

1 **TITLE PAGE**

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3 Adherence to dietary and physical activity guidelines among shift workers: associations with
4 individual and work-related factors.

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34 **ABSTRACT**

35 **Objectives:** Shift work is associated with adverse effects on the health and lifestyle behaviours of
36 employees. This study aimed to examine factors associated with adherence among shift workers to
37 selected indicators of dietary and physical activity guidelines.

38 **Methods:** A cross-sectional study was conducted on 1300 shift workers. Data were collected using a
39 15-minute telephone-administered questionnaire. Logistic regression methods were used for data
40 analysis.

41 **Results:** Male shift workers [$p < 0.001$, OR = 0.55, 95% CI (0.40 – 0.74)] and those of lower socio-
42 economic status [$p = 0.046$, OR = 0.75, 95% CI (0.57 – 0.99)] were significantly less likely to consume
43 five or more daily servings of fruits and vegetables. Shift workers with access to workplace vending
44 machines were significantly more likely to consume soft drinks at least weekly [$p = 0.003$, OR = 1.64,
45 95% CI [1.18 – 2.27]]. Middle-aged shift workers [$p = 0.012$, OR = 0.65, 95% CI (0.46 - 0.91)] and
46 those reporting insufficient break times at work [$p = 0.026$, OR = 0.69, 95% CI (0.49 – 0.96)] were
47 significantly less likely to be sufficiently active.

48 **Conclusions:** Individual, work schedule and workplace environment-related factors were
49 independently associated with selected indicators of adherence to dietary and physical activity
50 guidelines in this cohort of shift workers.

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57 **KEY MESSAGES**

58 **What is already known about this subject?**

- 59 • Shift work is associated with adverse effects on the health and lifestyle behaviours of
60 employees.
- 61 • This study aimed to examine factors associated with adherence among shift workers to
62 selected indicators of dietary and physical activity guidelines.

63 **What are the new findings?**

- 64 • Males and those of lower socio-economic status were significantly less likely to consume at
65 least 5 servings of fruits and vegetables per day.
- 66 • Those working predominantly nights, rotating or other shifts (compared to day shifts) were
67 significantly less likely to consume wholegrains at least once per day.
- 68 • Shift workers with access to workplace vending machines were significantly more likely to
69 consume soft drinks at least once per week.
- 70 • Middle-aged shift workers and those reporting insufficient break times at work were
71 significantly less likely to adhere to aerobic physical activity guidelines.

72 **How might this impact on policy or clinical practice in the foreseeable future?**

- 73 • The optimisation of dietary intake and physical activity levels among shift workers should be
74 a priority for occupational and public health medicine.
- 75 • Insights provided by this study may inform the development of occupational medicine policy
76 and interventions for shift workers tailored according to individual and work-related factors.

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79 **Introduction**

80 Shift work is defined by the Council of the European Union¹ as *'any method of organising work in*
81 *shifts whereby workers succeed each other at the same work stations according to a certain pattern'*.

82 Traditionally, only a limited proportion of the workforce was engaged in shift work - however, many
83 employment sectors have now adopted shift work schedules². In 2010, 17% of the workforce in the
84 European Union was employed in shift work³, a proportion which had increased to 21% by 2015⁴. In
85 Ireland, approximately 15% of the working population are employed in shift and/or night work².

86 Shift work has been associated with adverse effects on the physical and mental health of those
87 engaged in it - in particular, increased risks of being overweight or obese, the metabolic syndrome
88 and other non-communicable diseases (NCDs) including type 2 diabetes mellitus, cardiovascular
89 disease, gastrointestinal and mental health disorders^{5,6}. In 2019, the International Agency for
90 Research on Cancer categorised 'night shift work' as a Group 2A carcinogen⁷. The disruptive and
91 irregular nature of shift work schedules may also adversely affect the worker's ability and motivation
92 to maintain health-promoting lifestyle behaviours⁸. Many such behaviours, including an unhealthy
93 diet, physical inactivity, smoking, excess alcohol consumption, being overweight, and having
94 insufficient sleep are considered to be risk factors for NCDs and have been more frequently reported
95 among shift workers^{5,9}. Shift work has been shown to adversely affect the quality and quantity of
96 dietary intake as well as meal frequency, with greater meal skipping and unconventional meal timing
97 reported among shift workers compared to non-shift workers¹⁰. Shift workers may also have
98 difficulty engaging in regular exercise due to factors such as time constraints, sleep disruption,
99 fatigue, lack of availability of leisure facilities and opportunities to exercise outside of working hours,
100 and internal factors such as individual motivation to exercise¹¹.

101 The limited published data on the experience of Irish shift workers have demonstrated that shift
102 work may negatively affect their health behaviours and psycho-social well-being¹². Factors relating
103 to the work environment have been identified which may act as barriers or facilitators in their effect

104 on the ability of Irish shift workers to maintain healthy lifestyle behaviours both at work and at
105 home. Further evidence-based insights of this nature are required to inform the development of
106 public and occupational health measures to optimise the health and health behaviours of shift
107 workers. The aim of this study was to examine individual and work-related factors associated with
108 adherence among shift workers to selected indicators of national dietary and physical activity
109 guidelines.

110 **Methods**

111 **Study Design and Participants**

112 This cross-sectional study was conducted on a population of 1300 shift workers from the Republic of
113 Ireland (RoI) (n = 850) and Northern Ireland (NI) (n = 450), which was demographically,
114 geographically and occupationally representative of the estimated 270,000 shift workers on the
115 island of Ireland. The study population was derived from a previous larger study commissioned by
116 *safefood* entitled 'Managing Food on Shift Work', comprised of quantitative and qualitative
117 components¹³. The data for the original *safefood* study were collected by the market research
118 company Millward Brown Ulster (MBU) using a 15-minute telephone-administered questionnaire,
119 developed by the research team for the *safefood* study. The content of this study questionnaire was
120 informed by the qualitative component of the *safefood* study, the published shift work literature and
121 national dietary intake data. A random digit dial sample of telephone numbers in the RoI and NI was
122 generated using a mathematical formula by MBU, then pulsed to ensure they were 'live' numbers.
123 Random real numbers were then selected from the database via specialised telephone software.
124 Eligibility criteria for this study included being aged 18 years or older and working in a shift work
125 pattern at the time of contact. During the 15-minute telephone interview, participants were asked a
126 series of questions (referring to the previous one month period of their lives) to obtain information
127 on their demographic characteristics, shift work pattern, typical dietary intake, physical activity
128 levels and workplace environment. The questionnaire used to collect data for the *safefood* study

129 was reviewed prior to the commencement of this study, and variables relevant to the research
130 question and the questions pertaining to those variables were chosen. The original questionnaire is
131 available as Appendix 1 (online-only supplementary material) with the questions considered relevant
132 for the current study indicated (highlighted in yellow).

133 **Data Management**

134 Upon receipt of the raw data from the original *safefood* study variables not intended for use were
135 removed and missing values were coded (these data were not included in the analysis of data for the
136 current study). Selected variables were re-coded into categorical variables. Age was re-coded into
137 three categories; 18-34 years, 35-54 years and 55+ years, in order to examine age profiles of shift
138 workers in relation to outcomes of interest. Body mass index (BMI), calculated based on self-
139 reported height and weight measures, was re-coded into four categories based on the WHO BMI
140 classification system¹⁴; underweight (<18.50 kg/m²), normal weight (18.50-24.99 kg/m²), overweight
141 (25.00-29.99 kg/m²) and obese (≥30 kg/m²). Socio-economic status (SES) was derived in the original
142 *safefood* study from the occupation of the head of the household, categorised according to the
143 National Readership Survey (2015) classification system¹⁵ into classes ABC1 and C2DE. ABC1 included
144 those in the upper middle, middle, and lower middle classes, while C2DE included those in the skilled
145 working, working and non-working classes. Duration of exposure to shift work measured in years
146 and the average length of shift measured in hours were re-coded respectively into '*less than 8 years*'
147 and '*8 years or more*', and '*less than 8 hours*', '*8-11 hours*' and '*12 or more hours*.' The predominant
148 shift pattern of participants was re-coded into '*days*', '*nights*', '*rotating*', and '*other*' (which included
149 split, inconsistent and equal day/afternoon/night rotating shifts) – Supplementary Table 1, available
150 as online-only supplementary material, provides further information on this categorisation.

151 Consumption of fruits, vegetables, wholegrains and soft drinks were selected as dietary outcomes of
152 interest for this study, representing markers of adherence to Irish dietary guidelines. These were

153 chosen following review of the shift work literature, and of dietary intake data and guidelines for the
154 Irish adult population. These guidelines advise consumption of a minimum of 5-7 daily servings of
155 fruits and vegetables (unsweetened fruit juice, smoothies, tinned and dried fruit are also counted)
156 and 3-5 daily servings of foods from the '*wholemeal cereal and breads, potatoes (cooked any way),*
157 *pasta and rice*' group of the Irish food pyramid¹⁶, as these are highly nutrient-dense foods associated
158 with reductions in risk of several chronic diseases and overall mortality^{17,18}. The sub-optimal
159 compliance of the adult population of the RoI and NI with these specific dietary guidelines is well-
160 described^{19,20,21}, while lower intakes of fruit, vegetables, dietary fibre, and various micronutrients
161 have been observed among shift workers compared to non-shift day workers^{22,23,24}.

162 Consumption of fruits and vegetables was re-coded in a binary manner into those who consumed
163 five or more daily servings of these foods and those who consumed them less frequently than this.
164 Consumption of wholegrains (a food category which included '*brown pasta, brown rice, wholegrain*
165 *bread, wholegrain cereals, and porridge*' in the study questionnaire) was also re-coded in a binary
166 manner into those who consumed one or more daily servings of these foods and those who
167 consumed them less frequently than this.

168 The frequency of consumption of soft drinks was re-coded into those who consumed one or more
169 servings of these beverages per week and those who consumed them less frequently than this, as
170 Irish adults are advised to avoid daily consumption of soft drinks and to limit overall intake to a
171 maximum of one or two servings per week¹⁶.

172 National and international physical activity guidelines advise adults to undertake a minimum 150
173 minutes of moderate intensity aerobic physical activity per week^{25,26}. In this study, physical activity
174 was recorded in minutes per week per participant based on self-reported frequency of episodes of
175 moderate to vigorous physical activity performed per week and the average length of each. The total
176 time engaged in physical activity per week was then calculated and categorised according to
177 whether the participant was meeting the above guideline or not.

178 **Data Analysis**

179 SPSS (IBM Version 24) was used for data management and statistical analysis. A descriptive analysis
180 of the study population was initially conducted. Pearson's chi square tests were used to compare
181 categorical variables and examine associations between these. Logistic regression methods were
182 chosen for the analysis of this study as the selected outcomes were binary in nature i.e. meeting the
183 relevant guideline or not. Univariable binary logistic regression analyses were then performed for
184 the four (three dietary and one physical activity) outcomes of interest using the same independent
185 variables for each outcome. Independent variables pertained to the individual (gender, age category,
186 SES and BMI), shift work exposure (occupational sector, duration of shift work exposure, average
187 shift length and predominant shift pattern) and the workplace environment (availability of food
188 preparation, food storage and leisure facilities, vending machines and adequate break times,
189 whether participants were satisfied with healthy food options at work and whether they felt their
190 workplace helped them lead a healthy lifestyle). Health and social work was chosen as the reference
191 occupational sector for the analysis as it is acknowledged that these shift workers may have
192 achieved greater levels of health literacy and education compared to those working in other
193 sectors²⁷. Independent variables significantly associated with the four outcomes in the univariable
194 regression analyses were added to separate multivariable logistic regression models for the four
195 outcomes. All independent variables were mutually adjusted for in the multivariable models for each
196 of the four outcomes of interest. Significant results were determined by a p-value of <0.05.

197 **Results**

198 **Demographic Characteristics**

199 Table 1 provides information on the shift workers' demographic characteristics. There was a similar
200 proportion of males and females, and of those in both categories of socio-economic status. Middle-
201 aged (35-54 years old) shift workers comprised the largest proportion of participants.

Table 1: Demographic and health-related characteristics of shift workers (n = 1300)		
Variables	n	%
Country of Residence		
Republic of Ireland	850	65.4
Northern Ireland	450	34.6
Gender		
Male	672	51.7
Female	628	48.3
Age Category¹		
18-34 years	490	38.2
35-54 years	606	47.2
55-65 years	187	14.6
Marital Status		
Single never married	528	40.6
Married and living with spouse	637	49.0
Civil partnership	27	2.1
Married and separated from spouse	47	3.6
Divorced	45	3.5
Widowed	16	1.2
Socio-economic status^{a, 2}		
ABC1	599	48.2
C2DE	644	51.8
Calculated BMI^{b, 3}		
Underweight	30	2.7
Normal weight	504	45.4
Overweight	397	35.8
Obese	179	16.1
<small>BMI = Body Mass Index ^aBased on the occupation of the head of household. ABC1 denotes upper middle class, middle class and lower middle class. C2DE denotes skilled working class, working class and non-workers¹⁵ ^bCalculated based on self-reported height and weight and categorised according to the World Health Organisation BMI classification¹⁴ ^cValid denominator = 1283 ²Some participants declined to respond (n = 57) ³Valid denominator = 1110</small>		

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203 **Shift work schedule and work environment characteristics**

204 Table 2 provides information on the characteristics of the shift workers' work schedule and work
 205 environment. The most common average shift length reported was 8-11 hours. In terms of the
 206 predominant pattern of shifts worked, those in the 'other' category and those working
 207 predominantly day shifts comprised the largest groups.

208 Over half of participants had access to food preparation and storage facilities at work. Less than one-
209 third had access to vending machines. Most participants reported receiving adequate work break
210 times. The majority did not have access to leisure facilities at work.

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Table 2: Shift schedule and work environment characteristics of shift workers (n = 1300)

Variables	n	%
Occupational Sector		
Accommodation and Food Services	218	16.8
Health and Social Work	355	27.3
Retail	229	17.6
Manufacturing	110	8.5
Other ^a	388	29.8
Pattern of SW		
Predominantly days	460	35.4
Predominantly nights	164	12.6
Predominantly rotating	168	12.9
Other	508	39.1
Duration of exposure to SW		
<8 years	622	47.8
≥8 years	678	52.2
Average length of shift		
<8 hours	379	29.2
8-11 hours	622	47.8
≥12 hours	299	23.0
Availability and use of food preparation facilities		
Yes	685	52.7
No	327	25.2
Not available	288	22.1
Availability and use of food storage facilities		
Yes	784	60.3
No	267	20.5
Not available	249	19.2
Availability and use of vending machines		
Yes	355	27.3
No	408	31.4
Not available	537	41.3
Receiving adequate break times¹		
Agree	776	69.7
Disagree	337	30.3
Satisfied with healthy meal/snack availability²		
Agree	551	59.3
Disagree	378	40.7
Availability of leisure facilities		
Yes	142	10.9
No	1158	89.1
SW = Shift work		
³ Denotes those employed in sectors of transport/communications, agriculture/animals, construction, call centre/telesales, computer-related activity, distribution and logistics and finance/banking/insurance		
¹ Valid denominator = 1113		
² Valid denominator = 929		

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231 **Dietary and physical activity characteristics**

232 Table 3 provides information on the shift workers’ dietary behaviours and physical activity levels.
 233 Approximately 40% reported consuming five or more daily servings of fruits and vegetables, while
 234 61% did not consume wholegrains on a daily basis. Over one-third consumed soft drinks at least
 235 once per week. Thirty-nine per cent adhered to national aerobic physical activity guidelines, while
 236 59% were engaged in minimal physical effort at work and approximately one-fifth reported mostly
 237 sedentary occupational behaviour.

Table 3: Dietary behaviours and physical activity levels of shift workers (n = 1300)		
Variables	n	%
Fruit and vegetable consumption*		
≥5 servings/day	522	40.2
<5 servings/day	778	59.8
Wholegrain consumption*		
≥1 serving per day	512	39.4
<1 serving per day ^a	788	60.6
Soft drink consumption*		
≥1 serving per week	487	37.5
<1 serving per week ^b	813	62.5
Type of occupational PA		
Mostly sitting	262	20.2
Minimal physical effort	762	58.6
Moderate physical effort	212	16.3
Vigorous physical effort	64	4.9
Time spent in MVPA per week^{c, 1}		
≥150 minutes	509	39.2
<150 minutes	789	60.8
<small>MVPA = Moderate-vigorous physical activity ^aDenotes frequency of consumption according to the Food Safety Authority of Ireland dietary guidelines¹⁶ ^bDenotes consumption multiple times per week, less than weekly or not at all ^cDenotes consumption less than weekly or not at all ^dBased on national and international physical activity guidelines^{25,26} ¹Valid denominator = 1298</small>		

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239 **Multivariable regression analysis**

240 The univariable regression analyses which informed the multivariable regression models are
 241 available as (online-only) Supplementary Tables 2, 3, 4 and 5. Tables 4 and 5 combined present the
 242 four multivariable regression models with all independent variables listed.

Table 4: Multivariable analysis of individual and workplace factors independently associated with dietary behaviours and physical activity levels of shift workers (n = 1300)[†]

Variables	Fruit/Veg Intake ≥ 5 servings/day* (n = 522)		Wholegrain Intake ≥1 serving/day* (n = 512)		Soft Drink Intake ≥1 serving/week* (n = 487)		Physical Activity ≥150 minutes/week** (n = 509)	
	p- Value	OR (95% CI)	p- Value	OR (95% CI)	p- Value	OR (95% CI)	p- Value	OR (95% CI)
Gender (ref: Female) Male	<0.001	0.55 (0.40-0.74)	N/A		ns	1.29 (0.93-1.80)	N/A	
Age Category ¹ (ref: 18-34 years)								
Middle-aged (35-54 years)	N/A		ns	0.93 (0.70-1.24)	<0.001	0.50 (0.34-0.73)	0.012	0.65 (0.46-0.91)
Older age (55-65 years)	N/A		ns	1.27 (0.87-1.86)	<0.001	0.33 (0.18-0.59)	ns	0.74 (0.46-1.18)
BMI ^{2,a} (ref: Normal)								
Overweight/Obese	ns	0.80 (0.61-1.07)	N/A		N/A		N/A	
SES ^{3,b} (ref: ABC1) C2DE	0.046	0.75 (0.57-0.99)	N/A		N/A		N/A	
Vending Machines (ref: None)								
Available at Work	N/A		N/A		0.003	1.64 (1.18-2.27)	0.025	0.71 (0.52-0.96)
Break Time Adequate ⁴ (ref: Agree)								
Disagree	N/A		N/A		N/A		0.026	0.69 (0.49-0.96)
Satisfied with healthy food availability ⁵ (ref: Agree)								
Disagree	N/A		N/A		ns	1.01 (0.71-1.44)	N/A	
Workplace helps lead a healthy lifestyle ⁶ (ref: Agree)								
Disagree	0.028	0.73 (0.55-0.97)	N/A		0.047	1.43 (1.01-2.04)	ns	0.75 (0.55-1.02)

[†]The full list of co-variables included in the analysis is represented by those in the left-hand columns of Tables 4 and 5.
OR, 95% CI = Odds Ratio, 95% Confidence Interval
N/A = Not applicable (not significantly associated with the outcome of interest in univariable analysis), ns = not significant in the multivariable analysis
¹According to the Food Safety Authority of Ireland dietary guidelines¹⁵
²Minutes per week based on national and international physical activity guidelines^{25,26}
Significant odds ratios (p<0.05) are denoted in bold font (these remained significantly associated with the outcome of interest after multivariable analysis)
³Valid denominator = 1283
BMI^{2,a} = Body Mass Index, calculated based on self-reported height and weight and categorised according to the World Health Organisation BMI classification¹⁴ ('Underweight' participants were excluded (n = 30))
SES^{3,b} = Socio-economic status, based on the occupation of the head of household. ABC1 denotes upper middle class, middle class and lower middle class. C2DE denotes skilled working class, working class and non-workers¹⁵ (Valid denominator = 1243)
⁴Valid denominator = 1113
⁵Valid denominator = 929
⁶Valid denominator = 1035

Table 5: Multivariable analysis of shift work exposure factors independently associated with dietary behaviours and physical activity levels of shift workers (n = 1300) †

Variables	Fruit/Veg Intake ≥ 5 servings/day* (n = 522)		Wholegrain Intake ≥1 serving/day* (n = 512)		Soft Drink Intake ≥1 serving/week* (n = 487)		Physical Activity ≥150 minutes/week** (n = 509)	
	p-value	OR (95% CI)	p-value	p-value	p-value	OR (95% CI)	p-value	OR (95% CI)
Occupational Sector								
(ref: Health & Social Work)								
Accommodation & Food	ns	1.06 (0.67-1.66)	ns	0.85 (0.58-1.23)	ns	ns	ns	0.70 (0.39-1.26)
Retail	ns	0.80 (0.52-1.24)	0.022	0.65 (0.44-0.94)	ns	0.81 (0.48-1.35)	ns	1.52 (0.85-2.71)
Manufacturing	ns	1.05 (0.60-1.82)	ns	0.91 (0.58-1.42)	0.019	2.03 (1.12-3.68)	ns	1.34 (0.66-2.75)
Other	ns	0.90 (0.61-1.33)	ns	1.17 (0.86-1.58)	ns	1.11 (0.71-1.75)	ns	1.33 (0.79-2.24)
Duration of SW Exposure								
(ref: <8 years)								
≥8 years	N/A		0.02	1.38 (1.05-1.82)	ns	0.89 (0.62-1.30)	ns	1.15 (0.74-1.80)
Average Shift Length								
(ref: <8 hours)								
8-11 hours	N/A		ns	0.99 (0.75-1.32)	ns	0.73 (0.50-1.06)	ns	0.99 (0.63-1.55)
≥12 hours	N/A		ns	1.26 (0.89-1.79)	0.032	0.59 (0.37-0.96)	ns	1.12 (0.64-1.96)
Predominant SW Pattern								
(ref: Days)								
Nights	N/A		0.011	0.61 (0.41-0.89)	N/A		N/A	
Rotating	N/A		0.026	0.65 (0.45-0.95)	N/A		N/A	
Other	N/A		0.002	0.65 (0.50-0.86)	N/A		N/A	

†The full list of co-variables included in the analysis is represented by those in the left-hand columns of Tables 4 and 5.
SW = Shift work
OR, 95% CI = Odds Ratio, 95% Confidence Interval
N/A = Not applicable (not significantly associated with the outcome of interest in univariable analysis), ns = not significant following multivariable analysis
*According to the Food Safety Authority of Ireland dietary guidelines¹⁶
**Minutes per week based on national and international physical activity guidelines^{25,26}
Significant odds ratios (p<0.05) are denoted in bold font (these remained significantly associated with the outcome of interest after multivariable analysis)

243 **Fruit and vegetable intake**

244 Male shift workers (relative to females) and those in the lower C2DE social class (relative to those in
245 the upper ABC1 class) were 45% [$p < 0.001$, OR = 0.55, 95% CI (0.40 – 0.74)] and 25% [$p = 0.046$, OR =
246 0.75, 95% CI (0.57 – 0.99)] less likely to consume five or more daily portions of fruits and vegetables
247 respectively.

248 **Wholegrain intake**

249 Those exposed to shift work for 8 years or more (compared to those exposed for less) were 38%
250 more likely [$p = 0.02$, OR = 1.38, 95% CI (1.05 – 1.82)] to consume wholegrains at least daily, while
251 compared to those working mostly day shifts, participants working predominantly nights, rotating or
252 other shift patterns were each over one-third less likely to do so [$p = 0.011$, OR = 0.61, 95% CI [0.41 –
253 0.89), $p = 0.026$, OR = 0.65, 95% CI (0.45 – 0.95) and $p = 0.002$, OR = 0.65, 95% CI [0.50 – 0.86)
254 respectively]. Retail shift workers were 35% less likely [$p = 0.022$, OR = 0.65, 95% CI (0.44 – 0.94)] to
255 consume wholegrains on a daily basis compared to those working in health and social work services.

256 **Soft drinks intake**

257 Middle-aged shift workers (35-54 years old) were half as likely [$p < 0.001$, OR = 0.50, 95% CI (0.34 –
258 0.73)] to consume soft drinks at least weekly relative to the youngest participants (18-34 years old),
259 while the oldest age group of shift workers were 67% less likely to consume soft drinks at least
260 weekly relative to the youngest group [$p < 0.001$, OR = 0.33, 95% CI (0.18 – 0.59)]. When compared to
261 those working in health and social work, manufacturing employees were just over twice as likely [$p =$
262 0.019, OR = 2.03, 95% CI (1.12 – 3.68)] to consume soft drinks at least once per week. Shift workers
263 with access to vending machines at work (compared to those without) were 64% [$p = 0.003$, OR =
264 1.64, 95% CI [1.18 – 2.27)] more likely to consume soft drinks at least once per week.

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266 **Physical Activity**

267 Middle-aged shift workers were 35% [$p = 0.012$, OR = 0.65, 95% CI (0.46 - 0.91)] less likely to adhere
268 to national physical activity guidelines relative to the youngest participants, while those who did not
269 receive adequate break times at work (relative to those who did) were 31% [$p = 0.026$, OR = 0.69,
270 95% CI (0.49 – 0.96)] less likely to do so.

271

272 **Discussion**

273 This study identified factors pertaining to the individual, shift work exposure and the workplace
274 environment that were independently associated with adherence among a large cohort of shift
275 workers employed on the island of Ireland to selected indicators of population dietary and physical
276 activity guidelines. Overall, adherence among participants to these guidelines was sub-optimal - less
277 than half were adherent to each of the indicators of interest. With respect to dietary intake, this
278 supports previous studies which have demonstrated lower intakes of fruits, vegetables and dietary
279 fibre^{22,23,24} as well as carbohydrates^{28,29} among shift workers compared to day workers. Consistent
280 observations of higher intakes of soft drinks, and of poorer dietary quality and quantity, have also
281 been reported among shift workers compared to non-shift workers¹⁰. In contrast, previous research
282 has yielded conflicting results regarding the leisure physical activity of shift workers⁵, making
283 comparison with our findings challenging. The low level of occupational activity, however, among
284 participants is consistent with some previous data³⁰ although others have reported greater levels of
285 same compared to day workers³¹. Such differences may be explained by variable methodological
286 approaches to measuring physical activity levels across these studies - nonetheless, there are
287 significant risks to physical and mental health associated with physical inactivity and sedentary
288 lifestyles³².

289 We found that males and those of lower socio-economic status (SES) were significantly less likely to
290 consume the recommended daily servings of fruits and vegetables. Social class and gender
291 differences in intake of these foods have been described previously in the general Irish adult
292 population^{19,33} – however, to the authors knowledge, this is the first time this finding has been
293 confirmed specifically in a range of shift workers. One study conducted on airline shift workers found
294 lower fruit and vegetable intake among males without in-flight work compared to day and in-flight
295 workers²³.

296 Differences in dietary quality according to age among shift workers have been reported previously³⁴.
297 Age category also emerged as a significant factor in our analysis. Younger shift workers, compared to
298 those who were middle-aged and older, were more likely to consume soft drinks at least weekly. In
299 the general Irish population, young adults aged 15-34 years have been shown to have the highest
300 intakes of sugar-sweetened beverages, many of which are soft drinks¹⁹. In contrast, middle-aged
301 shift workers, compared to the youngest group, were less likely to adhere to aerobic physical activity
302 guidelines. Declining levels of awareness of and adherence to these guidelines with age have been
303 reported in the Irish adult population which may in part explain this finding³⁵.

304 We examined several factors pertaining to shift work exposure - duration of exposure, occupational
305 sector, average shift length, and predominant shift pattern. We found, relative to those working in
306 health and social work, retail sector shift workers were less likely to consume wholegrain foods daily,
307 while manufacturing workers were more likely to consume soft drinks at least weekly – the latter
308 supports prior research demonstrating greater energy intake and poorer dietary quality in the
309 manufacturing occupational sub-group²². Participants working predominantly non-day shifts were
310 less likely to consume wholegrain foods daily, which is somewhat consistent with previous findings
311 of poorer dietary quality among night and rotating shift workers compared to day workers^{34,36}.
312 However, we did not observe any significant differences in consumption of fruits and vegetables or
313 soft drinks across shift pattern. Cumulative years employed in shift work also emerged as a

314 significant factor in relation to daily wholegrain intake even when adjusted for age category, which
315 may suggest improvements in health and nutritional knowledge among those with greater
316 experience working in shift systems.

317 With regard to the work environment of participants, we observed two main findings. Those with
318 access to vending machines at work, compared to those without, were more likely to consume soft
319 drinks at least weekly - an important finding given improvements in availability (and price) of
320 healthier choices in vending machines have been shown to improve sales of healthier products^{37,38}.
321 In addition, those who reported that they did not receive adequate break times at work were less
322 likely to be sufficiently active compared to those who did, supporting previous Irish research which
323 identified a perceived lack of time to be a barrier to physical activity among shift workers³⁹.

324 **Implications of Findings**

325 The gender, age and social class differences we observed across specific dietary behaviours highlight
326 that nutritional aspects of health education and interventions for shift workers which seek to
327 improve their adherence to population dietary guidelines should be developed with these
328 characteristics in mind. Our findings also highlight the need to target middle-aged shift workers with
329 workplace interventions which aim to improve their adherence to population physical activity
330 guidelines.

331 Our findings regarding the shift work schedule and occupation of participants in relation to their
332 adherence to selected indicators of dietary and physical activity guidelines may help employers to
333 devise and adapt workplace policy and interventions which aim to improve adherence among
334 employees to such guidelines. The workplace is a social context within which shift workers may
335 spend a large amount of time and should support health-promoting lifestyle behaviours⁴⁰. This study
336 has highlighted that provision for shift workers of healthy vending machines, food preparation and
337 storage facilities, and adequate break times should be a priority for employers.

338 **Strengths and Limitations**

339 The study population was large in size, and was demographically, geographically and occupationally
340 representative of the Irish shift work population, about whom little is known from a research
341 perspective to date. Factors independently associated with adherence among participants to
342 selected indicators of dietary and physical activity guidelines were identified, the optimisation of
343 which is of importance from a public and occupational health perspective. Although a non-shift
344 worker control group was not available to us against which the adherence of participants could be
345 compared, nationally representative data for the general adult populations of the Republic (ROI) and
346 North of Ireland (NI) were included where appropriate for comparison and context.

347 The cross-sectional design of this study precludes the potential to draw causal inferences from
348 findings. Data were collected using a questionnaire, raising the possibility of recall and self-report
349 bias pertaining to potential misreporting of weight, height, dietary behaviours and physical activity.
350 Minor differences between the dietary and physical activity guidelines used and the corresponding
351 questions in the questionnaire may have led to a slight under- or over-estimation of adherence to
352 the selected indicators of the guidelines among participants. The study questionnaire did not
353 capture all domains of shift work - further research is needed to examine dietary and physical
354 activity behaviours across different shift schedules and systems. Occupational physical activity,
355 although not examined as an outcome in our study, remains an important consideration in relation
356 to the health of shift workers. The possibility of residual confounding due to factors not included or
357 measured in our analysis cannot be excluded. Finally, multicollinearity was not examined - as such
358 the possibility of correlation between independent variables remains, which may have affected the
359 validity of our findings.

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362 **Conclusions**

363 Individual, work schedule and workplace environment-related factors were independently
364 associated with selected indicators of adherence to dietary and physical activity guidelines in this
365 cohort of shift workers. Shift workers face unique challenges to their health at the biological,
366 psychological and social level. Tailored occupational health measures are required which address
367 these challenges and provide solutions for them. This study has provided insights which may
368 contribute to the development of such measures, targeting individual and organisational factors to
369 protect the health of this vulnerable sub-population of the global workforce.

370 **Ethical Approval**

371 An ethics exemption application was approved by the Taught Masters Research Ethics Committee
372 (TM-REC) of the UCD School of Public Health, Physiotherapy and Sports Science on the basis of
373 previously granted ethical approval for the original safefood study by the DIT Research Ethics
374 Committee in 2014 (Ethical Clearance Reference 14-09) - this application and approval from DIT
375 were also reviewed and agreed by the Biomedical Sciences Ethics Committee of UU, Coleraine,
376 Northern Ireland at the time. No new data were collected for this study.

377 **Contributorship Statement**

378 This study was a secondary analysis of data collected for a previous larger study commissioned by
379 safefood entitled 'Managing Food on Shift Work'. CC was the project lead for the original safefood
380 study, in collaboration with JK and MBL. FN and KP contributed to data collection, analysis and
381 interpretation for the original safefood study. CK and CC conceptualised the present study and its
382 methodology. CK lead the statistical analysis and data interpretation and wrote the manuscript. CC
383 supervised the present study and contributed to data analysis and interpretation, and the writing
384 and critical review of the manuscript. VOB and MBL contributed to data interpretation and the
385 critical review of the manuscript. FN, KP and JK contributed to the critical review of the manuscript.
386 All authors read the manuscript, contributed comments to its revision and have approved and

387 agreed to the final version. CK submitted the manuscript and is responsible for the overall content as
388 guarantor.

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392 **Competing Interests**

393 Nil.

394 **Acknowledgement**

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Supplementary Table 1. Predominant shift work pattern of study participants (re-coded and original categories).

Predominant Shift Work Pattern (Re-coded)	Predominant Shift Work Pattern (Original)
Days	<ul style="list-style-type: none"> • Days (the majority of the shift falls between 06.00-14.00) • Afternoons (the majority of the shift falls between 14.00-22.00)
Nights	<ul style="list-style-type: none"> • Nights (the majority of the shift falls between 22.00-06.00)
Rotating	<ul style="list-style-type: none"> • Rotating but predominantly working days • Rotating but predominantly working afternoons • Rotating but predominantly working nights
Other	<ul style="list-style-type: none"> • Equal day/afternoon/night rotation (roughly equal split between the above described day/afternoon/night shifts, but does not need to include all 3 types, and can be rotation between just 2 types) • Split shifts (defined as two shifts worked in a 24-hour period, with a short break in between) • Inconsistent shifts • Other (i.e. a shift type which does not fit into the above patterns)

Supplementary Table 2: Univariable analysis of individual, shift work exposure and workplace environment factors and number of daily servings of fruits and vegetables^a of participants (n = 1300)

<u>Variables</u>	<u>≥5/day</u>	<u><5/day</u>	<u>p-value*</u>	<u>OR</u>	<u>95% CI</u>
	<u>(n = 522)</u>	<u>(n = 778)</u>			
	<u>n (%)</u>	<u>n (%)</u>			
Gender (ref: Female) Male	227 (43.5)	445 (57.2)	<0.001	0.58	(0.46 - 0.72)
Age Category¹ (ref: 18-34 years)					
Middle-aged (35-54 years)	249 (48.6)	357 (46.3)	ns	1.15	(0.90 - 1.47)
Older age (55-65 years)	78 (15.2)	109 (14.1)	ns	1.18	(0.84 - 1.66)
BMI² (ref: Normal)					
Overweight/Obese	215 (49.0)	361 (56.3)	0.018	0.74	(0.58 - 0.95)
Socio-economic status³ (ref: ABC1)					
C2DE	237 (46.9)	407 (55.1)	0.004	0.72	(0.57 - 0.90)
Occupational Sector					
(ref: Health & Social Work)					
Accommodation & Food	87 (16.7)	131 (16.8)	ns	0.77	(0.54 - 1.08)
Retail	89 (17.0)	140 (18.0)	ns	0.73	(0.52 - 1.03)
Manufacturing	44 (8.4)	66 (8.5)	ns	0.77	(0.50 - 1.19)
Other	137 (26.2)	251 (32.3)	0.002	0.63	(0.47 - 0.84)
Duration of SW Exposure (ref: 8 years)					
≥8 years	269 (51.5)	409 (52.6)	ns	0.96	(0.77 - 1.20)
Average Shift Length (ref: <8 hours)					
8-11 hours	243 (46.6)	379 (48.7)	ns	0.95	(0.73 - 1.23)
≥12 hours	126 (24.1)	173 (22.2)	ns	1.08	(0.79 - 1.46)
Predominant SW Pattern (ref: Days)					
Nights	56 (10.7)	108 (13.9)	ns	0.69	(0.48 - 1.00)
Rotating	76 (14.6)	92 (11.8)	ns	1.10	(0.77 - 1.57)
Other	193 (37.0)	315 (40.5)	ns	0.82	(0.63 - 1.06)
Food Preparation Facilities (ref: Yes)					
Not Available at Work	230 (44.1)	385 (49.5)	ns	0.80	(0.64 - 1.01)
Food Storage Facilities (ref: Yes)					
Not Available at Work	199 (38.1)	317 (40.7)	ns	0.90	(0.71 - 1.13)
Vending Machines (ref: None)					
Available at Work	379 (72.6)	566 (72.8)	ns	0.99	(0.77 - 1.27)
Break Times Adequate⁴ (ref: Agree)					
Disagree	145 (32.3)	192 (28.9)	ns	1.17	(0.91 - 1.52)
Satisfied with healthy food availability⁵ (ref: Agree)					
Disagree	154 (38.4)	224 (42.4)	ns	0.85	(0.65 - 1.10)
Workplace helps lead a healthy lifestyle⁶ (ref: Agree)					
Disagree	186 (43.3)	310 (51.2)	0.011	0.73	(0.57 - 0.93)
Leisure facilities (ref: Yes)					
Not Available at Work	459 (87.9)	699 (89.8)	ns	0.82	(0.58 - 1.17)

BMI = Body Mass Index

*P values <0.05 were deemed significant (denoted in bold font)

^aAccording to the Food Safety Authority of Ireland dietary guidelines¹⁶

²Valid denominator = 1283

³Those categorised as 'Underweight' were excluded (n = 30)

OR, 95% CI = Odds Ratio, 95% Confidence Interval

⁵Some participants declined to respond (n = 57)

⁶Valid denominator = 1113

⁷Valid denominator = 929

⁸Valid denominator = 1035

Supplementary Table 3: Univariable analysis of individual, shift work exposure and workplace environment factors and frequency of wholegrain consumption^a of participants (n = 1300)

<u>Variables</u>	<u>≥1 serv/day</u>	<u><1 serv/day</u>	<u>p-value*</u>	<u>OR</u>	<u>95% CI</u>
	<u>(n = 512)</u>	<u>(n = 788)</u>			
	<u>n (%)</u>	<u>n (%)</u>			
Gender (ref: Female) Male	269 (52.5)	403 (51.1)	ns	1.06	(0.85 - 1.32)
Age Category¹ (ref: 18-34 years)					
Middle-aged (35-54 years)	239 (47.2)	367 (47.2)	ns	1.15	(0.90 - 1.47)
Older age (55-65 years)	90 (17.8)	97 (12.5)	0.004	1.64	(1.17 - 2.31)
BMI² (ref: Normal)					
Overweight/Obese	237 (54.0)	339 (52.9)	ns	1.05	(0.82 - 1.33)
Socio-economic status³ (ref: ABC1)					
C2DE	257 (51.8)	387 (51.8)	ns	1.00	(0.80 - 1.33)
Occupational Sector					
(ref: Health & Social Work)					
Accommodation & Food	77 (15.0)	141 (17.9)	ns	0.78	(0.55 - 1.11)
Retail	69 (13.5)	160 (20.3)	0.007	0.62	(0.43 - 0.88)
Manufacturing	43 (8.4)	167 (8.5)	ns	0.92	(0.59 - 1.42)
Other	177 (34.6)	211 (26.8)	ns	1.20	(0.90 - 1.61)
Duration of SW Exposure (ref: <8 yrs)					
≥8 years	299 (58.4)	379 (48.1)	<0.001	1.52	(1.21 - 1.90)
Average Shift Length (ref: <8 hours)					
8-11 hours	241 (47.1)	381 (48.4)	ns	1.09	(0.84 - 1.43)
≥12 hours	132 (25.8)	167 (21.2)	0.049	1.37	(1.00 - 1.86)
Predominant SW Pattern (ref: Days)					
Nights	54 (10.5)	110 (14.0)	0.007	0.60	(0.41 - 0.87)
Rotating	61 (11.9)	107 (13.6)	ns	0.70	(0.48 - 1.00)
Other	190 (37.1)	318 (40.4)	0.017	0.73	(0.57 - 0.94)
Food Preparation Facilities (ref: Yes)					
Not Available at Work	248 (48.4)	367 (46.6)	ns	1.08	(0.86 - 1.35)
Food Storage Facilities (ref: Yes)					
Not Available at Work	210 (41.0)	306 (38.8)	ns	1.10	(0.87 - 1.37)
Vending Machines (ref: None)					
Available at Work	133 (26.0)	222 (28.2)	ns	1.12	(0.87 - 1.44)
Break Times Adequate⁴ (ref: Agree)					
Disagree	138 (31.9)	199 (29.2)	ns	1.14	(0.88 - 1.48)
Satisfied with healthy food availability⁵ (ref: Agree)					
Disagree	140 (37.9)	238 (42.5)	ns	0.83	(0.63 - 1.08)
Workplace helps lead a healthy lifestyle⁶ (ref: Agree)					
Disagree	196 (46.6)	300 (48.9)	ns	0.91	(0.71 - 1.17)
Leisure Facilities (ref: Yes)					
Not Available at Work	462 (90.2)	696 (88.3)	ns	1.22	(0.85 - 1.76)

BMI = Body Mass Index

Serv = Serving, yrs = years

*P values <0.05 were deemed significant (denoted in bold font)

^aAccording to the Food Safety Authority of Ireland dietary guidelines¹⁶

⁵Valid denominator = 1283

⁶Those categorised as 'Underweight' were excluded (n = 30)

OR, 95% CI = Odds Ratio, 95% Confidence Interval

⁵Some participants declined to respond (n = 57))

³Valid denominator = 1113

⁴Valid denominator = 929

⁶Valid denominator = 1035

Supplementary Table 4: Univariable analysis of individual, shift work exposure and workplace environment factors and frequency of soft drink consumption^a of participants (n = 1300)

<u>Variables</u>	<u>≥1/week</u>	<u><1/week</u>	<u>p-value*</u>	<u>OR</u>	<u>95% CI</u>
	<u>(n = 487)</u>	<u>(n = 813)</u>			
	<u>n (%)</u>	<u>n (%)</u>			
Gender (ref: Female) Male	273 (56.1)	399 (49.1)	0.015	1.32	(1.06 - 1.66)
Age Category¹ (ref: 18-34 years)					
Middle-aged (35-54 years)	203 (42.4)	403 (50.1)	<0.001	0.50	(0.39 - 0.64)
Older age (55-65 years)	31 (6.5)	156 (19.4)	<0.001	0.20	(0.13 - 0.30)
BMI² (ref: Normal)					
Overweight/Obese	221 (55.8)	355 (51.9)	ns	1.17	(0.91 - 1.50)
Socio-economic status³ (ref: ABC1)					
C2DE	245 (53.6)	398 (50.8)	ns	1.12	(0.89 - 1.41)
Occupational Sector (ref: Health & Social Work)					
Accommodation & Food	100 (20.5)	118 (14.5)	0.001	1.79	(1.27 - 2.54)
Retail	75 (15.4)	154 (18.9)	ns	1.03	(0.72 - 1.47)
Manufacturing	52 (10.7)	58 (7.1)	0.004	1.90	(1.23 - 2.93)
Other	146 (30.0)	242 (29.8)	ns	1.28	(0.94 - 1.73)
Duration of SW Exposure (ref: <8 years)					
≥8 years	205 (42.1)	473 (58.2)	<0.001	0.52	(0.42 - 0.66)
Average Shift Length (ref: <8 hours)					
8-11 hours	241 (49.5)	381 (46.9)	ns	0.90	(0.67 - 1.17)
≥12 hours	90 (18.5)	209 (25.7)	0.003	0.62	(0.45 - 0.85)
Predominant SW Pattern (ref: Days)					
Nights	73 (15.0)	91 (11.2)	ns	1.42	(0.99 - 2.04)
Rotating	63 (12.9)	105 (12.9)	ns	1.06	(0.74 - 1.53)
Other	185 (38.0)	323 (39.7)	ns	1.01	(0.78 - 1.32)
Food Preparation Facilities (ref: Yes)					
Not Available at Work	233 (47.8)	382 (47.0)	ns	1.04	(0.83 - 1.30)
Food Storage Facilities (ref: Yes)					
Not Available at Work	186 (38.2)	330 (40.6)	ns	0.90	(0.72 - 1.14)
Vending Machines (ref: None)					
Available at Work	169 (34.7)	186 (22.9)	<0.001	1.79	(1.40 - 2.30)
Break Times Adequate⁴ (ref: Agree)					
Disagree	133 (31.6)	204 (29.5)	ns	1.11	(0.85 - 1.44)
Satisfied with healthy food availability⁵ (ref: Agree)					
Disagree	160 (44.9)	218 (38.0)	0.038	1.33	(1.02 - 1.74)
Workplace helps lead a healthy lifestyle⁶ (ref: Agree)					
Disagree	208 (54.0)	288 (44.3)	0.003	1.48	(1.15 - 1.90)
Leisure Facilities (ref: Yes)					
Not Available at Work	430 (88.3)	728 (89.5)	ns	0.88	(0.62 - 1.26)

BMI = Body Mass Index

*P values <0.05 were deemed significant (denoted in bold font)

^aAccording to the Food Safety Authority of Ireland dietary guidelines¹⁶

²Valid denominator = 1283

³Those categorised as 'Underweight' were excluded (n = 30)

OR, 95% CI = Odds Ratio, 95% Confidence Interval

⁵Some participants declined to respond (n = 57)

⁶Valid denominator = 1113

⁷Valid denominator = 929

⁸Valid denominator = 1035

Supplementary Table 5: Univariable analysis of individual, shift work exposure and workplace environment factors and weekly physical activity levels^a of participants (n = 1298)

<u>Variables</u>	<u>≥150min/wk</u>	<u><150min/wk</u>	<u>p-value*</u>	<u>OR</u>	<u>95% CI</u>
	<u>(n = 509)</u>	<u>(n = 789)</u>			
	<u>n (%)</u>	<u>n (%)</u>			
Gender (ref: Female) Male	242 (47.5)	385 (48.8)	ns	1.05	(0.84 - 1.31)
Age Category¹ (ref: 18-34 years)					
Middle-aged (35-54 years)	207 (41.2)	398 (51.2)	<0.001	0.62	(0.49 - 0.79)
Older age (55-65 years)	73 (14.5)	114 (14.7)	ns	0.76	(0.54 - 1.08)
BMI² (ref: Normal)					
Overweight/Obese	223 (50.1)	353 (55.6)	ns	0.80	(0.63 - 1.02)
Socio-economic status³ (ref: ABC1)					
C2DE	246 (49.5)	397 (53.4)	ns	0.86	(0.68 - 1.08)
Occupational Sector (ref: Health & Social Work)					
Accommodation & Food	100 (19.6)	118 (15.0)	0.008	1.59	(1.13 - 2.25)
Retail	90 (17.7)	138 (17.5)	ns	1.23	(0.87 - 1.73)
Manufacturing	37 (7.3)	73 (9.3)	ns	0.95	(0.61 - 1.50)
Other	159 (31.2)	229 (29.0)	ns	1.30	(0.97 - 1.76)
Duration of SW Exposure (ref: <8 yrs)					
≥8 years	246 (48.3)	431 (54.6)	0.027	0.78	(0.62 - 0.97)
Average Shift Length (ref: <8 hours)					
8-11 hours	253 (49.7)	369 (46.8)	ns	0.90	(0.70 - 1.17)
≥12 hours	93 (18.3)	205 (26.0)	0.002	0.60	(0.44 - 0.82)
Predominant SW Pattern (ref: Days)					
Nights	63 (12.4)	101 (12.8)	ns	0.89	(0.62 - 1.28)
Rotating	60 (11.8)	108 (13.7)	ns	0.79	(0.55 - 1.14)
Other	197 (38.7)	311 (39.4)	ns	0.90	(0.70 - 1.17)
Food Preparation Facilities (ref: Yes)					
Not Available at Work	235 (46.2)	379 (48.0)	ns	0.93	(0.74 - 1.16)
Food Storage Facilities (ref: Yes)					
Not Available at Work	195 (38.3)	319 (40.4)	ns	0.92	(0.73 - 1.15)
Vending Machines (ref: None)					
Available at Work	119 (23.4)	235 (29.8)	0.012	0.72	(0.56 - 0.93)
Break Time Adequate⁴ (ref: Agree)					
Disagree	113 (25.3)	223 (33.5)	0.004	0.67	(0.52 - 0.88)
Satisfied with healthy food availability⁵ (ref: Agree)					
Disagree	133 (37.9)	245 (42.5)	ns	0.83	(0.63 - 1.09)
Workplace helps lead a healthy lifestyle⁶ (ref: Agree)					
Disagree	179 (42.4)	317 (51.8)	0.003	0.67	(0.53 - 0.88)
Leisure facilities (ref: Yes)					
Not Available at Work	445 (87.4)	711 (90.1)	ns	0.76	(0.54 - 1.08)

BMI = Body Mass Index

Min/wk = Minutes per week, yrs = years

*P values <0.05 were deemed significant (denoted in bold font)

^aAccording to national and international physical activity guidelines^{25,26}

^bValid denominator = 1281

^cThose categorised as 'Underweight' were excluded (n = 30) (Valid denominator = 759)

OR, 95% CI = Odds Ratio, 95% Confidence Interval

^dn = 57 participants declined to respond (Valid denominator = 864)

^eValid denominator = 1111

^fValid denominator = 928

^gValid denominator = 1034