

1 **Associations between alcohol and obesity in more than 100,000 adults in England and**
2 **Scotland**

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16 Shot title: Alcohol consumption and obesity risk

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18 Key words: Observational study; surveys and questionnaires; overweight; alcohol drinking.

19 **Abstract**

20

21 The objective of this cross-sectional study was to clarify the association between alcohol and
22 obesity using data from 106,182 adults in England and Scotland (46.7% male; 46.9±16.9
23 years [mean±SD]). Trained interviewers asked participants about alcohol intake. Obesity
24 was defined as body mass index $\geq 30 \text{ kg}\cdot\text{m}^{-2}$. Potential confounders included age, sex,
25 smoking, physical activity, longstanding illness, psychological distress, and socioeconomic
26 status. Compared with those who drank at least five times a week, obesity risk was 1.21
27 (95% confidence interval: 1.15, 1.27) in those who drank one to four times a week, 1.53
28 (1.43, 1.62) in those who drank one to two times a month, 1.61 (1.52, 1.71) in those who
29 drank less than once every couple of months, 1.34 (1.23, 1.47) in those who were former
30 drinkers, and 1.03 (0.95, 1.11) in those who were never drinkers. Compared with those who
31 drank a harmful volume, obesity risk was 0.78 (0.68, 0.90) in those who drank within
32 guidelines, 0.69 (0.54, 0.88) in former drinkers, and 0.50 (0.40, 0.63) in never drinkers; And,
33 these associations were biased away from the null after adjustment for drinking volume.
34 Abstinence was associated with increased risk of obesity in women. These data suggest that
35 the association between drinking frequency and obesity is bell-shaped, with obesity risk not
36 significantly different in those who drink most often and never drinkers. Drinking volume has
37 a positive confounding effect on the association between drinking frequency and obesity,
38 which may help explain the conflicting findings of other studies.

39 **Introduction**

40

41 The UK government has slashed drinking guidelines, citing concerns about cancer, heart
42 disease and other health risks ⁽¹⁾. Obesity is associated with cancer, heart disease and other
43 health risks ⁽²⁾ and the government has also raised concerns about middle-aged people
44 drinking too much and weighing too much ⁽³⁾. Observational studies of alcohol consumption
45 and obesity have produced conflicting findings ^(4; 5). There are many factors that make it
46 difficult to determine the independent influence of alcohol on obesity ⁽⁴⁾. It is particularly
47 difficult to distinguish the influence of drinking frequency from drinking volume ⁽⁴⁾. A frequent
48 drinking pattern may go hand in hand with lifestyle choices that decrease the risk of obesity
49 like taking exercise and eating fruits and vegetables ^(4; 6). Conversely, a high drinking volume
50 may increase the risk of obesity ⁽⁴⁾ and the risks of morbidity and mortality ⁽⁷⁾. Socioeconomic
51 factors may also confound the association between alcohol and obesity. Lower
52 socioeconomic groups tend to make worse lifestyle choices than higher socioeconomic
53 groups in the United Kingdom ^(8; 9). At the same time, drinking volume tends to increase with
54 socioeconomic status ⁽⁷⁾. More research is required to clarify the link between alcohol intake
55 and obesity and to explain the conflicting findings ⁽⁴⁾. The objective of this cross-sectional
56 study was to help clarify the association between alcohol and obesity using a pooled
57 analysis of 11 population-based studies.

58 **Methods**

59

60 *Participants*

61

62 The Health Survey for England and the Scottish Health Survey are household-based
63 surveillance studies that are described in detail elsewhere ^(10; 11). The present study included
64 participants from the Health Survey for England in 1994, 1997, 1998, 1999, 2003, 2004,
65 2006 and 2008. The present study also included participants from the Scottish Health
66 Survey in 1995, 1998 and 2003. The same organization carried out the surveys using
67 consistent methods ^(10; 11). The samples were selected using a multistage, stratified
68 probability design to be representative of the target populations of the corresponding
69 countries. Stratification was based on geographical areas and not on individual
70 characteristics: postcode (zip code) sectors were selected at the first stage and household
71 addresses selected at the second stage. Local research ethics committees approved all
72 aspects of each survey and all participants gave written informed consent.

73

74 *Independent variables*

75

76 Trained interviewers asked participants about alcohol intake ⁽¹¹⁾. The interviewers could also
77 ask those aged 18 to 24 years to fill in a booklet if they thought it would be difficult for them
78 to give honest answers in front of other members of the household ⁽¹¹⁾. Participants were
79 asked about whether they drank alcohol nowadays. Those who said not were asked whether
80 they were always a non-drinker or whether they used to drink and had stopped. Drinkers
81 were asked, "How often have you had an alcoholic drink of any kind during the last 12
82 months?" And, "On how many days out of the last seven did you have an alcoholic drink?"
83 Then, "Which day last week did you have the most to drink?" Drinkers were also asked to
84 describe the type or types of drink they had on that day. Total weekly alcohol units were
85 calculated by summing the units of each type of beverage and multiplying by the frequency.

86 In the UK, one unit is eight grammes of alcohol, which roughly corresponds to a 25 ml
87 measure of spirits or a half-pint of beer ⁽¹²⁾; And, a 175 mL glass of wine contains two units of
88 alcohol ⁽¹²⁾. Alcohol drinking frequency was derived from six frequency categories: at least
89 five times a week in the last 12 months; one to four times a week; one to two times a month;
90 less than once every couple of months; former drinker of alcohol; and, never drinker of
91 alcohol. Alcohol drinking volume was derived from six intake categories: harmful (≥ 49 units
92 in men and ≥ 35 units in women); hazardous (21-48 units in men and 14-34 units in women),
93 within guidelines (< 21 units in men and < 14 units in women); drinker, but not in last seven
94 days; former drinker of alcohol; and, never drinker of alcohol. The drinking guidelines used in
95 the present study were those that existed in the UK at the same period of time as the
96 surveys and binge drinking was defined as drinking double or more the limit on the heaviest
97 day in past week (> 8 units in men and > 6 units in women) ⁽¹³⁾.

98

99 *Dependent variables*

100

101 Trained interviewers measured weight and height ⁽¹¹⁾, and body mass index (BMI) was
102 expressed as weight in kilograms divided by height in metres squared. Underweight was
103 defined as BMI $< 18.5 \text{ kg}\cdot\text{m}^{-2}$, normal weight as BMI $18.5\text{-}24.9 \text{ kg}\cdot\text{m}^{-2}$, overweight as BMI 25-
104 $< 30 \text{ kg}\cdot\text{m}^{-2}$, and obesity as BMI $\geq 30 \text{ kg}\cdot\text{m}^{-2}$ ⁽¹⁴⁾. Weight was measured without shoes, heavy
105 garments, heavy jewellery, loose change, or keys. Height was measured with the participant
106 in the Frankfort plane and without shoes. Trained nurses measured waist circumference at
107 the midpoint of the iliac crest and costal margin (lower rib) and hip circumference at the
108 widest point over the buttocks and below the iliac crest ⁽¹¹⁾. Waist and hip circumference
109 were measured over light clothing. Abdominal obesity was defined as waist-hip ratio > 0.90 in
110 men and > 0.85 in women ⁽¹⁵⁾.

111

112 *Potential confounders*

113

114 The trained interviewers also asked about age, sex, smoking, physical activity, longstanding
115 illness, psychological distress, occupation, and fruit and vegetable intake ⁽¹¹⁾. Participants
116 were asked, “Do you smoke cigarettes at all nowadays?” Those who answered yes were
117 regarded as current smokers. The questionnaires used to assess physical activity in the
118 Health Survey for England and Scottish Health Survey are described in detail elsewhere ⁽¹⁶⁾.
119 Participants were regarded as physically active if they reported meeting current physical
120 activity guidelines of at least 150 minutes per week of moderate-intensity physical activity, at
121 least 75 minutes per week of vigorous-intensity physical activity, or equivalent combinations
122 ⁽¹⁷⁾. Longstanding illness was defined as any illness, disability or infirmity that had troubled
123 the respondent over a period of time or was likely to affect them over a period of time. A
124 longstanding illness was regarded as limiting if the respondent said that it limited their
125 activities in any way. The 12 item General Health Questionnaire was used to assess current
126 mental health and a score of four or more was used to define psychological distress ^(18; 19).
127 Socioeconomic status was assessed using the four-group version of the Registrar General's
128 classification: professional and managerial occupations; skilled, non-manual occupations;
129 skilled manual occupations; and, routine and manual occupations. Participants in more
130 recent surveys were asked how many fruit and vegetables they ate yesterday and whether it
131 was more or less than usual.

132

133 *Statistical analysis*

134

135 Multinomial logistic regression was used to investigate associations between alcohol and
136 BMI, a nominal dependent variable with more than two levels. Logistic regression was used
137 to investigate associations between alcohol drinking and abdominal obesity, a dependent
138 variable with two levels. The reference category for the dependent variable was normal BMI
139 or normal waist-hip ratio. Odds ratio and 95% confidence interval were calculated for risk of

140 obesity according to alcohol drinking with the reference group being those who reported
141 drinking alcohol at least five times a week in the last 12 months. Regression models were
142 adjusted for potential confounders, including age, sex, smoking, physical activity,
143 longstanding illness, psychological distress, and socioeconomic status. Cigarette smoking
144 was categorised into five groups: never regular smoker; ex-smoker; less than ten per day;
145 ten to nineteen per day; twenty or more per day. Physical activity was also categorised into
146 two groups: meeting physical activity guidelines or not. Longstanding illness and
147 psychological distress was also dichotomous variables: yes or no. Socioeconomic status
148 was categorised into the four groups of the Register General's classification. In secondary
149 analyses, we investigated associations in the subsamples of men and women and the
150 subsample that reported fruit and vegetable intake. In sensitivity analyses, we excluded
151 participants with diabetes or cardiovascular disease. All analyses were performed using
152 SPSS version 22 (IBM Inc.).

153 **Results**

154

155 *Participant characteristics*

156

157 The core samples of the Health Survey for England and the Scottish Health Survey are
158 designed to be representative; however, missing data may introduce bias in sub-samples.
159 Body mass index was not measured in 13,876 adults and BMI was the main cause of
160 missing data. Those excluded because of missing BMI were older than those included in the
161 present study (60 versus 47 years, $p < 0.001$), were more often female (62 versus 53%,
162 $p < 0.001$), and were of lower socioeconomic status (3.9 versus 4.9% in professional and
163 managerial occupations, $p < 0.01$). There were 106,182 participants in the present study
164 (46.7% male; 53.3% female; 46.9 ± 16.9 years of age [mean \pm standard deviation]). Table 1
165 shows participants' characteristics according to drinking frequency. Some 18% of
166 participants reported drinking alcohol at least five times a week in the last 12 months, 45.2%
167 reported drinking alcohol one to four times a week, 13% reported drinking alcohol one to two
168 times a month, 14% reported drinking alcohol less than once every couple of months, 3.8%
169 reported being former drinkers of alcohol, and 6.4% reported never being drinkers of alcohol.
170 Those who reported drinking alcohol at least five times a week in the last 12 months
171 included a higher proportion of men, a higher proportion in professional and managerial
172 occupations, and a higher proportion of binge drinkers than those who reported drinking
173 alcohol less frequently. The proportion of obese individuals was lower in those who reported
174 drinking alcohol at least five times a week and those who reported drinking alcohol one to
175 four times a week than those who reported drinking alcohol less frequently. The proportion
176 meeting physical activity guidelines was higher in those who reported drinking alcohol at
177 least five times a week, those who reported drinking alcohol one to four times a week, and
178 those who reported drinking alcohol one to two times a month than those who reported
179 drinking alcohol less frequently. There were no obvious relationships between age and
180 drinking frequency, smoking and drinking frequency, or psychological distress and drinking

181 frequency. Abdominal obesity was present in 60.7% of men and only 26.4% of women,
182 which may explain why there was no obvious relationship between abdominal obesity and
183 drinking frequency in the whole sample. Less than 10% of participants were aged 18 to 24
184 years and were eligible to fill in a booklet if they wished; And, the removal of these
185 individuals did not change the results.

186

187 *Primary analyses*

188

189 Some 39% of participants were overweight and 21.6% obese. Figure 1, top, shows the
190 association between drinking frequency and obesity in 106,182 participants. Compared with
191 those who reported drinking alcohol at least five times a week in the last 12 months, the risk
192 of obesity rose in those who reported drinking alcohol less frequently before falling in those
193 who reported being former drinkers of alcohol and falling again in those who reported never
194 being drinkers of alcohol (a bell-shaped association). Figure 1, middle, shows the
195 association between alcohol volume and obesity in 49,073 participants. Compared with
196 those who reported drinking a harmful volume of alcohol in the last seven days, the risk of
197 obesity was not significantly different in those who reported drinking a hazardous volume of
198 alcohol in the last seven days, was lower in those who reported drinking a volume of alcohol
199 that was within the guidelines, and was lower in those who reported being former drinkers of
200 alcohol and those who reported never being drinkers of alcohol (a linear association). Figure
201 1, bottom, shows the association between drinking frequency and obesity after adjustment
202 for drinking volume. Drinking volume had a positive confounding effect on the association
203 between drinking frequency and obesity (the observed association was biased away from
204 the null) (Table S1 in the online supplement shows the numbers in each group, the odds
205 ratios, and the 95% confidence intervals). Table S2 in the online supplement shows the
206 associations of drinking frequency and drinking volume with overweight. Abdominal obesity
207 was present in 42.5% of the present sample. Figure 2 shows the association between
208 drinking frequency and abdominal obesity in 71,990 participants. Compared with those who

209 reported drinking alcohol at least five times a week in the last 12 months, the risk of
210 abdominal obesity was not significantly different in those who reported drinking one to four
211 times a week or one to two times a month; however, the risk of abdominal obesity was
212 higher in those who reported drinking less than once every couple of months, those who
213 reported being former drinkers of alcohol, and those who reported never being drinkers of
214 alcohol.

215

216 *Secondary analyses*

217

218 Table S3 in the online supplement shows the associations of drinking frequency with
219 overweight and obesity in 49,530 men and 56,526 women. In men, the association between
220 drinking frequency and obesity was bell-shaped, with obesity risk not significantly different
221 between those who drank most often and those who were ex-drinkers or had never drunk. In
222 women, compared with those who reported drinking alcohol at least five times a week in the
223 last 12 months, the risk of obesity rose in those who reported drinking one to four times a
224 week (odds ratio: 1.36; 95% CI: 1.26, 1.46), rose again in those who reported drinking
225 alcohol one to two times a month (1.89; 1.73, 2.06), and rose still in those who reported
226 drinking alcohol less than once every couple of months (2.03; 1.87, 2.20); the risk of obesity
227 fell but remained significantly different in women who reported being former drinkers of
228 alcohol (1.76; 1.56, 1.99) and women who reported never being drinkers of alcohol (1.47;
229 1.33, 1.64). Table S4 in the online supplement shows the association between drinking
230 frequency and abdominal obesity in 33,803 men and 38,187 women. The associations were
231 similar in the entire sample and the subsamples. Table S5 in the online supplement shows
232 that the associations between drinking frequency and overweight and obesity were similar
233 with adjustment for fruit and vegetable consumption (n=48,905). Table S6 in the online
234 supplement shows that the associations between drinking frequency and overweight and
235 obesity were similar after excluding those with diabetes or cardiovascular disease
236 (n=93,542).

237 **Discussion**

238

239 The objective of this cross-sectional study was to help clarify the association between
240 alcohol and obesity. The association between drinking frequency and obesity was bell-
241 shaped, with obesity risk not significantly different between those who drank most often and
242 those who had never drunk. The association between drinking volume and obesity was
243 linear, with obesity risk lowest in those who had never drunk. Drinking volume had a positive
244 confounding effect on the association between drinking frequency and obesity, which may
245 help explain the conflicting findings of other studies.

246

247 This study has some notable strengths but also some limitations. The main strengths are the
248 large sample size, the detailed characterisation of drinking frequency, the detailed
249 characterisation of drinking volume, and the adjustment for several potential confounders.
250 The main limitation is the cross-sectional design, where independent and dependent
251 variables are assessed at the same time. Alcohol intake, fruit and vegetable intake and
252 physical activity were self-reported. Participants were asked about their mental health in the
253 last four weeks, their drinking frequency in the last 12 months, and their drinking volume in
254 the last seven days and we cannot exclude the possibility that those with a long-term history
255 of depression drink less alcohol ⁽²⁰⁾. Beer is carbohydrate rich and provides more energy
256 than wine per standard drink ⁽²¹⁾. No adjustment for alcohol type was made in the present
257 study; however, men are more likely to drink beer and women are more likely to drink wine
258 ⁽⁴⁾; and, associations between alcohol and obesity were investigated separately in men and
259 women. Beer and spirit drinkers appear to have poorer diets than wine drinkers ⁽⁴⁾ and an
260 adjustment for fruit and vegetable intake was also made. No adjustment was made for
261 sleeping habit (insufficient sleep may be associated with greater alcohol consumption and
262 excess body weight ⁽⁴⁾). Data from sub-samples of the Health Survey for England and the
263 Scottish Health Survey may not be representative of the target populations.

264

265 Observational studies of alcohol consumption and obesity have produced conflicting
266 findings: some show a positive association, some show a negative association, and some
267 show no association ^(4; 5). Many factors are thought to explain these conflicting findings and a
268 better characterisation of those more likely to be obese with alcohol has been called for ⁽⁴⁾. It
269 has been suggested that individuals who frequently drink moderate amounts of alcohol may
270 enjoy a healthier lifestyle in general that may protect them from weight gain ⁽⁴⁾. In a sample
271 of 230,856 adults representative of the US population, it was found that men and women
272 who frequently drank were far more likely to exercise vigorously than abstainers ⁽⁶⁾. Those
273 who drank most often in the present study were more physically active and were less likely
274 to be obese than those who drank less than once every couple of months and those who
275 were ex-drinkers. The detailed characterisation of drinking in the present study may explain
276 the conflicting findings of other studies. The association between drinking frequency and
277 obesity was bell-shaped, with obesity risk not significantly different between those who drank
278 most often and those who had never drunk. Drinking volume had a positive confounding
279 effect on the association between drinking frequency and obesity; that is, the observed
280 association was biased away from the null.

281

282 Compared with women who reported drinking alcohol at least five times a week in the
283 present study, the risk of obesity was higher in women who reported being former drinkers of
284 alcohol and women who reported never being drinkers of alcohol. These data suggest that
285 abstinence increases the risk of obesity in women. Although there is conflicting evidence ⁽²²⁾,
286 a frequent but moderate drinking pattern may be part of a healthy lifestyle ^(4; 6) and
287 longitudinal data from the Health Survey for England and the Scottish Health Survey suggest
288 that there may be safe limits in relation to mortality risk ^(23; 24). For example, Perreault and
289 colleagues ⁽²⁴⁾ investigated the joint association of alcohol and physical activity with mortality
290 in 36,370 adults followed for 9.7±4.3 years and found that all-cause mortality risk was
291 considerably attenuated and cancer mortality risk was nearly nullified in those who met
292 physical activity guidelines. In the same study, cardiovascular disease mortality risk was

293 lower in occasional drinkers than never drinkers (occasional drinkers were those who
294 declared being drinkers but reported not drinking in the last seven days; never drinkers were
295 those who reported never having consumed alcohol) ⁽²⁴⁾.

296

297 The present study may help to clarify the association between alcohol and obesity. The
298 present study suggests that the association between drinking frequency and obesity is bell-
299 shaped, with obesity risk not significantly different between those who drink most often and
300 those who have never drunk. The present study also suggests that drinking volume has a
301 positive confounding effect on the association between drinking frequency and obesity. More
302 longitudinal research is required to clarify the independent associations of drinking frequency
303 and drinking volume with obesity.

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305

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312

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314

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316

317 **Conflict of interest**

318

319 None.

320

321 **Authorship**

322

323 O'Donovan conceived the study. Stamatakis acquired the data and harmonised the
324 datasets. Hamer carried out the statistical analysis. All authors contributed substantially to
325 the study design, data interpretation, and writing of the manuscript. Hamer is the guarantor
326 and takes responsibility for the content of the manuscript, including the data and the
327 analysis.

328 **Table 1.** Participants characteristics according to drinking frequency*

329

| | Frequency of alcohol intake in last 12 months | | | | | |
|----------------------------|---|------------------|-------------------|---------------------------|------------|---------------|
| | ≥5 times a week | 1-4 times a week | 1-2 times a month | <1 every couple of months | Ex-drinker | Never drinker |
| Age, years | 51.9±15.9 | 44.0±16.0 | 44.4±16.9 | 50.6±17.6 | 54.2±16.6 | 47.1±19.0 |
| Men, % | 60.3 | 51.0 | 37.0 | 29.6 | 42.1 | 39.2 |
| Obese, % | 18.6 | 19.4 | 24.1 | 28.6 | 27.7 | 21.6 |
| Abdominally obese, % | 51.1 | 39.8 | 36.4 | 42.1 | 54.0 | 43.0 |
| Binge drinking, % | 16.9 | 14.4 | 3.2 | 0.6 | 0 | 0 |
| Smoker, % | 26.8 | 27.3 | 26.6 | 27.7 | 31.6 | 16.5 |
| Physically active, % | 22.1 | 25.6 | 21.3 | 14.3 | 13.4 | 13.7 |
| Longstanding illness, % | 45.0 | 37.6 | 41.5 | 50.6 | 63.2 | 42.3 |
| Psychological distress, % | 13.0 | 13.1 | 14.9 | 16.9 | 22.6 | 16.0 |
| Professional occupation, % | 7.5 | 5.5 | 3.8 | 2.1 | 2.2 | 3.6 |

330

331 *Sample size is 106,182 except abdominal obesity, where sample size is 71,990. Age is
 332 mean±SD. Obese is BMI ≥ 30 kg·m⁻². Abdominally obese is waist-hip ratio >0.90 in men and
 333 >0.85 in women. Binge drinking is drinking double or more the limit on heaviest day in past
 334 week (>8 units in men and >6 units in women). Physically active is meeting current physical

335 activity guidelines of at least 150 minutes per week of moderate-intensity physical activity, at
336 least 75 minutes per week of vigorous-intensity physical activity, or equivalent combinations.
337 Longstanding illness is any illness, disability or infirmity that troubled the participant over a
338 period of time. Psychological distress is a General Health Questionnaire score of four or
339 more. Professional occupation is professional or managerial occupation according to the
340 Register General's classification.

341 [insert figure: "Figure 1, top.tif"]

342 [insert figure: "Figure 1, middle.tif"]

343 [insert figure: "Figure 2, bottom.tif"]

344

345 **Figure 1.** Associations of drinking frequency and drinking volume with obesity. Top:
346 Association between drinking frequency and obesity in 106,182 adults. Middle: Association
347 between drinking volume and obesity in 49,073 adults. Bottom: Association between
348 drinking frequency and obesity after adjustment for drinking volume in 48,905 adults. The
349 reference category for the dependent variable was normal BMI. Multinomial regression
350 models were adjusted for age, sex, smoking, physical activity, longstanding illness,
351 psychological distress, and socioeconomic status. Underweight individuals were removed.
352 Normal weight was defined as BMI 18.5-24.9 kg·m⁻², obesity as BMI ≥ 30 kg·m⁻², overweight
353 as BMI 25-<30 kg·m⁻², and underweight as BMI <18.5 kg·m⁻². The numbers in each group,
354 the odds ratios, and the 95% confidence intervals are reported in Table S1 in the online
355 supplement.

356 [insert figure: "Figure 2.tif"]

357

358 **Figure 2.** Association between drinking frequency and abdominal obesity in 71,990 adults.

359 The reference category for the dependent variable was normal waist-hip ratio. Logistic

360 regression models were adjusted for age, sex, smoking, physical activity, longstanding

361 illness, psychological distress, and socioeconomic status. Abdominal obesity was defined as

362 a waist-hip ratio >0.90 in men and >0.85 in women. The numbers in each group, the odds

363 ratios, and the 95% confidence intervals are reported in Table S4 in the online supplement.

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