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Citation:

Hobbs, M and Duncan, MJ and Collins, P and McKenna, J and Schoeppe, S and Rebar, AL and Alley, S and Short, C and Vandelanotte, C (2019) Clusters of health behaviours in Queensland adults are associated with different socio-demographic characteristics. *J Public Health (Oxf)*, 41 (2). pp. 268-277. ISSN 1741-3850 DOI: <https://doi.org/10.1093/pubmed/fdy043>

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28 **Abstract**

29 **Background:** The co-occurrence of unhealthy lifestyles, calls for interventions that target
30 multiple health behaviours. This study investigates the clustering of health behaviours and
31 examines demographic differences between each cluster.

32 **Methods:** 934 adults from Queensland, Australia completed a cross-sectional survey
33 assessing multiple health behaviours. A two-step hierarchical cluster analysis using multiple
34 iterations identified the optimal number of clusters and the subset of distinguishing health
35 behaviour variables. Univariate analyses of variance and chi-squared tests assessed
36 difference in health behaviours by socio-demographic factors and clusters.

37 **Results:** Three clusters were identified: the 'lower risk' cluster (n=436) reported the
38 healthiest profile and met all public health guidelines. The 'elevated risk' cluster (n=105)
39 reported a range of unhealthy behaviours such as excessive alcohol consumption, sitting
40 time, fast-food consumption, smoking, inactivity and a lack of fruit and vegetables. The
41 'moderate risk behaviour' cluster (n=393) demonstrated some unhealthy behaviours with low
42 physical activity levels and poor dietary outcomes. The 'elevated risk' cluster were
43 significantly younger and more socio-economically disadvantaged than both the 'lower and
44 moderate risk' clusters.

45 **Discussion:** Younger people who live in more deprived areas were largely within the
46 'elevated risk' cluster and represent an important population for MHBC interventions given
47 their wide range of unhealthy behaviours.

48

49 **Keywords:** Public Health, Clustering, Health Behaviours, Multiple Health Behaviour
50 Change.

51

52

53

54 **Introduction**

55 Modifiable health behaviours such as physical inactivity, excessive sedentary behaviour,
56 alcohol, smoking and a poor diet contribute to morbidity and mortality (Lim et al., 2012).
57 These health behaviours are the primary causes of non-communicable diseases, which
58 account for almost 70% of deaths globally and 91% of total deaths in Australia (World Health
59 Organisation, 2014). However, these health behaviours do not occur in isolation (Prochaska
60 and Prochaska, 2011). Therefore modifying one health behaviour in isolation (Busch et al.,
61 2013) may not be an adequate health behaviour change strategy.

62

63 Studies in the UK (Poortinga, 2007, Buck and Frosini, 2012) and Australia (Feng and Astell-
64 Burt, 2013) have demonstrated that unhealthy behaviours co-exist. A study of English adults
65 demonstrated that one in four individuals had three or more health risk behaviours
66 simultaneously (Poortinga, 2007). Similar findings were reported in Australian and Dutch
67 studies that reported clustering at both ends of the risk factor spectrum (all risk factors and
68 no risk factors) as well as clustering of smoking with other lifestyle risk behaviours (Schuit et
69 al., 2002). This clustering of unhealthy behaviours may have important implications for
70 health promotion, particularly if health behaviours share underlying psychological
71 characteristics and can be changed using the same behaviour change techniques (e.g., self-
72 monitoring) (Băban and Crăciun, 2007). To maximise change in behaviours in multiple
73 behaviour change interventions it is necessary to target multiple behaviours with specific
74 behaviour change techniques (Pronk et al., 2004).

75

76 Interventions focusing on multiple health behaviours have demonstrated improved health
77 outcomes compared with single behaviour interventions (Goldstein et al., 2004). However,
78 reaching people through health behaviour change interventions remains challenging. It may
79 be therefore more cost-effective to change multiple behaviours simultaneously once
80 individuals have been reached (Prochaska and Prochaska, 2011, Prochaska et al., 2008).

81 This is important as more cost-effective health behaviour interventions are needed due to
82 increasing pressures on health services (Australian Government Department of Health and
83 Ageing, 2006). Furthermore, when two behaviours are closely related to one another,
84 intervening on only one behaviour is not likely to generate lasting effects (Busch et al.,
85 2013).

86

87 Few studies have explored whether specific clusters of risk factors are more or less
88 prevalent in population subgroups. This is important to better target the right multiple health
89 behaviour change interventions to specific population subgroups. Previous research has
90 demonstrated how a 'one-size-fits-all' approach to health behaviour change is generally
91 ineffective (Ball et al., 2006). A cluster analysis will help to identify individuals who express
92 similar health behaviours, therefore identifying potential target populations for health
93 promotion efforts. With these considerations in mind, this study aims to investigate the
94 prevalence of individual health behaviours by socio-demographic factors such as age,
95 gender and socio-economic factors. Secondly, it aims to examine the clustering of these
96 health behaviours. Thirdly, it aims to examine any between cluster differences in socio-
97 demographic factors.

98 **Methods**

99 **Study Population**

100 Data were collected as part of the Queensland Social Survey (QSS) via computer-assisted
101 telephone interviews. The QSS is an omnibus survey of households in the state of
102 Queensland, Australia administered by the Population Research Laboratory at Central
103 Queensland University. For sampling purposes the state of Queensland was delineated into
104 two areas for telephone interviewing; first, South-East Queensland and second, the
105 remainder of Queensland. A two-stage selection process was then employed; first, selection
106 of households and second, selection of respondent gender within each household. A sample
107 of 1293 Australian adults were reached by randomly selecting households in the state of

108 Queensland (Australia) and then quota sampling by gender. Overall, there was variation
109 from the Queensland population from which they were drawn with an over-sampling in the
110 55 and above age categories, and under sampling in the under 35 age categories. The QSS
111 included socio-demographic and health behaviour-related questions (Department of Health
112 and Ageing, 2013). The overall response rate of the QSS was 41.2% (n = 1,293). Ethical
113 approval was obtained through the Central Queensland University research ethics
114 committee and all participants provided informed consent. Data collection took place
115 between June and July 2013.

116 **Health behaviours**

117 Physical activity

118 Physical activity (PA) data were captured using the Active Australia Survey. The Active
119 Australia Survey is a brief PA questionnaire (Australian Institute of Health and Welfare
120 (AIHW), 2003) demonstrating acceptable validity compared with Actigraph accelerometry
121 ($r = 0.46\text{--}0.50$) (Helmerhorst et al., 2012). Questions include items on duration and
122 frequency of walking and moderate and vigorous-intensity physical activity in the previous
123 week. All activities had to be performed continuously for at least 10 minutes at a time. Total
124 duration of physical activity (TPA) was calculated using this formula: total walking minutes +
125 moderate activity minutes + (vigorous activity minutes * 2). In line with current public health
126 guidance (Australian Bureau of Statistics, 2013), to meet the physical activity guideline, 150
127 minutes of activity a week over 5 days were needed. A binary outcome was created with
128 ≥ 150.00 minutes of total activity in 5 or more session classed as meeting the guidelines.

129 Sitting time

130 Sitting time was calculated as the average daily time spent sitting in the past week, as
131 reported on the Workforce Sitting Questionnaire (Chau et al., 2011). On this 10-item
132 measure, participants were asked how much time they spent sitting on non-work and work
133 days while working, commuting, using a computer, watching TV, and during other leisure-

134 time activities. This measure has demonstrated acceptable reliability ($r=0.58$, $p<0.05$) and
135 validity ($r=0.48$, $p<0.01$) (Chau et al., 2012). As there is no concrete guideline (Department
136 of Health, 2014); a recent meta-analysis (Chau et al., 2013) was used as a guide to
137 dichotomise sitting time. Accordingly, a binary outcome was defined with sitting time of > 7
138 hours per day classed as excessive sitting time, given its association with increased risk in
139 all-cause mortality.

140 Fruit and vegetable consumption

141 Fruit and vegetable consumption was assessed by two items used previously in research
142 (Smith et al., 2009b): 'How many serves of vegetables do you eat on a usual day?' and 'How
143 many serves of fruit do you eat on a usual day?' In line with recent research (Australian
144 Bureau of Statistics, 2015, Oyebode et al., 2014) a binary outcome was created based on
145 whether or not participants were meeting the public health guidance recommendation of ≥ 5
146 servings of vegetables and ≥ 2 fruit (Department of Health and Ageing, 2013).

147 Fast-food consumption

148 Fast-food consumption was assessed using one item: "In the last 7 days, how many times
149 did you eat something from a fast-food restaurant like McDonald's, Hungry Jacks, KFC, etc?
150 This also includes other fast-food and takeaway such as fish and chips, Chinese food and
151 pizza." There was little literature to guide a binary outcome for fast-food, therefore a
152 threshold of ≥ 1 fast-food meal per week equated to not meeting public health guidelines
153 (Australian Government Department of Health, 2015). The Australian recommendation is to
154 limit fast food as much as possible, so logically none in the last week is ideal (Australian
155 Government Department of Health, 2015). Fast-food consumption was used as a proxy for
156 unhealthy food behaviour as it has been associated with weight gain (Paquet et al., 2010,
157 Thornton et al., 2009, Thornton et al., 2016) and deleterious health outcomes (Pereira et al.,
158 2005, An, 2016).

159 Smoking

160 Smoking status was assessed using one item: ‘Are you presently a smoker?’ (yes/no). In line
161 with current public health recommendations smoking is not recommended (Zwar et al.,
162 2005).

163 Alcohol consumption

164 Participants were asked: “During the past 30 days did you consume at least one drink of any
165 alcoholic beverage”, and if yes, “how many drinks did you have on average each day”. An
166 estimate of alcohol consumption was created by multiplying the number of drinks per day in
167 the last month and the average number of drinks per day divided by 30 to give an estimate
168 of drinks per day. Based on established public health guidelines a binary outcome was
169 created based on the guideline of ≥ 2 drinks per day (Australian Government National Health
170 and Medical Research Council, 2014).

171 Socio-demographic factors

172 Socio-demographic factors measured included age group (18-34, 35-44, 45-54, 55-64, 65+),
173 gender (male, female), level of education (pre-school, primary or high school and college or
174 university), BMI (underweight, healthy weight, overweight and obese) (calculated from self-
175 report height (cm) and weight (kg)) and postcode. Post codes were linked to the socio-
176 economic index for areas (SEIFA) developed by the Australian Bureau of Statistics
177 (Australian Bureau of Statistics, 2016). As part of this The Index of Relative Disadvantage
178 which ranks community areas in Australia according to relative socio-economic
179 disadvantage using census data on education, employment, occupation, housing and
180 English proficiency was used (Australian Bureau of Statistics, 2016). The Index of Relative
181 Disadvantage was then split into four equal quartiles specific to this population (Q1 0-964;
182 Q2 965-1020; Q3 1021-1058; Q4 1059-1129) with a lower score meaning greater
183 disadvantage.

184 **Statistical Analysis**

185 Only individuals with complete data for all health behaviour and demographic variables were
186 included in the final sample (n=934) resulting in the exclusion of 359 individuals. A sensitivity
187 analysis showed no differences by socio-demographic factors and health behaviours in
188 excluded data (Additional File 1). Prior to cluster analysis, engagement in the health
189 behaviours were presented as simple proportions of those who meet the public health
190 guidelines.

191

192 To identify clusters of multiple health behaviours a two-step cluster approach was used
193 which ensures that the size of the distance matrix is determined by the number of pre-
194 clusters rather than individual cases (Bitman and Gelbard, 2007). Firstly, based on the
195 distance criterion, cases were either assigned to an existing pre-cluster or assigned a new
196 pre-cluster. Pre-clusters were then clustered in the second step using the standard
197 hierarchical clustering algorithm, which assessed multiple cluster solutions and automatically
198 determined the optimal number of clusters. The researchers made no assumptions
199 regarding cluster membership or number, as this was determined in the hierarchical two-step
200 clustering approach (Bitman and Gelbard, 2007).

201

202 The cluster analysis was conducted multiple times with multiple iterations undertaken to
203 establish both the optimum number of clusters and the format of health behaviour variables
204 to be included. This process initially included conducting the analysis with continuous
205 behavioural variables and smoker or not, before multiple versions were conducted
206 alternating an additional categorical variable. For example, the inclusion of fast-food as both
207 continuous (servings per week) and categorical (meeting guidelines or not) was explored.

208

209 The final combination of variables included within the cluster was determined using the
210 Schwarz Bayesian Criterion (Bitman and Gelbard, 2007). Based on this analysis, the
211 following variables were included in the final cluster analysis: physical activity, sedentary

212 behaviour, fruit and vegetable intake, fast-food intake, smoking and alcohol consumption.
213 The silhouette measure used to validate the cluster indicated 0.5, which demonstrates a
214 good level of both cohesion and separation, and provided a stronger solution than
215 comparative 2-cluster and 4-cluster alternative solutions. To examine differences between
216 clusters on socio-demographic factors Pearson chi squared was used with independent
217 variables as categorical predictors. For all tests, significance levels were set at $p < 0.05$.
218 Analyses were undertaken in SPSS v22 (IBM Corporation).

219 **3.0 Results**

220 **Demographic characteristics**

221 In the sample of 934 individuals, 495 (53.0%) were male and 439 (47.0%) were female
222 (Table 1). The mean age of participants was 53.79 years (± 14.92). Using the index of
223 relative disadvantage, and defining deprivation as living in the top 25% deprived areas (IRD
224 < 964), 238 (25.5%) adults were categorised as living in the most deprived areas (Table 1).
225 Most individuals were either college or university educated (64.5% $n=602$) and 35.0%
226 ($n=327$) and 23.1% ($n=215$) were classified as overweight and obese, respectively.

227

228 INSERT TABLE 1 HERE

229

230 **Behaviours**

231 Physical activity

232 In total, participants reported an average of 317.72 (SD ± 322.78) minutes of physical activity
233 per week with 48.9% ($n=457/934$) categorised as not meeting the physical activity guidelines
234 (Table 1). The percentage of participants meeting physical activity guidelines was not
235 associated with gender ($p > 0.05$), deprivation ($p > 0.05$) or age ($p > 0.05$).

236 Sitting time

237 A mean value of 413.37 (± 193.59) minutes/day of sitting time was reported (≈ 7 hours/day)
238 with 45.5% ($n=425$) of people categorised as sitting >7 hours/day. Sitting time was
239 associated with gender ($\chi^2 [1] = 14.46, p < .001$), with more males than females exceeding the
240 guideline to sit >7 hours per day (50.5% vs. 39.9%) (*Cramer's V* = 0.124). Sitting time was
241 not associated with deprivation ($p > 0.05$). However, sitting time was lower in those with
242 increasing age ($\chi^2 [5] = 25.77, p < 0.001, Cramer's V = 0.17$). Fewer people reported sitting for
243 >7 hours/day as age increased (18-34 years, 55.8%, >65 years 34.5%).

244 Fruit and vegetable

245 A daily mean value of 1.95 (± 1.27) fruit servings and 2.96 (± 1.59) vegetable servings was
246 reported; 86.1% ($n=804$) of participants were categorised as not meeting the recommended
247 guidelines that combine >2 fruit and >5 vegetables. More females (63.1% vs. 45.1%) than
248 males met the guidelines ($\chi^2 [1] = 30.46, p < 0.001, Cramer's V = 0.18$). There was no
249 association between fruit and vegetable consumption and deprivation ($p > 0.05$) or age
250 ($p > 0.05$).

251 Fast-food

252 Participants reported consuming an average of 1.61 (± 0.79) servings of fast-food in the
253 previous week (44.9% exceeded ≥ 1 fast-food meal per week). There was a significant
254 association between fast-food consumption and gender ($\chi^2 [4] = 16.57, p < 0.01$): more males
255 (48.5%) than females (40.8%) consumed ≥ 1 fast food meal per week. Deprivation was not
256 associated with fast-food intake ($p > 0.05$), whereas age was associated with intake ($\chi^2 [20] =$
257 120.12, $p < 0.001$). The percentage of individuals consuming at least one weekly serving of
258 fast-food was significantly higher for those with a lower age.

259 Smoking

260 In total, 10.8% ($n=101$) of individuals smoked. There was no association between smoking
261 (yes/no) and gender ($p > 0.05$). However, there was an association of deprivation and

262 smoking; residents of the most disadvantaged quartile (Q1) reported higher levels of
263 smoking (38.6% vs. 13.9%) than those in the least disadvantaged quartile (Q4 ; χ^2 [3] = 7.44,
264 $p < 0.01$, *Cramer's V* = 0.12). Smoking was also associated with age (χ^2 [3] = 15.17, $p < 0.01$,
265 *Cramer's V* = 0.13); A higher proportion of younger participants smoked compared to older
266 participants.

267 Alcohol

268 Participants reported a mean value of 0.83 (± 1.75) alcoholic drinks per day. On average,
269 14.0% of participants exceeded the guideline of ≥ 2 drinks per day. Alcohol consumption
270 differed by gender (χ^2 [1] = 31.47, $p < 0.001$): 20.0% of males and 7.3% of females exceeding
271 alcohol guidelines. There was no association between alcohol and deprivation ($p > 0.05$) or
272 age ($p > 0.05$).

273

274 **Clustering of health behaviours**

275 Descriptive characteristics of the cluster profiles can be seen in Table 2. Three clusters were
276 identified; the '*lower risk behaviour*' cluster included 46.7% (n=436) participants, 42.1%
277 (n=393) of participants were in the '*moderate risk behaviour*' cluster and 11.2% (n=105) were
278 in '*elevated risk behaviour*' cluster. All '*lower risk behaviour*' cluster members were non-
279 smokers (100%) and sufficiently active (100%); they also consumed the most fruit and
280 vegetables (5.34 servings/day) and had the lowest levels of sitting time (400 mins/day). This
281 differs considerably from the '*moderate risk behaviour*' cluster which included insufficiently
282 active adults (100%), non-smokers (100%) and poorer dietary behaviours (4.56 servings of
283 fruit and vegetables per day). Most individuals in the '*elevated risk behaviours*' cluster
284 smoked (96.2%), were insufficiently active (61%), were sedentary for the highest amount of
285 time (437 minutes/day) and consumed the least fruit and vegetables per day (4.43 servings),
286 the most fast-food meals per week (1.68 meals) and the most alcohol per day on average
287 (1.83 drinks/day).

288

289 There was a statistically significant difference between clusters for smoking behaviours
290 ($F(2,931) = 10,432, p < 0.001$). A Bonferroni post hoc test showed no difference between 'low
291 risk behaviours' and 'moderate risk behaviours' ($p > 0.05$). However, 'low risk behaviours'
292 were significantly different to 'elevated risk behaviours' ($p < 0.001$). 'Moderate risk behaviours'
293 were significantly different to 'elevated risk behaviours'. Physical activity levels were
294 significantly between all three clusters ($F(2,931) = 3881.93, p < 0.001$). Another one-way
295 ANOVA ($F(2,931) = 20.51, p < 0.001$) demonstrated drinks per day in 'low risk behaviours'
296 were significantly lower than in the 'elevated risk behaviours', and 'elevated risk behaviours'
297 were significantly higher than 'moderate risk behaviours'. ($p < 0.05$). Despite this, there was no
298 difference between 'low risk behaviours' and 'moderate risk behaviours' ($p > 0.05$). Fruit and
299 vegetable intake also differed significantly between clusters ($F(2,931) = 14.38, p < 0.001$).
300 Although post-hoc tests revealed no different between 'elevated risk behaviours' and
301 'moderate risk behaviours' in fruit and vegetable intake ($p < 0.05$), there were statistically
302 significant differences between 'low risk behaviours' and 'elevated risk behaviours' ($p < 0.001$).
303 Moreover, there were also statistically significant differences between 'low risk behaviours'
304 and 'moderate risk behaviours' in fruit and vegetable intake ($p < 0.001$). In contrast there were
305 no statistically significant differences for sitting time ($F(2,931) = 2.32, p = 0.10$) or fast-food
306 consumption ($F(2,931) = 1.97, p = 0.14$) between clusters.

307

308 INSERT TABLE 2 HERE

309

310 Table 3 shows demographic differences between the three clusters. There was no significant
311 gender differences for cluster membership; however, there was a significant effect for cluster
312 membership by age ($\chi^2 [8] = 17.95, p = 0.02, Cramer's V = 0.10$). The 'elevated risk
313 behaviour' cluster included significantly younger adults than the 'moderate risk behaviour'
314 cluster and 'lower risk behaviour' cluster. Deprivation also differed as a function of cluster
315 membership ($\chi^2 [6] = 16.46, p = 0.01, Cramer's V = 0.10$). The 'elevated risk behaviour'
316 cluster was significantly more disadvantaged than the 'moderate risk' and 'lower risk

317 *behaviour*' cluster. In contrast, there was no significant difference between clusters on
318 education level ($p>0.05$).

319

320 INSERT TABLE 3 HERE

321

322 **Discussion**

323

324 *Main findings of this study*

325 There is a growing body of literature examining clusters of health behaviours. However, few
326 present findings on a wide range of health behaviours by age, gender and area-level
327 deprivation. Three clusters were identified within this study as '*lower risk*', '*elevated risk*' and
328 '*moderate risk*' behaviour clusters. The '*elevated risk*' cluster were younger and more socio-
329 economically disadvantaged. As such, this study is among the first to suggest different
330 clusters of individuals may require different types of multiple health behaviour change
331 (MHBC) interventions.

332

333 *What is already known on this topic*

334 This study supports previous evidence that shows how health behaviours are socio-
335 demographically related (Buck and Frosini, 2012). Younger and more disadvantaged
336 individuals were more likely to smoke. Although smoking rates continue to decline
337 (Australian Institute of Health and Welfare, 2014), Australian data highlights that individuals
338 living in the low socio-economic (SES) areas are three times more likely to smoke (daily)
339 than people within the highest SES areas (19.9% vs. 6.7%) (The Department of Health,
340 2015). Similar to previous research, 48.9% of adults were categorised as insufficiently active
341 (Duncan et al., 2012). However, in contrast to previous research (Department of Health,
342 2014, Feng and Astell-Burt, 2013) physical activity was independent of age, gender and
343 deprivation. Also similar to other population based data, males reported consuming more

344 alcohol, fast-food and less fruit and vegetables (Smith et al., 2009a, White, 2013). Finally,
345 females and older participants were more likely to sit less than 7 hours per day. This is in
346 contrast to a plethora of previous research which suggests as people age they become more
347 sedentary (Hallal et al., 2012). Evidence of an association between deprivation and sitting
348 time remains equivocal (O'Donoghue et al., 2016). We suggest dissimilarities may occur due
349 to the differences in arbitrary cut-offs used to define higher or lower levels of sitting time.
350 Findings within this study show that sitting time was independent of level of disadvantage.
351 This study also highlights how these behaviours converge by demonstrating three unique
352 and distinct clusters of health behaviours.

353

354 *What this study adds*

355 In public health terms, the behaviour of those in the '*elevated risk*' cluster, who did not meet
356 most public health guidelines, is concerning. It is worth noting that while the '*elevated risk*'
357 cluster were significantly younger than the other clusters, the '*elevated risk*' cluster was
358 balanced towards younger middle-aged people, rather than older middle-aged people.
359 Consistent with previous research (Poortinga, 2007, Schuit et al., 2002) our findings show
360 that excessive alcohol consumption, smoking, poor diet and to a lesser extent inactivity were
361 found to cluster together within the '*elevated risk*' cluster. A recent review (Noble et al.,
362 2015) concluded that males and those with greater social disadvantage showed riskier
363 patterns of health behaviours. However, several of the included studies were poor quality. In
364 contrast, findings in this study showed no differences by gender, potentially as a result of the
365 wider range of behaviours considered (MacArthur et al., 2012). Considering the greater risk
366 posed by each of these behaviours and the likely exacerbated risk associated with engaging
367 in multiple risky behaviours this population subgroup is an obvious target for preventive
368 health initiatives. The high levels of inactivity and poor diet demonstrated within the
369 '*moderate risk*' cluster are also a public health concern.

370

371 Although both *'moderate'* and *'elevated risk'* clusters are unhealthy and at risk, there are
372 important differences in health behaviours between them. For instance, compared to the
373 *'moderate risk'* cluster the *'elevated risk'* cluster consumes more alcohol (1.83 drinks vs.
374 0.65 drinks/day per day), cigarettes (100% vs 3.8% were non-smokers) with differences in
375 physical activity too. In a recent study, deaths for all-cause mortality were advanced by 4.0
376 years for physically inactive adults. However, the rate advancement period for all-cause
377 mortality was 7.9 years among current smokers (Borrell, 2014). Those in the *'moderate risk'*
378 cluster may represent very different attitudes and intentions towards health behaviours
379 (Prochaska et al., 2008, Prochaska and Prochaska, 2011). However, such between cluster
380 differences are important and should not be ignored, as these two unhealthy clusters will
381 require different behaviour change interventions. They represent an important opportunity to
382 tailor public health interventions. Interventions have been successful in changing two, three
383 or even four or more health behaviours simultaneously, suggesting that MHBC is possible
384 (Hyman et al., 2007).

385

386 Due to both the wider range and greater extent of unhealthy behaviours, and perhaps more
387 serious consequences in terms of all-cause mortality (Borrell, 2014), individuals within the
388 *'elevated risk'* cluster may require a much more intense behaviour change intervention
389 compared to those who are within the *'moderate risk'* cluster. In addition to this, given that a
390 dose-response relationship exists between health behaviours and health outcomes – where
391 there is the greatest benefit of improving health behaviours of individuals who are the most
392 unhealthy (Lee and Skerrett, 2001) – the overall health of the population may be improved
393 most by focusing on those within the *'elevated risk'* cluster. In contrast to this, a significant
394 proportion of the *'moderate risk'* cluster may only require small changes to health behaviours
395 to meet public health guidelines, which is also a viable option for intervention.

396 *Limitations of this study*

397 A cross-sectional design remains strong for observational purposes however it does
398 encounter causality limitations. Subjective measures were used throughout the research
399 design and are subject to measurement error due to recall limitations and social desirability
400 bias (Atkin et al., 2012). Furthermore, alcohol data could have been standardised around
401 units per day rather than drinks per day. Moreover, while fast-food consumption has been
402 associated with deleterious health outcomes and weight gain it is also plausible that other
403 foods not captured within this study may be adverse for weight gain and health. Valid and
404 reliable self-report measures were used where available (Helmerhorst et al., 2012, Chau et
405 al., 2012). Although not always possible, future research should use objective measures of
406 health behaviours. Furthermore, there are currently no accepted thresholds for excessive
407 sedentary behaviour or fast-food; therefore classifications are arbitrary and may vary
408 considerably between studies (Owen et al., 2011). Results may also not be generalisable
409 beyond the study sample and area as the study is restricted to one geographical area, the
410 sample was divided into clusters based on a data driven approach and adults aged over 50
411 were oversampled. Future research should consider stronger research designs to build on
412 existing, tentative support for the implementation of MHBC into public health policy. Further
413 research is needed to assess interactions between multiple health behaviours and any
414 mediation or relationships between different behaviours and chronic disease.

415 **Conclusion**

416 This study has progressed our understanding of the clustering of the most prevalent health
417 behaviours in adults and is amongst the first to identify clusters of health behaviours within
418 population subgroups. Younger people who lived in the more deprived areas were largely
419 within the '*elevated risk*' cluster representing an important target group for MHBC
420 interventions given their wide range of unhealthy behaviours. The '*moderate risk*' cluster still
421 exhibited a range of unhealthy behaviours but may benefit from a less intensive MHBC
422 intervention that focuses on smaller changes in health behaviours. This study supports

423 previous calls for a more comprehensive approach to behaviour change. Future
424 interventions and policies should acknowledge a range of behaviours when designing MHBC
425 interventions, particularly for those who are younger and reside within deprived
426 neighbourhoods.

427

428

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Table 1: Demographic characteristics of participant's and the percentage (% (n)) that meet public health guidelines

Demographic characteristic	Total sample	Non-smoker	Alcohol	Physically Active	<7 hours sitting time	Fruit and vegetable	Fast-food
Overall	100.0 (934)	89.2 (833)	86.0 (803)	51.1 (477)	54.5 (509)	13.9 (130)	55.1 (515)
Gender							
Male	53.0 (495)	88.3 (437)	80.0 (396)	49.5 (245)	58.6 (290)	45.1 (223)	51.5 (255)
Female	47.0 (439)	90.2 (396)	92.7 (407)	60.1 (264)	73.3 (322)	63.1 (277)	59.2 (260)
Age							
18-34	9.2 (86)	14.0 (12)	86.0 (74)	57.0 (49)	58.1 (50)	44.2 (38)	37.2 (32)
35-44	18.4 (172)	14.5 (25)	91.9 (158)	50.6 (87)	64.5 (111)	49.4 (85)	41.3 (71)
45-54	22.7 (212)	14.6 (31)	85.8 (182)	45.3 (96)	62.3 (132)	50.9 (108)	46.7 (99)
55-64	24.2 (226)	8.8 (20)	83.2 (188)	52.2 (118)	61.9 (140)	54.4 (123)	61.9 (140)
65+	25.5 (238)	5.5 (13)	84.5 (201)	53.4 (127)	75.2 (179)	61.3 (146)	72.7 (173)
SEIFA IRD Quintiles							
1 < 964 (Lowest IRD)	25.5 (238)	83.6 (199)	85.7 (204)	48.3 (115)	68.5 (163)	53.8 (128)	55.9 (133)
2 965 – 1020	24.8 (232)	90.9 (211)	87.5 (203)	49.1 (114)	71.1 (165)	49.6 (115)	49.1 (114)

3	1021- 1058	26.4 (247)	89.1 (220)	84.6 (209)	56.7 (140)	62.3 (154)	53.4 (132)	60.3 (149)
4	> 1059 (Highest IRD)	23.2 (217)	93.5 (203)	86.2 (187)	49.8 (108)	59.9 (130)	57.6 (125)	54.8 (119)

Education

	Pre, Primary or High School	35.5 (332)	87.3 (290)	84.0 (279)	47.9 (159)	70.8 (235)	57.2 (190)	57.2 (190)
	College/University	64.5 (602)	90.2 (543)	87.0 (524)	52.8 (318)	62.6 (377)	51.5 (310)	54.0 (325)

Weight Status (BMI)

	Underweight (<18.5)	1.7 (16)	75.0 (12)	100.0 (16)	43.8 (7)	87.5 (14)	62.5 (10)	68.8 (11)
	Healthy weight (18.5-24.99)	34.5 (332)	87.0 (280)	88.5 (285)	54.0 (174)	69.6 (224)	55.9 (180)	59.3 (191)
	Overweight (25.00-29.99)	35.0 (327)	92.7 (303)	84.4 (276)	54.4 (178)	61.8 (202)	53.5 (175)	54.4 (327)
	Obese (≥30.00)	23.0 (215)	87.9 (189)	84.7 (182)	40.5 (87)	59.5 (128)	47.0 (101)	48.4 (104)

Note: SEFIA= Socio-Economic Indexes for Areas; IRD = Index of relative disadvantage; IRD lower score = greater disadvantage

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611 **Table 2:** Health behaviours by cluster membership
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	Cluster 1	Cluster 2	Cluster 3	Overall Sample
	'Lower risk behaviour' (46.7%, n=436)	'Moderate risk behaviour' (42.1%, n=393)	'Elevated risk behaviour' (11.2%, n=105)	(n=934)
Smoker (% do not smoke)	100	100	3.8	89.2
Physical Activity (% active)	100	0	61	51.1
Alcohol (drinks/day)	0.75	0.65	1.83	0.83
Fruit and Vegetable (servings/day)	5.34	4.56	4.43	4.91
Sitting time (minutes/day)	400	422	437	413
Fast-food (meals/week)	1.56	1.65	1.68	1.61

613 **Table 3:** Between group differences in cluster demographics (% of participants (n))

	Cluster 1	Cluster 2	Cluster 3
	Lower risk	Moderate risk	Elevated risk
	behaviours	behaviours	behaviours
Total	46.7 (436)	42.1 (393)	11.2 (105)
Gender			
Male	55.3 (241)	49.4 (194)	57.1 (60)
Female	44.7 (195)	50.6 (199)	42.9 (45)
Age years* (Mean, (SD))			
18-34	10.5 (46)	6.1 (28)	11.4 (12)
35-44	17.7 (77)	17.6 (69)	24.8 (26)
45-54	19.5 (85)	24.4 (96)	29.5 (31)
55-64	25.0 (109)	24.2 (95)	21.0 (22)
65+	27.3 (119)	26.7 (105)	13.3 (14)
IRD* (Mean, (SD))			
Quartile 1	23.4 (102)	24.4 (96)	38.1 (40)
Quartile 2	23.9 (104)	27.0 (106)	21.0 (22)
Quartile 3	29.4 (128)	23.2 (91)	26.7 (28)
Quartile 4	23.4 (102)	25.4 (100)	14.3 (15)
Education			
Pre, Primary or High school	32.6 (142)	37.4 (9)	41.0 (43)
College/University	67.4 (294)	62.6 (246)	59.0 (62)

BMI (Mean, (SD))	26.73 (\pm 5.25)	27.88 (\pm 5.83)	26.71 (\pm 5.68)
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Weight Status

Underweight	1.6 (7)	1.0 (5)	3.8 (4)
Healthy weight	35.6 (155)	31.6 (124)	41.0 (43)
Overweight	38.8 (169)	33.8 (133)	23.8 (25)
Obese	17.6 (77)	28.2 (110)	26.7 (28)

614 Note: * significantly differences by cluster membership $p < 0.05$.

615 Figures are reported as % (n) unless stated as mean, SD.

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