

# Journal Pre-proof

Is urban growing of fruit and vegetables associated with better diet quality and what mediates this relationship? Evidence from a cross-sectional survey

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PII: S0195-6663(21)00125-2

DOI: <https://doi.org/10.1016/j.appet.2021.105218>

Reference: APPET 105218

To appear in: *Appetite*

Received Date: 6 October 2020

Revised Date: 11 December 2020

Accepted Date: 15 March 2021

Please cite this article as: Mead B.R., Christiansen P., Davies J.A.C., Falagán N., Kourmpetli S., Liu L., Walsh L. & Hardman C.A., Is urban growing of fruit and vegetables associated with better diet quality and what mediates this relationship? Evidence from a cross-sectional survey, *Appetite*, <https://doi.org/10.1016/j.appet.2021.105218>.

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**Abstract**

Urban agriculture (UA), the growing of fruits and vegetables in urban and peri-urban areas, may improve food security and access, public health and dietary quality on both a broad and personal scale. However, there is little research on the relationship between UA and diet, and potential mediating factors are also unclear. This study aimed to investigate if proximity to and engagement with UA is associated with better diet quality, and what accounts for this relationship. UK-based adults (N=583, 69% Female) completed measures of proximity to and engagement with UA, perceived access to fruits and vegetables, health and ethical food choice motivations, connection with nature, psychological distress and dietary quality in an online survey. Participants were recruited from UA-related groups and the general public. Proposed relationships were analysed using a structural equation model. Greater proximity to and engagement with UA was associated with greater perceived access to fruits and vegetables, more health-related food choice motivations, more ethical-related food choice, feeling more connected with nature, and, surprisingly greater psychological distress. Furthermore, proximity to and engagement with UA was indirectly associated with better diet quality via health-, and ethical-related, food choice motivations. While the direct pathway between proximity to and engagement with UA and diet quality was not significant, UA is associated with better diet quality, partly via healthier and ethical food choice motivations. Upscaling UA may have benefits for dietary quality via these factors, and more research is needed to test causal relationships and understand these complex interactions.

Keywords: urban agriculture, food production, diet, food choice motivations, rurbanisation, health, sustainability

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2 **and what mediates this relationship? Evidence from a cross-sectional survey.**

3

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**27 Abstract**

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30 scale. However, there is little research on the relationship between UA and diet, and potential  
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45 test causal relationships and understand these complex interactions.

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48 sustainability

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**50 1. Background**

51 The negative consequences of poor diet are well-documented and far reaching. Overconsumption of  
52 energy dense, unhealthy food is a major driver of overweight and obesity, and the associated

53 comorbidities are creating a major global public health challenge (Ng et al., 2014). Under-  
54 consumption of fruits and vegetables also presents chronic disease risks, such as heart disease  
55 (Boeing et al., 2012; van Breda & de Kok, 2018). The EAT-Lancet report recommended that fruit and  
56 vegetable consumption needs to double in order to achieve optimal diets for planetary and human  
57 health (Willett et al., 2019), highlighting the critical need to rapidly increase access and availability of  
58 such foods to support healthy, sustainable diets. In addition, food insecurity affects an estimated 2  
59 billion people worldwide, including 8% of the populations of Northern America and Europe (FAO,  
60 2019). In the United Kingdom (UK), a significant proportion of households are unable to achieve  
61 sufficient nutrition because of limited food access (Loopstra et al., 2019; Taylor & Loopstra, 2016).  
62 The consequences of this include stress, reduced well-being and unhealthy eating habits, therefore  
63 contributing further to poor diet and health (Taylor & Loopstra, 2016). Also, political uncertainty  
64 (e.g. Brexit), climate concerns, and the COVID-19 pandemic pose added threats to food security  
65 (Garnett et al., 2020), prompting the need for sustainable solutions to ensure adequate, nutritious  
66 food for the population. Tackling these global challenges is a priority as shown by the Sustainable  
67 Development Goals of the United Nations number 2 – Zero Hunger and 12 – Responsible  
68 consumption and production (United Nations, 2020).

69  
70 Urban agriculture (UA), the growing of fruits and vegetables in urban and peri-urban (suburban)  
71 areas may represent a solution to ensure a sustainable, efficacious and holistic food system,  
72 improving health, well-being, and food security (Audate et al., 2019; Brown & Jameton, 2000; Draper  
73 & Freedman, 2010; Genter et al., 2015; Soga, Gaston, et al., 2017; Van Den Berg et al., 2010). UA  
74 encompasses a broad range of informal and formal food production operations, from urban  
75 allotments and home/ community garden growing, to commercial urban farms (De Zeeuw, 2004).  
76 Historically, UA has been relied upon to mitigate food shortages during crises, such as war (Mok et  
77 al., 2014). More recently, evidence suggests that UA may help improve diet quality and reduce food

78 inequalities (Edmondson et al., 2020; Martinho da Silva et al., 2016; Poulsen et al., 2015; Zezza &  
79 Tasciotti, 2010).

80

81 Recent findings have suggested that UA has positive impacts on health (Genter et al., 2015), and on  
82 determinants of health, such as nutrition, physical activity, and well-being (Aude et al., 2019). A  
83 range of small-scale studies indicate that engagement with UA of various forms may promote well-  
84 being (Kingsley et al., 2009; Soga, Gaston, et al., 2017; Van Den Berg & Custers, 2011; Wood et al.,  
85 2016). For example, adults who took part in regular allotment gardening scored higher on a measure  
86 of general mental health than non-gardeners (Soga, Cox, et al., 2017). A recent meta-analysis (Spano  
87 et al., 2020) also indicated that community gardens and horticultural interventions have therapeutic  
88 benefits for psychosocial well-being; however this meta-analysis also highlighted poor study quality  
89 and the need for more controlled, quantitative assessment of these benefits.

90

91 Furthermore, there is some evidence that engagement in urban growing is associated with healthier  
92 diet (Kamphuis et al., 2006). Increased access to healthier food is an important motivating factor for  
93 home growing (Garcia et al., 2018; Lanier et al., 2015; Ruggeri et al., 2016), and these motivations  
94 may translate into healthier dietary choices; for example, participation in community gardens and  
95 urban home garden programmes is associated with increased fruit and vegetable consumption in  
96 adults (Alaimo et al., 2008; Litt et al., 2011; Palar et al., 2019). UA may also have a positive impact in  
97 reducing the likelihood of having overweight and obesity (Zick et al., 2013). However, there are also  
98 methodological limitations in this literature, such as uncontrolled studies, insufficient data analysis,  
99 and small sample sizes which limit the strength of these conclusions and require further  
100 investigation.

101

102 Thus, while there is preliminary evidence linking engagement in UA with healthier diets, the  
103 mechanisms that may account for this relationship are not well-understood. Identifying the drivers

104 of this relationship is important as a means of informing changes in policy and good practice if UA is  
105 to be supported as a food systems solution. A plausible explanation is that UA simply provides  
106 greater access to fruits and vegetables, and this is an often-cited benefit of UA (Garcia et al., 2018).  
107 However, the individual differences and situational factors underpinning food choice are more  
108 complex than this, and other factors are likely involved (Connors et al., 2001; Prescott et al., 2002;  
109 Sobal et al., 2014).

110

111 Motivations to eat healthily and ethically/ sustainably are often cited as motivations for engaging in  
112 UA (Al-Mayahi et al., 2019; Martinho da Silva et al., 2016; Ruggeri et al., 2016) and may explain the  
113 relationship between UA and diet. Furthermore, studies of non-gardening populations suggest that  
114 people with such motivations typically report healthier and more environmentally-conscious diet  
115 patterns. For example, reporting pro-environmental behaviours appears to be associated with  
116 following a health-conscious diet (Asvatourian et al., 2018). Similarly, others have shown that  
117 individuals who report more environmental and ethics-related concerns about food also have  
118 healthier diets (Allès et al., 2017) and healthy eating attitudes (Sun, 2008).

119

120 UA may also serve as a way of reconnecting people with nature, which could, in turn, have health  
121 benefits. As population centres move away from rural areas, a disconnect with nature and green  
122 space may be experienced (Maller et al., 2006), which seems to be detrimental to well-being and  
123 associated with stress (Uhlmann et al., 2018). Stress has been identified as a driver of poor health  
124 and unhealthy dietary choices (Ng et al., 2014; Sominsky & Spencer, 2014). Conversely, exposure to  
125 nature appears to have benefits for sustainable behaviours, well-being and diet. Nature exposure  
126 promotes environmentally sustainable behaviour, as evidenced by more co-operative and  
127 sustainable harvesting strategies in an experimental task (Zelenski et al., 2015), whilst also having  
128 benefits for well-being and stress reduction (Bowler et al., 2010; Greiman, 2014; Hazer et al., 2018;  
129 Hunter et al., 2019; Pamela Pensini et al., 2016; Roe et al., 2013; South et al., 2018). Exposure to

130 nature scenes has also been shown to increase healthier dietary choices by encouraging people to  
131 be more future thinking and delay short-term gratification (Kao et al., 2019). Therefore, as exposure  
132 to nature is likely to happen when engaging in UA, increased connection with nature and wellbeing  
133 may also be potential explanations for the relationship between UA and diet.

134

135 Taken together, while there is emerging evidence for a relationship between UA and improved diet  
136 quality, there is a lack of understanding of the mediating factors which may underpin this  
137 relationship; identifying such mechanisms is critical for future work that seeks to develop the  
138 beneficial impacts of UA. Considering the evidence described above, theoretically, UA may be  
139 associated with i) greater perceived access to fruits and vegetables, ii) increased connection with  
140 nature, iii) lower psychological distress, and iv) increased health and ethical food choice motivations,  
141 which may in turn promote improved dietary quality and health. However, to our knowledge, there  
142 has been no empirical investigation of these potential pathways linking UA with healthier diets.

143

144 Finally, although much of the evidence for associations between UA and better dietary choices and  
145 well-being is based on reports of *engagement* with UA, some findings suggest that proximity to UA  
146 may be enough to have some benefits. Alaimo et al (2008) found that increases in fruit and  
147 vegetable intake were seen in participants with household members involved in a community  
148 garden, suggesting that such distal exposure to UA might act to improve diet by increasing access to  
149 fruit and vegetables or by priming healthy eating motivations of those not necessarily directly  
150 involved in UA. Similarly, Hawkins et al (2013) found that even just exposure to UA (“being” at an  
151 allotment) had similar well-being benefits to engagement in UA (gardening activities). Therefore, the  
152 benefits of UA may be experienced via a combined effect of proximity and engagement with UA,  
153 although research that has tested this is lacking. This is an important aspect to consider as many  
154 more people are proximal to urban food growing activities compared with those that are directly

155 engaged, and if benefits are conferred with proximity this has important implications for urban food  
156 growing as a health intervention.

157

158 Addressing these gaps, the current study used a cross-sectional online survey to test if proximity to  
159 and engagement with UA is associated with better diet quality, and what mediates this relationship.

160 We collected data from a large sample of adults across the UK and used a structural equation model  
161 to test the following hypothesis.

162

163 Hypothesis: Greater proximity to, and engagement with, urban agriculture will be positively  
164 associated with greater perceived access to fruit and vegetables, more health and ethical concern-  
165 related choice motivations, feeling more connected to nature, and negatively associated with  
166 psychological distress; in turn, these factors will be positively associated with a healthier diet, apart  
167 from psychological distress, which will be negatively associated with healthier diet. These  
168 predictions are displayed as a hypothesised statistical model in Figure 1.

169

## 170 **2. Method**

### 171 *2.1 Participants*

172 Participants were recruited from the Qualtrics participant panel and by an opportunity sample of  
173 members of the general public. The Qualtrics participant panel is an online platform where  
174 individuals participate in online studies and are financially reimbursed for their time. Qualtrics  
175 distributed the survey to members of their panel, and were paid a fee by the research team for  
176 doing so. The survey was distributed to panel members aged 18 years and over, who were based in  
177 the UK. To ensure that our participant sample would include participants who were engaged or  
178 interested in urban agriculture (as this was critical to addressing our research questions), we  
179 supplemented the Qualtrics participant panel recruitment by specifically targeting study adverts to  
180 urban growing and home gardening groups based in the UK, such as allotment societies,

181 horticultural groups, social media communities and discussion forums related to home food  
182 growing. We took this recruitment approach in order to capture the experiences of participants from  
183 a range of backgrounds.

184

185 We aimed to recruit 595 participants. A sample size calculation indicated that 475 participants were  
186 needed for 90% power at alpha .05 ( $H_0$ , Root Mean Square Error of Approximation (RMSEA) = .01,  
187  $H_1$  = RMSEA = .08 (Hu & Bentler, 1999; MacCallum et al., 1996)). We increased this by 20% to allow  
188 for attrition. We aimed to recruit 400 participants via the Qualtrics participant panel, plus 195  
189 participants from the general public to ensure that our sample contained a mixture of participants  
190 who did and did not have experience of urban agriculture. Participants were eligible to take part in  
191 the study if they were aged 18 years or over and based in the UK.

192

## 193 *2.2 Measures*

### 194 *2.2.1 Demographics*

195 Participants indicated their gender (male, female, other, prefer not to say), age (years), height and  
196 weight, employment status, and ethnic group (Asian/Asian British; Black/ African /Caribbean/ Black  
197 British; Mixed/ Multiple ethnic groups; White; Other; prefer not to say). They also reported their  
198 education level, post-tax household income and household composition (the number of adults, and  
199 children under 14 years old). Income and household composition were used to calculate Equivalised  
200 Household Disposable Income (EHDI; 55). We used EHDI and education level as a proxy for  
201 Socioeconomic status (SES).

202

### 203 *2.2.2 Urban Agriculture Proximity and Engagement (UAPE)*

204 We devised a series of questions to measure participants' proximity to and engagement with urban  
205 agriculture on a continuous scale. Participants were presented with the following definition of UA:  
206 "*Urban agriculture is defined as growing fruits and vegetables in urban or suburban areas*". They

207 then completed a series of four questions to assess their proximity to (3 questions) and engagement  
208 (1 question) with UA. Proximity questions asked about participants' awareness of examples of UA,  
209 such as allotments, growing in gardens, growing on balconies, within their i) neighbourhood (defined  
210 as 1 mile/20-minute walk of their home), ii) within their town or city, or iii) elsewhere. Responses  
211 were scored so that higher scores reflected participants indicating awareness of higher number of  
212 UA examples in their proximity. Engagement questions asked if participants took part in any forms of  
213 UA and how frequently they engaged in this (daily to less often Scores reflected the number of  
214 examples of UA participants engaged in and the frequency they engaged in this, with higher scores  
215 representing greater engagement in UA. Scores for proximity and engagement were combined to  
216 give a total score; higher total scores indicated greater proximity to and engagement with UA.  
217 Further details of the questions and scoring are shown as Supplementary Material. Cronbach  $\alpha$  value  
218 for the measure was .851.

219

### 220 *2.2.3 Perceived accessibility of fruits and vegetables*

221 Three questions, adapted from previous studies (Caldwell et al., 2009; Ma et al., 2013) were used to  
222 assess perceived accessibility of fruit and vegetables. Participants reported the following: i) the  
223 number of supermarkets and shops selling fresh fruits and vegetables, and farmers' markets within 1  
224 mile/20-minute walk of their home. ii) their level of agreement with the following statements: 1. "A  
225 large selection of fresh fruit and vegetables is available in my neighbourhood" (responses 1= strongly  
226 disagree to 5= strongly agree); and iii) how easy or difficult they find it to access fresh fruits and  
227 vegetables (response 1= very difficult to 4 = very easy). Higher scores on these questions represent  
228 better perceived access to fruit and vegetables. Cronbach  $\alpha$  value for the measure was .614.

229

### 230 *2.2.4 Food Choice Questionnaire – Health and Ethics subscales*

231 Endorsement of health-related and ethics-related eating motives was assessed using the Health  
232 Concern (6 items) and Ethics Concern (3 items) subscales of the Food Choice Motivations

233 Questionnaire (FCQ; Steptoe et al., 1995). Health Concern (FCQ-H) items assess motivations for food  
234 that are driven by health concerns (for example, “It is important to me that the food I eat on a  
235 typical day keeps me healthy”). Items on the Ethics Concern (FCQ-E) subscale assess food choice  
236 motivations motivated by political and environmental concerns (e.g. “It is important to me that the  
237 food I eat on a typical day is packaged in an environmentally friendly way”). Responses are scored  
238 from 1 (not at all important) to 4 (very important) and a mean for each subscale is calculated.  
239 Greater mean scores for each subscale indicate more health- and ethics-related food choice  
240 motivations. Cronbach  $\alpha$  value was .881 for the Health Concern subscale, and .782 for the Ethics  
241 Concern subscale.

242

#### 243 *2.2.5 Nature Relatedness Scale (NR-6)*

244 Feelings of connection with nature were assessed using the 6-item Nature Relatedness Scale (Nisbet  
245 & Zelenski, 2013). Participants reported their agreement with statements about the way they view  
246 their relationship with the natural world (e.g. “My relationship with nature is an important part of  
247 who I am”). Responses were scored 1 (disagree strongly) to 5 (agree strongly). Mean of the total  
248 response was calculated as a score for connection with nature, with higher scores representing  
249 greater feelings of connection. Cronbach  $\alpha$  value for the measure was .862

250

#### 251 *2.2.6 Depression Anxiety Stress Scales 21 (DASS-21)*

252 Psychological distress was measured using the 21-item Depression Anxiety Stress Scales (DASS-21;  
253 62). This scale comprises of 3 subscales: Depression, Anxiety and Stress, measured by 7 items each.  
254 Participants responded on a 4-item Likert scale, anchored 0 (did not apply to me at all) to 3 (applied  
255 to me very much of most of the time) to indicate how much they felt each statement applied to  
256 them over the previous week. Statements refer to feelings of depression, anxiety and stress.  
257 Cronbach  $\alpha$  value for the three subscales were: Depression  $\alpha$  = .945; Anxiety  $\alpha$  = .902; Stress  $\alpha$  =  
258 .917.

259

260 *2.2.7 Short Food Frequency Questionnaire (SFFQ)*

261 Diet quality was assessed with a short food frequency questionnaire (SFFQ), which has been used in  
262 previous studies (Green et al., 2016; Keenan et al., 2020; Robinson et al., 2021). Such brief dietary  
263 quality assessments that are based on larger food frequency questionnaires, including a similar  
264 measure which includes most of the foods used in the SFFQ, are predictive of diet quality and have  
265 acceptable reliability and validity (Roberts et al., 2018; Roberts, 2017; Schaffer et al., 1997).

266

267 Participants reported how many portions of 1) fruits and 2) vegetables they ate per day; response  
268 options were none to five or more (scored none = 0 to five or more = 5). Participants reported how  
269 often they consume the following foods: wholemeal bread, white bread, fried chicken, crisps,  
270 processed meat, sugary drinks, oily fish, other fish. Responses options ranged from “more than once  
271 per day” to “never” and were coded more than once a day = 7 to never = 1. Responses for white  
272 bread, fried chicken processed meat, crisps, and sugary drinks were reverse coded (more than once  
273 a day = 1; never = 7) and summed with scores for wholemeal bread, oily fish, other fish, and fruit and  
274 vegetables. A higher total score represents better diet quality. Cronbach  $\alpha$  value for the measure  
275 was .683.

276

277 Participants also reported how many of the portions of fruits and vegetables they consume were  
278 grown locally (response range “all” to “none” plus “I don’t know” option). These data were for  
279 descriptive purposes and do not form part of the diet quality score.

280

281 *2.3 Procedure*

282 The survey was delivered through Qualtrics via a weblink. Participants viewed the Participant  
283 Information Sheet and provided informed consent at the start of the study. Then they were  
284 presented with the definition of UA and completed the UAPE. Next the NR-6, questions about

285 perceived access to fruits and vegetables, FCQ-E, FCQ-H, DASS-21, SFFQ, Demographic and SES  
286 questionnaires were presented in a random order. Survey completion took approximately 20  
287 minutes. Participants from the general public were offered entry to a prize draw at the end of the  
288 study to win a share of £250 shopping vouchers as thanks for their time. The £250 prize fund  
289 comprised of five prizes: a £100 voucher, two £50 vouchers, and two £25 vouchers. Winners were  
290 selected at random upon completion of all data collection. Participants recruited from the Qualtrics  
291 participant panel were paid by Qualtrics for the time spent completing the survey. The study was  
292 approved by the University of Liverpool Health and Life Sciences Research Ethics Committee,  
293 Reference 5383. Data were collected in July-August 2019.

294

#### 295 *2.4 Analysis*

296 Scale scores were calculated in accordance with author recommendations (NR-6, FCQ-E, FCQ-H,  
297 DASS-21, SFFQ) or as detailed above. Descriptive data were processed using SPSS 24 (IBM Corp,  
298 2016). The proposed structural equation model was analysed in MPLUS (Muthén & Muthén, 2017)  
299 with a Satorra-Bentler correction for non-normal data (Savalei, 2014). Model fit criteria were  
300 standardised root mean residual (SRMR) values  $<.08$ ; comparative fit index (CFI) and, Tucker-Lewis  
301 Index (TLI)  $\geq .95$  (Hu & Bentler, 1999); root mean square error of approximation (RMSEA)  $\leq .08$   
302 (Browne & Cudeck, 1992). Unstandardized regression coefficients and 95% Confidence Intervals (CI)  
303 are reported. Perceived access to fruits and vegetables and psychological distress were treated as  
304 latent variables and evaluated using Confirmatory Factor Analysis (CFA); model details and  
305 evaluations are presented in the Supplementary Material. Analysis of effects found in the model was  
306 carried out using bias corrected bootstrapping. Covariances between FCQ-E and FCQ-H, NR-6 and  
307 FCQ-E, NR-6 and FCQ-H, and Depression and Anxiety scales of the DASS-21 were added in the model  
308 based on Modification Indices.

309

310 Data from participants who were missing values for any of the key variables of interest (UAPE, NR-6,  
311 questions about perceived access to fruits and vegetables, FCQ-E, FCQ-H, DASS-21, SFFQ), or who  
312 provided improbable values (e.g. reporting 1000 supermarkets within their neighbourhood) were  
313 removed from the dataset. The study protocol and analysis plan were preregistered on Open Science  
314 Framework: <https://osf.io/4zrhy/>.

315

316 An adjusted, supplementary version of the proposed model controlling for age and EHDI (see  
317 Supplementary Material) was also run. Not all participants provided this data so sample size was  
318 reduced ( $N=520$ ). Model fit criteria and latent variables were as described above. Adding age and  
319 EHDI to the model did not improve model fit or explain the effects reported in the main analysis, so  
320 the unadjusted model based on a larger sample size is presented here, and the results for the  
321 adjusted analysis are available in the Supplementary Material.

322

### 323 **3. Results**

#### 324 *3.1 Participants*

325 Six hundred and twenty-four participants reached the end of the survey. Following removal of  
326 incomplete and improbable responses the sample available for analysis was  $N=583$ . Participants had  
327 a mean age of 42.75 years (*s.d.* 15.71, range 18-86 years).

328

329 Participant characteristics are displayed in in Table 1. Most participants were female ( $n=400$ ; 69%)  
330 and white (87.5%). Regarding employment status, 46.5% were employed full-time, 17.2% were  
331 employed part-time; 14.2% were retired; 7.2% were unable to work or a homemaker; 5.8% were  
332 students; 3.8% were unemployed and not seeking work; 2.1% were unemployed and seeking work;  
333 1.2% selected "prefer not to answer; 1.2% did not provide a response; 0.9% reported voluntary  
334 employment. Most participants (79.9%; 466) scored above 0 on the UAPE, indicating that most  
335 participants had some exposure to UA.

336

337 Table 1. *Participant characteristics.*

	<i>Mean</i>	<i>Standard deviation</i>	<i>Range</i>
Age (y)	42.75	15.708	18 – 86
BMI kg/m <sup>2</sup> *	27.14	6.15	16.38 – 57.09
UAPE-total score	34.43	30.56	0 – 133
Perceived access - Supermarkets	3.68	3.30	0 – 30
Perceived access- shops	3.06	4.08	0 - 30
Perceived access – farmers’ markets	1.07	2.59	0 – 30
Health-related Food Choice	3.11	.67	1 – 4
Motivations			
Ethics-related Food Choice	2.72	.85	1 – 4
Motivations			
Connection with nature	3.70	.87	1 – 5
DASS – Anxiety	8.33	9.91	0 – 42
DASS – Depression	10.90	12.02	0 - 42
DASS - Stress	11.93	10.93	0 – 42
Diet Quality	45.72	7.92	15 - 63

338 *Note.* BMI = Body Mass Index; UAPE = Urban Agriculture Proximity and Engagement Scale – total  
 339 score; DASS = Depression, Anxiety Stress Scales. \**n*=540 for BMI as not all participant provided these  
 340 data.

341

342 *3.2 Structural model*

343 The structural equation model is shown in Figure 2. The model was an acceptable fit of the data

344 (SRMR = .070, CFI = .964, TLI = .942, RMSEA = .058). Although the TLI was slightly below the  $\geq .95$  cut

345 off described by Hu and Bentler (1999), other model fit indices were good. Direct associations  
 346 between the variables are shown in Table 2.

347

348 Table 2. *Direct associations between the variables.*

Association	<i>b</i> ( <i>SE</i> )	<i>p</i>	95% CI
UAPE → Diet quality	-.002 (.013)	.850	-.024 to .019
UAPE → Perceived access to fruits and vegetables	.014 (.005)	.010	.006 to .023
UAPE → Health-related food choice motivations	.003 (.001)	<.001	.002 to .005
UAPE → Ethics-related food choice motivations	.008 (.001)	<.001	.006 to .009
UAPE → Connection with nature	.009 (.001)	<.001	.008 to .011
UAPE → Psychological distress	.045 (.016)	.004	.019 to .071
Perceived access to fruits and vegetables → Diet quality	-.371 (.038)	.010	-.609 to -.133
Health-related food choice motivations → Diet quality	2.469 (.570)	<.001	1.531 to 3.406
Ethics-related food choice motivations → Diet quality	1.259 (.391)	.001	.616 to 1.901
Connection with nature → Diet quality	.404 (.418)	.333	-.283 to 1.092
Psychological distress → Diet quality	-.273 (.038)	<.001	-.336 to -.210

349 *Note.* UAPE = Urban Agriculture Proximity and Engagement Scale – total score; CI =confidence  
 350 intervals; SE = standard error.

351

352 The direct effect of UAPE score on diet quality was not significant. However, consistent with our  
 353 hypothesis, greater UAPE total score was associated with greater perceived access to fruits and  
 354 vegetables, health-related food choice motivations, ethically- related food choice motivations, and  
 355 nature connectedness. However contrary to predictions, greater UAPE score was associated with  
 356 greater psychological distress

357

358 Both health-related food choices motivations and ethics-related food choices were associated with a  
 359 better diet quality. Greater perceived access to fruits and vegetables was unexpectedly related to  
 360 poorer quality diet, as was greater psychological distress. There was no association between  
 361 connection with nature and diet quality.

362

### 363 3.3 Mediation analysis

364 The indirect effects of UAPE on diet quality are shown in Table 3. There were significant indirect  
 365 effects of UAPE score on diet quality through health-related food choice motivations, ethics-related  
 366 food choice motivations and psychological distress. Indirect effects through perceived access to  
 367 fruits and vegetables, and connection with nature were not significant. Therefore, in line with our  
 368 hypothesis, higher UAPE total score predicted more health and ethics-related food choice  
 369 motivations, which in turn predict a better diet quality. However, an unexpected finding is that  
 370 higher UAPE total score also predicts greater psychological distress, which then predicts poorer diet  
 371 quality.

372

373 Table 3. *Hypothesised indirect effects.*

Association	<i>b</i> ( <i>SE</i> )	<i>p</i>	95% CI
UAPE → Perceived access to fruits and vegetables → Diet quality	-.005 (.003)	.105	-.011 to .000
UAPE → Health-related food choice motivations → Diet quality	.008 (.003)	.005	.004 to .013
UAPE → Ethics-related food choice motivations → Diet quality	.010 (.003)	.004	.004 to .015
UAPE → Connection with nature → Diet quality	.004 (.004)	.332	-.003 to .010
UAPE → Psychological distress → Diet quality	-.012 (.005)	.014	-.021 to -.004

374 *Note.* UAPE = Urban Agriculture Proximity and Engagement Scale – total score; CI =confidence  
375 intervals; SE = standard error.

376

### 377 *3.4 Structural model adjusted for age and SES*

378 We repeated the analysis of the structural equation model adjusting for the effects of age and EHDl  
379 on UAPE score and diet quality. Sample size for this analysis was reduced due to missing data ( $N =$   
380 520 from 583). Model fit for this model was poorer than for the structural model described above.  
381 This indicates that adjusting for the effects of age and EDHI did not explain any additional variance in  
382 the model or the results described above. AIC and BIC were 28328.626 and 28507.722, respectively,  
383 for the unadjusted model, compared to 41890.819 and 42111.918 for the adjusted model.  
384 Additional details of the adjusted model are shown in Supplementary Material.

385

### 386 *3.5 Exploratory Analysis - Separate effects of Proximity and Engagement Scores*

387 Two additional exploratory analyses were conducted to test if the effects seen in the hypothesised  
388 structural model were specific to UAPE-Proximity or UAPE-Engagement Scores by substituting these  
389 UAPE total score and re-running the analysis described above. The results of this analysis are  
390 presented as Supplementary Material (Tables S3-S6). The overall pattern of results from these  
391 analyses was similar to the results presented in the main analysis described above. Thus, the effect  
392 of UAPE total score on diet quality via health and ethics-related food choice motivations and  
393 psychological distress is being driven by both proximity and engagement with UA, rather than either  
394 one in isolation.

395

## 396 **4. Discussion**

397 This study explored the association between proximity to and engagement with UA and diet quality,  
398 and whether this relationship is explained by one or more of several mediating factors. Results  
399 indicated that greater proximity to and engagement with UA is associated with greater perceived

400 access to fruits and vegetables, health and ethical-related food choice motivations, nature  
401 connectedness, and, unexpectedly, greater psychological distress. Mediation analysis revealed that  
402 the relationship between UA and higher diet quality was indirectly explained by health and ethical-  
403 related food choices motivations. There was also a counter-intuitive indirect effect whereby UA was  
404 associated with poorer diet quality via higher psychological distress. Adding potential confounders to  
405 the model, namely age and EHDI, and exploring separate effects of proximity or engagement with  
406 UA, did not alter these findings.

407

408 Our findings indicate that participants who reported greater proximity to and engagement with UA  
409 were more motivated by health and ethical concerns when making food choices, which in turn was  
410 associated with having a better-quality diet. Thus, the relationship between UA and diet can be  
411 partially explained by people being more motivated by health and ethical issues when making food  
412 choices. This is partly consistent with previous literature, as health and sustainability motivations  
413 have been highlighted as reasons for taking part in UA (Al-Mayahi et al., 2019; Martinho da Silva et  
414 al., 2016; Ruggeri et al., 2016), and these motivations for food choices are associated with healthy  
415 eating attitudes (Sun, 2008). UA may also act as a potential health promotion intervention (Brown &  
416 Jameton, 2000; Genter et al., 2015; Howarth et al., 2020), and our findings suggest that specifically  
417 incorporating and targeting health and ethical-related food choice motivations within such  
418 interventions may facilitate UA's beneficial impact on diet quality

419

420 Contrary to our hypothesis, greater perceived access to fruits and vegetables was associated with a  
421 poorer quality diet. This is surprising as others have shown that such access is associated with  
422 increased fruit and vegetable consumption (Caldwell et al., 2009). One explanation could be that  
423 access to fruits and vegetables alone is not sufficient to improve diet quality. We quantified access  
424 to fruits and vegetables via numbers of local shops, supermarkets and farmers markets that sell such  
425 produce, however these retailers also likely sell other, less healthy foods that could contribute to

426 lower diet quality scores. However, it should be noted that the mediation pathway between UA-  
427 perceived access to fruits/vegetables and diet quality was not significant, meaning that this finding  
428 and potential explanation should be interpreted with caution.

429

430 The observed association between UA and *greater* psychological distress was unexpected and goes  
431 against a growing amount of evidence for beneficial effects of home growing and gardening on  
432 psychological wellbeing (Genter et al., 2015; Howarth et al., 2020). One tentative explanation is that,  
433 because these data are cross-sectional, we are unable to determine temporal relations between the  
434 variables, specifically whether participants in our sample who were already experiencing  
435 psychological distress may have turned to UA as a way of coping with distress. In our exploratory  
436 analysis we saw that scores for engagement with UA, not proximity to UA, were associated with  
437 greater psychological distress (Tables S4, S6), which may support this. This would fit with recent  
438 suggestions that gardening could be beneficial treatment for poor well-being (Howarth et al., 2020).  
439 It is also worth noting that the mean scores shown in Table 1 for Anxiety and Depression subscales  
440 of the DASS-21, our measure of psychological well-being, are within the ranges for “mild severity” of  
441 symptoms (Lovibond, S. H., & Lovibond, 1995). Estimated mean ( $\pm s.d.$ ) population norm scores for  
442 Depression, Anxiety and Stress DASS subscales are 5.55 (7.48), 3.56 (5.39) and 9.72 (8.04),  
443 respectively (Crawford & Henry, 2003). The scores reported by our participants are higher than these  
444 norms. It may be that participants in our sample do not reflect typical levels of psychological  
445 distress, so this finding warrants further consideration. Notwithstanding this, the association  
446 between greater psychological distress and poorer diet quality which we detected in our model  
447 conforms with previous findings that stress and depression are associated with poorer diet quality  
448 (Appelhans et al., 2012; Sominsky & Spencer, 2014).

449

450 *4.1 Limitations and Future Directions*

451 The cross-sectional nature of these data limits our ability to make any causal inferences regarding  
452 the relationships between UA, diet and mediating factors. We acknowledge that without  
453 longitudinal, intervention-based assessments this evidence base is still lacking and our study is  
454 limited in its ability to address methodological shortcomings in this area of research that have been  
455 highlighted by others (Spano et al., 2020) . Furthermore, we used a brief, self-reported proxy  
456 measure of dietary quality and the Cronbach  $\alpha$  reliability score for this scale was not optimal. Explicit  
457 assessments of food intake and food choice are needed to confirm such causal relationships.

458

459 We also developed our own measure of proximity to and engagement with UA as there was no pre-  
460 existing measure in the literature that would be suitable for our analytic approach. Further work is  
461 now needed to validate this tool to ensure it is an accurate reflection of participants' proximity to  
462 and engagement with UA.

463

464 Finally, our sample is comprised of mostly white, female participants who are in some form of  
465 employment. This limits the generalisability of our findings and future work should seek to include a  
466 more diverse sample of participants.

467

#### 468 *4.2 Conclusion*

469 Proximity to and engagement with urban agriculture (UA) is indirectly related to better diet quality  
470 via health and ethical-related food choice motivations. UA was also associated with greater  
471 perceived access to fruits and vegetables and nature connectedness, however these factors did not  
472 mediate an association with diet. UA was unexpectedly associated with higher psychological distress;  
473 however, this association is more plausibly explained by people engaging in urban growing as a way  
474 of coping with stress. However, these findings also highlight the complexity of the relationship  
475 between UA and diet and warrant further investigation using robust assessments of diet quality and  
476 via a longitudinal, intervention setting to confirm causal relationships. These findings will be relevant

477 to policy makers, health practitioners, and those involved in the design of UA-based interventions  
478 for diet.

479

480

## 481 **5. Declarations**

482

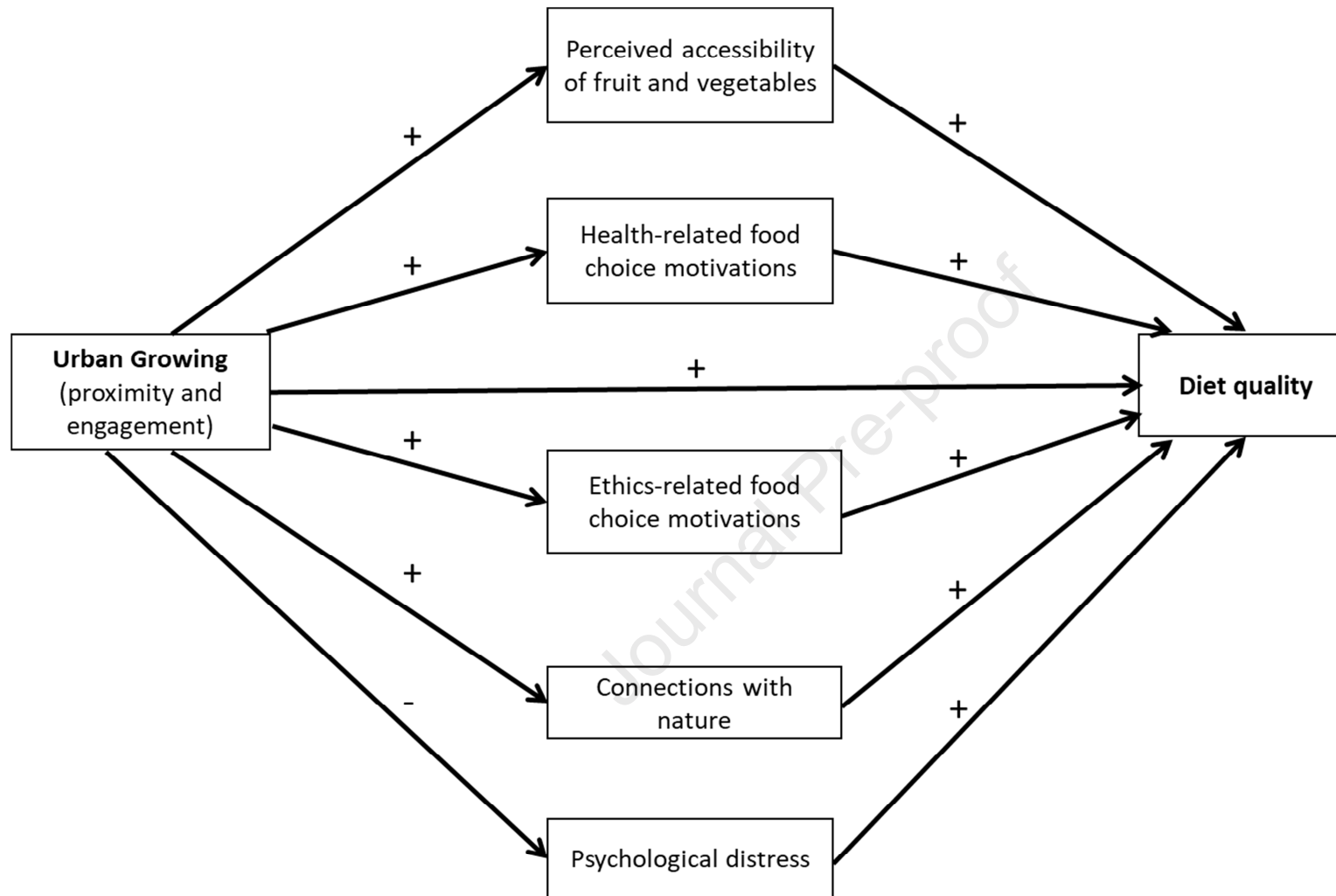
483 *5.1 Competing interests:* BRM has received funding to their institution from WW (formerly Weight  
484 Watchers International) for her PhD studentship. PC and CAH have received research funding from  
485 the American Beverage Association. CAH has received speaker fees from the International  
486 Sweeteners Association for work outside of the submitted manuscript. NF, JACD, SK, LW and LL  
487 declare that they have no conflict of interest.

488

489 *5.2 Funding:* This research was funded by the Global Food Security's 'Resilience of the UK Food  
490 System Programme', with support from BBSRC, ESRC, NERC and the Scottish  
491 Government (BB/S01425X/1).

492

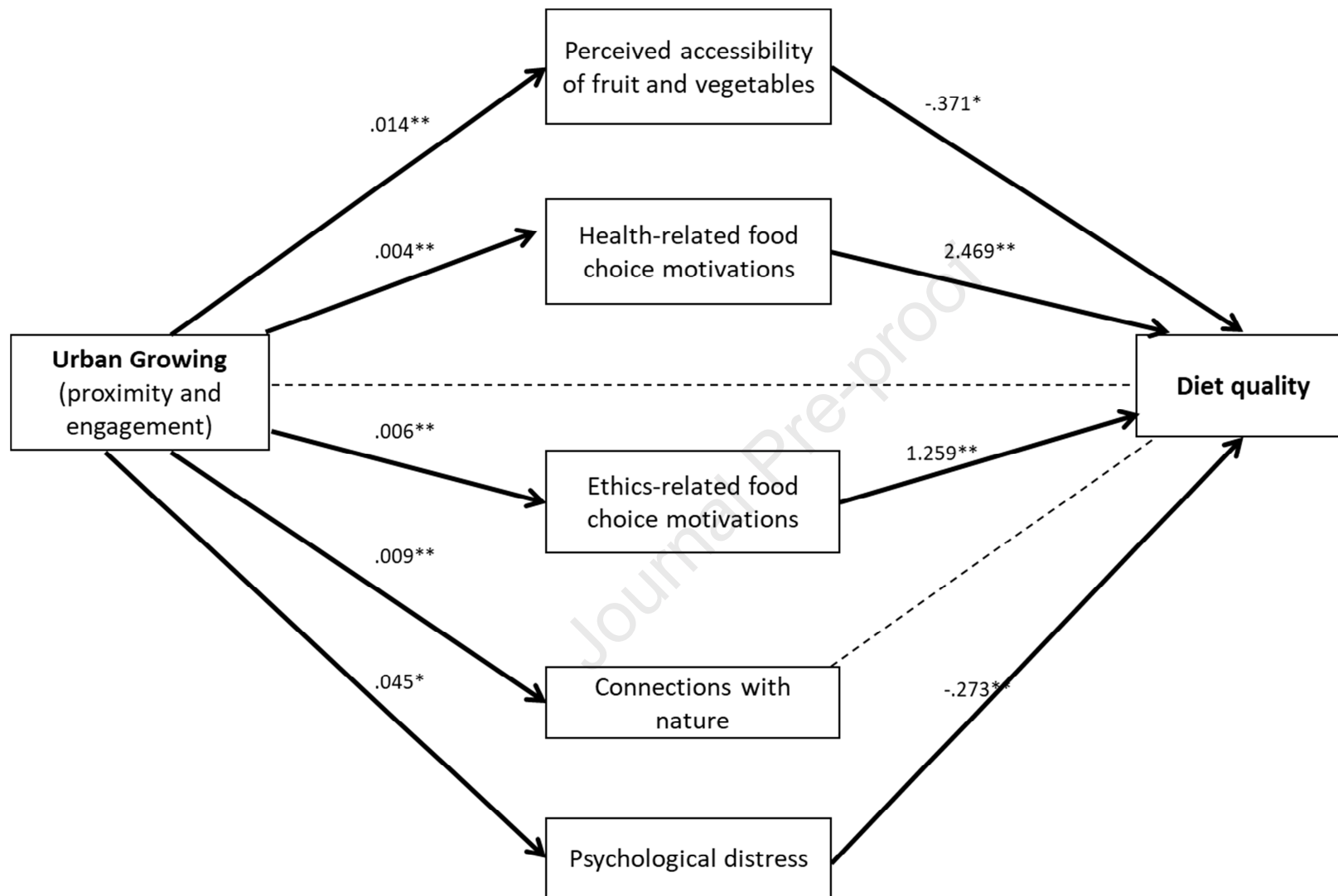
493 *5.3 Author Contributions:* BRM, JACD, NF, CAH, SK, LL, and LW contributed to designing this  
494 research. BRM undertook data collection. BRM and PC analysed the data. BRM drafted the  
495 manuscript. All authors contributed to the final written manuscript. All authors were responsible for  
496 the final approval of the manuscript.



497

498

499 *Figure 1.* Hypothesised structural model of the associations between UA, potential mediators, and diet quality. Associations predicted to be positive are  
500 indicated by a + symbol; associations predicted to be negative are indicated by a - symbol.



501

502 *Figure 2.* Associations between UA, potential mediators, and diet quality. Solid arrows indicate significant associations. Unstandardised regression  
 503 coefficients are shown.  $*p < .05$ ,  $**p < .001$ .

## 504 6. References

- 505 Al-Mayahi, A., Al-Ismaily, S., Gibreel, T., Kacimov, A., & Al-Maktoumi, A. (2019). Home gardening in  
506 Muscat, Oman: Gardener's practices, perceptions and motivations. *Urban Forestry & Urban*  
507 *Greening, 38*, 286–294. <https://doi.org/10.1016/j.ufug.2019.01.011>
- 508 Alaimo, K., Packnett, E., Miles, R. A., & Kruger, D. J. (2008). Fruit and Vegetable Intake among Urban  
509 Community Gardeners. *Journal of Nutrition Education and Behavior, 40*(2), 94–101.  
510 <https://doi.org/10.1016/j.jneb.2006.12.003>
- 511 Allès, B., Péneau, S., Kesse-Guyot, E., Baudry, J., Hercberg, S., & Méjean, C. (2017). Food choice  
512 motives including sustainability during purchasing are associated with a healthy dietary pattern  
513 in French adults. *Nutrition Journal, 16*(1), 58. <https://doi.org/10.1186/s12937-017-0279-9>
- 514 Appelhans, B. M., Whited, M. C., Schneider, K. L., Ma, Y., Oleski, J. L., Merriam, P. A., Waring, M. E.,  
515 Olendzki, B. C., Mann, D. M., Ockene, I. S., & Pagoto, S. L. (2012). Depression Severity, Diet  
516 Quality, and Physical Activity in Women with Obesity and Depression. *Journal of the Academy*  
517 *of Nutrition and Dietetics, 112*(5), 693–698. <https://doi.org/10.1016/j.jand.2012.02.006>
- 518 Asvatourian, V., Craig, T., Horgan, G. W., Kyle, J., & Macdiarmid, J. I. (2018). Relationship between  
519 pro-environmental attitudes and behaviour and dietary intake patterns. *Sustainable Production*  
520 *and Consumption, 16*, 216–226. <https://doi.org/10.1016/j.spc.2018.08.009>
- 521 Audate, P. P., Fernandez, M. A., Cloutier, G., & Lebel, A. (2019). Scoping review of the impacts of  
522 urban agriculture on the determinants of health. *BMC Public Health, 19*(1), 672.  
523 <https://doi.org/10.1186/s12889-019-6885-z>
- 524 Boeing, H., Bechthold, A., Bub, A., Ellinger, S., Haller, D., Kroke, A., Leschik-Bonnet, E., Müller, M. J.,  
525 Oberritter, H., Schulze, M., Stehle, P., & Watzl, B. (2012). Critical review: Vegetables and fruit in  
526 the prevention of chronic diseases. In *European Journal of Nutrition* (Vol. 51, Issue 6, pp. 637–  
527 663). Springer. <https://doi.org/10.1007/s00394-012-0380-y>
- 528 Bowler, D. E., Buyung-Ali, L. M., Knight, T. M., & Pullin, A. S. (2010). A systematic review of evidence  
529 for the added benefits to health of exposure to natural environments. *BMC Public Health, 10*.

- 530 <https://doi.org/10.1186/1471-2458-10-456>
- 531 Brown, K. H., & Jameton, A. L. (2000). Public health implications of urban agriculture. *Journal of*  
532 *Public Health Policy*, 21(1), 20–39. <https://doi.org/10.2307/3343472>
- 533 Browne, M. W., & Cudeck, R. (1992). Alternative Ways of Assessing Model Fit. *Sociological Methods*  
534 *& Research*, 21(2), 230–258. <https://doi.org/10.1177/0049124192021002005>
- 535 Caldwell, E. M., Miller Kobayashi, M., DuBow, W. M., Wytinck, S. M., Kobayashi, M. M., DuBow, W.  
536 M., & Wytinck, S. M. (2009). Perceived access to fruits and vegetables associated with  
537 increased consumption. *Public Health Nutrition*, 12(10), 1743–1750.  
538 <https://doi.org/10.1017/S1368980008004308>
- 539 Connors, M., Bisogni, C. A., Sobal, J., & Devine, C. M. (2001). Managing values in personal food  
540 systems. *Appetite*, 36(3), 189–200. <https://doi.org/10.1006/appe.2001.0400>
- 541 Crawford, J. R., & Henry, J. D. (2003). The Depression Anxiety Stress Scales (DASS): Normative data  
542 and latent structure in a large non-clinical sample. *British Journal of Clinical Psychology*, 42(2),  
543 111–131. <https://doi.org/10.1348/014466503321903544>
- 544 De Zeeuw, H. (2004). The development of Urban Agriculture; Some lessons learnt. In *International*  
545 *Conference “Urban Agriculture, Agro-tourism and City Region Development.”*
- 546 Draper, C., & Freedman, D. (2010). Review and analysis of the benefits, purposes, and motivations  
547 associated with community gardening in the United States. *Journal of Community Practice*,  
548 18(4), 458–492. <https://doi.org/10.1080/10705422.2010.519682>
- 549 Edmondson, J. L., Childs, D. Z., Dobson, M. C., Gaston, K. J., Warren, P. H., & Leake, J. R. (2020).  
550 Feeding a city – Leicester as a case study of the importance of allotments for horticultural  
551 production in the UK. *Science of The Total Environment*, 705, 135930.  
552 <https://doi.org/10.1016/j.scitotenv.2019.135930>
- 553 FAO. (2019). *The State of Food Security and Nutrition in the World 2019*. Accessed 07/07/2020.
- 554 Garcia, M. T., Ribeiro, S. M., Germani, A. C. C. G., & Bógus, C. M. (2018). The impact of urban gardens  
555 on adequate and healthy food: a systematic review. *Public Health Nutrition*, 21(2), 416–425.

- 556 <https://doi.org/10.1017/S1368980017002944>
- 557 Garnett, P., Doherty, B., & Heron, T. (2020). Vulnerability of the United Kingdom's food supply chains  
558 exposed by COVID-19. *Nature Food*, 1(6), 315–318. [https://doi.org/10.1038/s43016-020-0097-](https://doi.org/10.1038/s43016-020-0097-7)  
559 7
- 560 Genter, C., Roberts, A., Richardson, J., & Sheaff, M. (2015). The contribution of allotment gardening  
561 to health and wellbeing: A systematic review of the literature. In *British Journal of Occupational*  
562 *Therapy* (Vol. 78, Issue 10, pp. 593–605). British Journal of Occupational Therapy.  
563 <https://doi.org/10.1177/0308022615599408>
- 564 Green, M. A., Li, J., Relton, C., Strong, M., Kearns, B., Wu, M., Bissell, P., Blackburn, J., Cooper, C.,  
565 Goyder, E., Loban, A., & Smith, C. (2016). Cohort Profile: The Yorkshire Health Study.  
566 *International Journal of Epidemiology*, 45(3), 707–712. <https://doi.org/10.1093/ije/dyu121>
- 567 Greiman, V. (2014). Megaproject Research Paradigms: The Value of Empirical Evidence. In M. Brown,  
568 A and Rich (Ed.), *Proceedings of the 13th European Conference on Research Methodology for*  
569 *Business and Management Studies (ECRM 2014)* (pp. 169–176). ACAD Conferences LTD.
- 570 Hawkins, J. L., Mercer, J., Thirlaway, K. J., & Clayton, D. A. (2013). “Doing” gardening and “being” at  
571 the allotment site: Exploring the benefits of allotment gardening for stress reduction and  
572 healthy aging. *Ecopsychology*, 5(2), 110–125. <https://doi.org/10.1089/eco.2012.0084>
- 573 Hazer, M., Formica, M. K., Dieterlen, S., & Morley, C. P. (2018). The relationship between self-  
574 reported exposure to greenspace and human stress in Baltimore, MD. *Landscape and Urban*  
575 *Planning*, 169, 47–56. <https://doi.org/10.1016/J.LANDURBPLAN.2017.08.006>
- 576 Henry, J. D., & Crawford, J. R. (2005). The short-form version of the Depression anxiety stress scales  
577 (DASS-21): Construct validity and normative data in a large non-clinical sample. *British Journal*  
578 *of Clinical Psychology*, 44(2), 227–239. <https://doi.org/10.1348/014466505X29657>
- 579 Howarth, M., Griffiths, A., da Silva, A., & Green, R. (2020). Social prescribing: a ‘natural’ community-  
580 based solution. *British Journal of Community Nursing*, 25(6), 294–298.  
581 <https://doi.org/10.12968/bjcn.2020.25.6.294>

- 582 Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis:  
583 Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary*  
584 *Journal*, 6(1), 1–55. <https://doi.org/10.1080/10705519909540118>
- 585 Hunter, M. R., Gillespie, B. W., & Chen, S. Y.-P. (2019). Urban Nature Experiences Reduce Stress in  
586 the Context of Daily Life Based on Salivary Biomarkers. *Frontiers in Psychology*, 10(APR), 722.  
587 <https://doi.org/10.3389/fpsyg.2019.00722>
- 588 IBM Corp. Released 2016. IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp.
- 589 Kamphuis, C. B. M., Giskes, K., de Bruijn, G.-J., Wendel-Vos, W., Brug, J., & van Lenthe, F. J. (2006).  
590 Environmental determinants of fruit and vegetable consumption among adults: a systematic  
591 review. *British Journal of Nutrition*. 96(4), 620–635. <https://doi.org/10.1079/BJN20061896>
- 592 Kao, C.-C., Wu, W.-H., & Chiou, W.-B. (2019). Exposure to nature may induce lower discounting and  
593 lead to healthier dietary choices. *Journal of Environmental Psychology*, 65, 101333.  
594 <https://doi.org/10.1016/J.JENVP.2019.101333>
- 595 Keenan, G. S., Christiansen, P., & Hardman, C. A. (2020). Household Food Insecurity, Diet Quality,  
596 and Obesity: An Explanatory Model. *Obesity*, oby.23033. <https://doi.org/10.1002/oby.23033>
- 597 Kingsley, J. Y., Townsend, M., & Henderson-Wilson, C. (2009). Cultivating health and wellbeing:  
598 Members' perceptions of the health benefits of a Port Melbourne community garden. *Leisure*  
599 *Studies*, 28(2), 207–219. <https://doi.org/10.1080/02614360902769894>
- 600 Lanier, J., Schumacher, J., & Calvert, K. (2015). Cultivating Community Collaboration and Community  
601 Health Through Community Gardens. *Journal of Community Practice*, 23(3–4), 492–507.  
602 <https://doi.org/10.1080/10705422.2015.1096316>
- 603 Litt, J. S., Soobader, M. J., Turbin, M. S., Hale, J. W., Buchenau, M., & Marshall, J. A. (2011). The  
604 influence of social involvement, neighborhood aesthetics, and community garden participation  
605 on fruit and vegetable consumption. *American Journal of Public Health*, 101(8), 1466–1473.  
606 <https://doi.org/10.2105/AJPH.2010.300111>
- 607 Loopstra, R., Reeves, A., & Tarasuk, V. (2019). The rise of hunger among low-income households: an

- 608 analysis of the risks of food insecurity between 2004 and 2016 in a population-based study of  
609 UK adults. *Journal of Epidemiology and Community Health*, 73(7), 668–673.  
610 <https://doi.org/10.1136/jech-2018-211194>
- 611 Lovibond, S. H., & Lovibond, P. F. (1995). *Manual for the Depression Anxiety Stress Scales* (2nd ed.).  
612 Psychology Foundation of Australia.
- 613 Ma, X., Barnes, T. L., Freedman, D. A., Bell, B. A., Colabianchi, N., & Liese, A. D. (2013). Test-retest  
614 reliability of a questionnaire measuring perceptions of neighborhood food environment. *Health  
615 & Place*, 21, 65–69. <https://doi.org/10.1016/j.healthplace.2013.01.008>
- 616 MacCallum, R. C., Browne, M. W., & Sugawara, H. M. (1996). Power analysis and determination of  
617 sample size for covariance structure modeling. *Psychological Methods*, 1(2), 130–149.  
618 <https://doi.org/10.1037/1082-989X.1.2.130>
- 619 Maller, C., Townsend, M., Pryor, A., Brown, P., & St Leger, L. (2006). Healthy nature healthy people:  
620 ‘contact with nature’ as an upstream health promotion intervention for populations. *Health  
621 Promotion International*, 21(1), 45–54. <https://doi.org/10.1093/heapro/dai032>
- 622 Martinho da Silva, I., Oliveira Fernandes, C., Castiglione, B., & Costa, L. (2016). Characteristics and  
623 motivations of potential users of urban allotment gardens: The case of Vila Nova de Gaia  
624 municipal network of urban allotment gardens. *Urban Forestry and Urban Greening*, 20, 56–64.  
625 <https://doi.org/10.1016/j.ufug.2016.07.014>
- 626 Mok, H.-F. F., Williamson, V. G., Grove, J. R., Burry, K., Barker, S. F., & Hamilton, A. J. (2014).  
627 Strawberry fields forever? Urban agriculture in developed countries: A review. *Agronomy for  
628 Sustainable Development*, 34(1), 21–43. <https://doi.org/10.1007/s13593-013-0156-7>
- 629 Muthén, & Muthén. (2017). *MPLUS (Version 8)*.
- 630 Ng, M., Fleming, T., Robinson, M., Thomson, B., Graetz, N., Margono, C., Mullany, E. C., Biryukov, S.,  
631 Abbafati, C., Abera, S. F., Abraham, J. P., Abu-Rmeileh, N. M. E., Achoki, T., AlBuhairan, F. S.,  
632 Alemu, Z. A., Alfonso, R., Ali, M. K., Ali, R., Guzman, N. A., ... Gakidou, E. (2014). Global, regional,  
633 and national prevalence of overweight and obesity in children and adults during 1980–2013: a

- 634 systematic analysis for the Global Burden of Disease Study 2013. *The Lancet*, 384(9945), 766–  
635 781. [https://doi.org/10.1016/S0140-6736\(14\)60460-8](https://doi.org/10.1016/S0140-6736(14)60460-8)
- 636 Nisbet, E. K., & Zelenski, J. M. (2013). The NR-6: a new brief measure of nature relatedness. *Frontiers*  
637 *in Psychology*, 4, 813. <https://doi.org/10.3389/fpsyg.2013.00813>
- 638 Office for National Statistics. (2015). Chapter 3: Equivalised income. In *Compendium: Family*  
639 *Spending in the UK* (pp. 1–23).
- 640 Palar, K., Lemus Hufstedler, E., Hernandez, K., Chang, A., Ferguson, L., Lozano, R., & Weiser, S. D.  
641 (2019). Nutrition and Health Improvements After Participation in an Urban Home Garden  
642 Program. *Journal of Nutrition Education and Behavior*, 51(9), 1037–1046.  
643 <https://doi.org/10.1016/j.jneb.2019.06.028>
- 644 Pamela Pensini, Eva Horn, & Nerina J. Caltabiano. (2016). An Exploration of the Relationships  
645 between Adults' Childhood and Current Nature Exposure and Their Mental Well-Being.  
646 *Children, Youth and Environments*, 26(1), 125. <https://doi.org/10.7721/chilyoutenvi.26.1.0125>
- 647 Poulsen, M. N., McNab, P. R., Clayton, M. L., & Neff, R. A. (2015). A systematic review of urban  
648 agriculture and food security impacts in low-income countries. *Food Policy*, 55, 131–146.  
649 <https://doi.org/10.1016/j.foodpol.2015.07.002>
- 650 Prescott, J., Young, O., O'Neill, L., Yau, N. J. ., & Stevens, R. (2002). Motives for food choice: a  
651 comparison of consumers from Japan, Taiwan, Malaysia and New Zealand. *Food Quality and*  
652 *Preference*, 13(7–8), 489–495. [https://doi.org/10.1016/S0950-3293\(02\)00010-1](https://doi.org/10.1016/S0950-3293(02)00010-1)
- 653 Roberts, K., Cade, J., Dawson, J., & Holdsworth, M. (2018). Empirically Derived Dietary Patterns in UK  
654 Adults Are Associated with Sociodemographic Characteristics, Lifestyle, and Diet Quality.  
655 *Nutrients*, 10(2), 177. <https://doi.org/10.3390/nu10020177>
- 656 Roberts, K. E. (2017). *An investigation of dietary patterns in UK adults as a method for developing a*  
657 *brief diet quality*. University of Sheffield.
- 658 Robinson, E., Boyland, E., Chisholm, A., Harrold, J., Maloney, N. G., Marty, L., Mead, B. R., Noonan,  
659 R., & Hardman, C. A. (2021). Obesity, eating behavior and physical activity during COVID-19

- 660 lockdown: A study of UK adults. *Appetite*, 156, 104853.  
661 <https://doi.org/10.1016/j.appet.2020.104853>
- 662 Roe, J. J., Thompson, C. W., Aspinall, P. A., Brewer, M. J., Duff, E. I., Miller, D., Mitchell, R., Clow, A.,  
663 Roe, J. J., Thompson, C. W., Aspinall, P. A., Brewer, M. J., Duff, E. I., Miller, D., Mitchell, R., &  
664 Clow, A. (2013). Green Space and Stress: Evidence from Cortisol Measures in Deprived Urban  
665 Communities. *International Journal of Environmental Research and Public Health*, 10(9), 4086–  
666 4103. <https://doi.org/10.3390/ijerph10094086>
- 667 Ruggeri, G., Mazzocchi, C., & Corsi, S. (2016). Urban Gardeners' Motivations in a Metropolitan City:  
668 The Case of Milan. *Sustainability*, 8(11), 1099. <https://doi.org/10.3390/su8111099>
- 669 Savalei, V. (2014). Understanding Robust Corrections in Structural Equation Modeling. *Structural*  
670 *Equation Modeling*, 21(1), 149–160. <https://doi.org/10.1080/10705511.2013.824793>
- 671 Schaffer, D. M., Coates, A. O., Caan, B. J., Slattery, M. L., & Potter, J. D. (1997). Performance of a  
672 shortened telephone-administered version of a quantitative food frequency questionnaire.  
673 *Annals of Epidemiology*, 7(7), 463–471. [https://doi.org/10.1016/S1047-2797\(97\)00079-3](https://doi.org/10.1016/S1047-2797(97)00079-3)
- 674 Sobal, J., Bisogni, C. A., & Jastran, M. (2014). Food Choice Is Multifaceted, Contextual, Dynamic,  
675 Multilevel, Integrated, and Diverse. *Mind, Brain, and Education*, 8(1), 6–12.  
676 <https://doi.org/10.1111/mbe.12044>
- 677 Soga, M., Cox, D. T. C., Yamaura, Y., Gaston, K. J., Kurisu, K., & Hanaki, K. (2017). Health benefits of  
678 urban allotment gardening: Improved physical and psychological well-being and social  
679 integration. *International Journal of Environmental Research and Public Health*, 14(1), 71.  
680 <https://doi.org/10.3390/ijerph14010071>
- 681 Soga, M., Gaston, K. J., & Yamaura, Y. (2017). Gardening is beneficial for health: A meta-analysis.  
682 *Preventive Medicine Reports*, 5, 92–99. <https://doi.org/10.1016/j.pmedr.2016.11.007>
- 683 Sominsky, L., & Spencer, S. J. (2014). Eating behavior and stress: a pathway to obesity. *Frontiers in*  
684 *Psychology*, 5, 434. <https://doi.org/10.3389/fpsyg.2014.00434>
- 685 South, E. C., Hohl, B. C., Kondo, M. C., MacDonald, J. M., & Branas, C. C. (2018). Effect of Greening

- 686 Vacant Land on Mental Health of Community-Dwelling Adults. *JAMA Network Open*, 1(3),  
687 e180298. <https://doi.org/10.1001/jamanetworkopen.2018.0298>
- 688 Spano, G., D'Este, M., Giannico, V., Carrus, G., Elia, M., Laforteza, R., Panno, A., & Sanesi, G. (2020).  
689 Are Community Gardening and Horticultural Interventions Beneficial for Psychosocial Well-  
690 Being? A Meta-Analysis. *International Journal of Environmental Research and Public Health*,  
691 17(10), 3584. <https://doi.org/10.3390/ijerph17103584>
- 692 Steptoe, A., Pollard, T. M., & Wardle, J. (1995). Development of a Measure of the Motives Underlying  
693 the Selection of Food: the Food Choice Questionnaire. In *Appetite* (Vol. 25).
- 694 Sun, Y. H. C. (2008). Health concern, food choice motives, and attitudes toward healthy eating: The  
695 mediating role of food choice motives. *Appetite*, 51(1), 42–49.  
696 <https://doi.org/10.1016/j.appet.2007.11.004>
- 697 Taylor, A., & Loopstra, R. (2016). *Too Poor to Eat Food insecurity in the UK*.
- 698 Uhlmann, K., Lin, B. B., & Ross, H. (2018). Who Cares? The Importance of Emotional Connections  
699 with Nature to Ensure Food Security and Wellbeing in Cities. *Sustainability*, 10(6), 1844.  
700 <https://doi.org/10.3390/su10061844>
- 701 United Nations. (2020). *The Sustainable Development Goals Report 2020*. UN.  
702 <https://doi.org/10.18356/214e6642-en>
- 703 van Breda, S. G. J., & de Kok, T. M. C. M. (2018). Smart Combinations of Bioactive Compounds in  
704 Fruits and Vegetables May Guide New Strategies for Personalized Prevention of Chronic  
705 Diseases. *Molecular Nutrition & Food Research*, 62(1), 1700597.  
706 <https://doi.org/10.1002/mnfr.201700597>
- 707 Van Den Berg, A. E., & Custers, M. H. G. (2011). Gardening promotes neuroendocrine and affective  
708 restoration from stress. *Journal of Health Psychology*, 16(1), 3–11.  
709 <https://doi.org/10.1177/1359105310365577>
- 710 Van Den Berg, A. E., Van Winsum-Westra, M., De Vries, S., & Van Dillen, S. M. (2010). Allotment  
711 gardening and health: A comparative survey among allotment gardeners and their neighbors

- 712 without an allotment. *Environmental Health: A Global Access Science Source*, 9(1).  
713 <https://doi.org/10.1186/1476-069X-9-74>
- 714 Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., Garnett, T., Tilman, D.,  
715 DeClerck, F., Wood, A., Jonell, M., Clark, M., Gordon, L. J., Fanzo, J., Hawkes, C., Zurayk, R.,  
716 Rivera, J. A., De Vries, W., Majele Sibanda, L., ... Murray, C. J. L. (2019). Food in the  
717 Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. In  
718 *The Lancet* (Vol. 393, Issue 10170, pp. 447–492). Lancet Publishing Group.  
719 [https://doi.org/10.1016/S0140-6736\(18\)31788-4](https://doi.org/10.1016/S0140-6736(18)31788-4)
- 720 Wood, C. J., Pretty, J., & Griffin, M. (2016). A case–control study of the health and well-being  
721 benefits of allotment gardening. *Journal of Public Health*, 38(3), e336–e344.  
722 <https://doi.org/10.1093/pubmed/fdv146>
- 723 Zelenski, J. M., Dopko, R. L., & Capaldi, C. A. (2015). Cooperation is in our nature: Nature exposure  
724 may promote cooperative and environmentally sustainable behavior. *Journal of Environmental*  
725 *Psychology*, 42, 24–31. <https://doi.org/10.1016/J.JENVP.2015.01.005>
- 726 Zezza, A., & Tasciotti, L. (2010). Urban agriculture, poverty, and food security: Empirical evidence  
727 from a sample of developing countries. *Food Policy* 35(4), 265–273.  
728 <https://doi.org/10.1016/j.foodpol.2010.04.007>
- 729 Zick, C. D., Smith, K. R., Kowaleski-Jones, L., Uno, C., & Merrill, B. J. (2013). Harvesting more than  
730 vegetables: the potential weight control benefits of community gardening. *American Journal of*  
731 *Public Health*, 103(6), 1110–1115. <https://doi.org/10.2105/AJPH.2012.301009>  
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**Ethical statement**

**Authorship of the paper:** All authors made a significant contribution to the conception, design, execution, and/or interpretation of the reported study.

**Originality and plagiarism:** The article represents entirely original work. The work of others has been appropriately cited or quoted.

**Data access and retention:** Data are provided with the paper for editorial review, and this has been prepared to provide public access to the data.

**Multiple, redundant or concurrent publication:** This manuscript is not currently under consideration with another journal

**Acknowledgement of sources:** Proper acknowledgment of the work of others is given.

**Disclosure and conflicts of interest:** Disclosures of all relationships that could be viewed as presenting a potential conflict of interest are provided.

**Fundamental errors in published works:** We understand that, in the event an author discovers a significant error or inaccuracy in his/her own published work, it is the author's obligation to promptly notify the journal editor or publisher and cooperate with the editor to retract or correct the paper.

**Reporting standards:** Our paper presents an accurate account of the work performed as well as an objective discussion of its significance.

**Hazards and human or animal subjects:** This work involves data collected from human subjects. The work was approved by the University of Liverpool Health and Life Sciences Research Ethics Committee, Reference 5383

**Use of patient images or case details:** The study was approved by the University of Liverpool Health and Life Sciences Research Ethics Committee, Reference 5383. All participants provided informed consent to participate via online consent form prior to data collection.