.58–1.77)	0.97		
Infrastructure	1.18 (0.83–1.68)	0.35		
Material	1.35 (0.91–2.01)	0.14		
Traction	1.02 (0.65–1.60)	0.94		
Transportation	1.19 (0.81–1.74)	0.38		
Security	1.08 (0.45–2.59)	0.87		
Job seniority (years)				
≤ 10	1 (reference)			
11–20	1.16 (0.85–1.59)	0.35		
21–30	1.49 (1.09–2.04)	< 0.05		
≥ 30	1.71 (1.24–2.36)	< 0.01		
Work schedule				
Day only	1 (reference)			
Shift work	0.90 (0.69–1.17)	0.42		
Rotating shift work	1.12 (0.84–1.49)	0.44		
Night only	1.44 (0.66–3.12)	0.36		
BMI (kg/m <sup>2</sup> )				
25 to 27.4	1 (reference)			
27.5 to 29.9	1.21 (0.99–1.49)	0.07		
Waist circumference				
Normal	1 (reference)			
Elevated	1.06 (0.86–1.32)	0.58		

**Table 2** Unadjusted and adjusted ORs for predictors of elevated capillary blood glucose in overweight employees (*Continued*)

	Unadjusted ORs (95% CI)	<i>p</i> value	Adjusted ORs (95% CI)	<i>p</i> value
Blood pressure				
Normal	1 (reference)		1 (reference)	
High	1.54 (1.24–1.92)	< 0.001	1.35 (1.07–1.69)	< 0.05
Risk of sleep apnoea				
Low	1 (reference)			
High	1.23 (0.94–1.60)	0.12		
Physical activity				
Inactive	1 (reference)			
Moderately inactive	1.15 (0.86–1.54)	0.34		
Moderately active	1.08 (0.82–1.42)	0.59		
Active	0.98 (0.74–1.32)	0.91		
Diet				
Cereals/bread				
Never or less than 3 times per week	1 (reference)			
3 to 6 times per week	0.80 (0.51–1.26)	0.34		
1 or 2 times per day	0.90 (0.61–1.34)	0.63		
At least, three times per day	0.97 (0.64–1.45)	0.87		
Rice/pasta				
Never or less than 3 times per week	1 (reference)			
3 to 6 times per week	0.95 (0.69–1.31)	0.76		
1 or 2 times per day	0.97 (0.68–1.38)	0.85		
At least, three times per day	1.61 (0.55–4.76)	0.39		
Dairy products				
Never or less than 3 times per week	1 (reference)			
3 to 6 times per week	0.94 (0.64–1.40)	0.77		
1 or 2 times per day	1.02 (0.72–1.46)	0.90		
At least, three times per day	0.82 (0.51–1.31)	0.40		
Fruits and vegetables				
Never or less than 3 times per week	1 (reference)			
3 to 6 times per week	0.95 (0.65–1.38)	0.77		
1 or 2 times per day	0.81 (0.55–1.18)	0.26		
At least, three times per day	0.67 (0.41–1.13)	0.13		
Meat and poultry, eggs and fish				
Never or less than 3 times per week	1 (reference)			
3 to 6 times per week	0.76 (0.49–1.17)	0.21		
1 or 2 times per day	0.68 (0.45–1.04)	0.08		
At least, three times per day	0.73 (0.30–1.74)	0.47		
Ready-to-eat food				
Never or less than 3 times per week	1 (reference)			
3 to 6 times per week	0.90 (0.69–1.20)	0.48		
1 or 2 times per day	1.74 (0.97–3.11)	0.06		

**Table 2** Unadjusted and adjusted ORs for predictors of elevated capillary blood glucose in overweight employees (*Continued*)

	Unadjusted ORs (95% CI)	<i>p</i> value	Adjusted ORs (95% CI)	<i>p</i> value
Sugary food				
Never or less than 3 times per week	1 (reference)		1 (reference)	
3 to 6 times per week	1.14 (0.89–1.46)	0.28	1.20 (0.94–1.54)	0.14
Once per day or more	1.48 (1.14–1.92)	< 0.01	1.53 (1.17–2.00)	< 0.01
<i>You add to your meals...</i>				
Salt				
Never/sometimes	1 (reference)			
Often/always	0.99 (0.80–1.23)	0.95		
<i>You drink...</i>				
Sugary drinks				
Never or less than 3 times per week	1 (reference)			
3 to 6 times per week	1.14 (0.85–1.54)	0.38		
1 or 2 times per day	1.10 (0.84–1.44)	0.48		
At least, three times per day	1.57 (1.17–2.10)	< 0.01		
Alcoholic beverages				
Never or less than 3 times per week	1 (reference)			
3 times or more per week	1.29 (1.04–1.60)	< 0.05		

metabolism [19, 20, 60]. The presence of a social gradient has been also suggested; individuals with higher occupational class present a lower risk of hyperglycaemia than those individuals belonging to lower occupational class [61]. Our results, although not statistically significant, are in line with these previous findings. Due to the small sample size, our study may not have had sufficient power to detect statistically significant associations.

### Strengths and limitations

A major strength of this study is the diversity of factors included in the analysis: sociodemographic and occupational characteristics, health and anthropometric measurements, lifestyle characteristics (diet, physical activity), and current risk of sleep apnoea. Moreover, anthropometric and health data were measured and collected by trained occupational health professionals using standardised methods (i.e., same methods/equipment in all medical centres). However, our study has also some limitations. First, except for the anthropometric data and health information, all data were self-reported. This could have introduced a bias because participants tend to answer according to expected norms about physical activity and dietary characteristics [62, 63]. Moreover, underreporting about habitual food intake is more frequent in people with overweight and obesity than in individuals with normal body weight [64]. In addition, self-reported data are subject to recall bias. Second, capillary blood glucose measurement was used to identify elevated blood glucose among the study population.

Although capillary sampling is accepted by the WHO, venous plasma glucose is the recommended standard method for blood glucose measurement [12]. Moreover, given the schedule of the routine occupational health examinations during the work day, most employees were not in a fasted state at the time of capillary blood glucose measurement. However, it has been shown that the performance of random blood glucose measurements is not affected by meals [33]. Third, the data included in the analysis concerned overweight volunteers who agreed to participate in the health screening programme and a large proportion of participants were excluded from the analysis because of missing data. This can limit the generalisation of our findings. It is possible that due to the small sample size, our analysis did not have enough statistical power to detect all significant associations. To control for possible bias, we performed all the analyses also in the whole sample, including participants with missing values ( $n = 7224$ ), and we conducted sensitivity analyses using a multiple imputation model. Another limitation to take into account is the “healthy worker effect” because our study sample was based on data from workers who might probably have a better health status compared to the general population. Furthermore, blood pressure was measured only once and some participants could have been misclassified as having high blood pressure because of the stress or anxiety of visiting a doctor or due to the acute effect of caffeine taken before the occupational health examination [39, 65]. Similarly, some participants could have been classified as having

elevated capillary blood glucose, although they had a transitory abnormal glucose metabolism due to psychological stress [66] or glucocorticoid treatment [67, 68]. Moreover, participants with a prior diabetes diagnosis were not excluded from the screening programme, and information regarding diabetes confirmation and follow-up was not available for individuals with elevated capillary blood glucose. Additionally, our study did not assess the effect of work stress or psychological stress that could be additional risk factors for impaired glucose metabolism [69, 70]. Finally, due to the cross-sectional design of our study, causal inferences could not be established.

### Relevance of findings for health professionals and policymakers

The findings of our study may have implications for occupational health practice and for corporate public health policy. First, the characterisation of predictors of elevated capillary blood glucose among overweight individuals may facilitate the detection of individuals at high risk for diabetes by occupational health professionals. Then, for such high-risk individuals, capillary blood glucose screening could be included in their regular assessment performed during the occupational health examination. Occupational health professionals could refer overweight individuals with elevated capillary blood glucose for diabetes confirmatory testing and for behavioural counselling on diet and physical activity. Moreover, blood pressure control and confirmatory diagnosis of hypertension should be incorporated into the routine management of this high-risk population. Regarding corporate public health policies, our findings support the need of a workplace environment that provides easy healthier choices for employees. Previous research has shown that environmental strategies can contribute to encourage and facilitate health behaviours by modifying the placement and/or the properties of stimuli or objects in a specific environment [71–74]. For instance, these interventions could be focused on improving the availability of healthy options in the workplace canteens and vending machines and reducing the availability of sugary foods. In addition, implementation of workplace health promotion programmes, including diet behaviour counselling for high-risk individuals, could contribute to maintain a healthy working population.

### Conclusion

Our findings show that male sex, age  $\geq 50$  years, high blood pressure and a self-reported daily sugary food intake were associated with elevated capillary blood glucose in our population of overweight employees. Selecting overweight employees helped restricting size of the target population prone to the campaign for health promotion and prevention. In France, the prevalence of overweight is continuously increasing; therefore, targeted screening strategies at the workplace to detect overweight individuals with elevated

capillary blood glucose could contribute to the early identification of people with high risk of diabetes. This is particularly relevant for large companies that have their own occupational services because they could potentially play a major role in screening and prevention programmes. Moreover, among people with diabetes, elevated capillary blood glucose detection during the routine occupational health examination could help to improve glycaemic control and diabetes management. Our results suggest that some occupational characteristics (work schedule, job seniority, professional grade, and job sector) were not associated with elevated capillary blood glucose in overweight individuals probably due to lack of statistical power. Further research should be done to confirm and identify other potential predictors of elevated capillary blood glucose in overweight individuals in order to inform the development of specific prevention strategies in the workplace.

### Additional files

**Additional file 1: Table S1.** Adjusted ORs for predictors of elevated capillary blood glucose in the whole population ( $n = 7224$ ). Description of data: **Table S1.** presents the results from the multivariate analysis in the whole population ( $n = 7224$ ). Variables included in the model: sex, age, blood pressure, and sugary food. (DOCX 20 kb)

**Additional file 2: Table S2.** Multivariate logistic regression model using data from multiple imputation. Description of data: **Table S2.** presents the results obtained from sensitivity analyses (multiple imputation method) performed to assess the impact of missing data. (DOCX 18 kb)

### Abbreviations

BMI: Body mass index; CI: Confidence interval; GPPAQ: General Practice Physical Activity Questionnaire; h: Hour; kg: Kilogram; m: Metre; OR: Odds ratio; SNCF: French National Railways Company; WHO: World Health Organization

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### Availability of data and materials

The datasets generated and/or analysed during the current study are not publicly available due to reasons of data protection but are available from the corresponding author on reasonable request and with permission of the Medical Department of the French National Railways Company.

### Authors' contributions

ELLG, AF and JP conceived the study and its design. ELLG coordinated and supervised data collection, designed the analysis plan, performed the statistical analyses, interpreted the results and drafted the manuscript with the feedback and critical revisions by JP and AF. JP provided academic supervision at all stages of the research. DD and LC critically revised the manuscript. All the authors read and approved the final manuscript.

# Ethics approval and consent to participate

Written informed consent was obtained from participants. The study protocol and data collection were approved by the Data Protection Officer of the French National Railways Company (Correspondant Informatique et Libertés de la Société Nationale des Chemins de Fer Français) under the reference number: D14.022.V.M00.

# Consent for publication

Not applicable.

# Competing interests

The authors declare that they have no competing interests.

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