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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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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

1. Background

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

Urban agriculture (UA), the growing of fruits and vegetables in urban and peri-urban (suburban) areas may represent a solution to ensure a sustainable, efficacious and holistic food system, improving health, well-being, and food security (Audate et al., 2019; Brown & Jameton, 2000; Draper & Freedman, 2010; Genter et al., 2015; Soga, Gaston, et al., 2017; Van Den Berg et al., 2010). UA encompasses a broad range of informal and formal food production operations, from urban allotments and home/ community garden growing, to commercial urban farms (De Zeeuw, 2004). Historically, UA has been relied upon to mitigate food shortages during crises, such as war (Mok et al., 2014). More recently, evidence suggests that UA may help improve diet quality and reduce food inequalities (Edmondson et al., 2020; Martinho da Silva et al., 2016; Poulsen et al., 2015; Zezza & Tasciotti, 2010).

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

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

Thus, while there is preliminary evidence linking engagement in UA with healthier diets, the mechanisms that may account for this relationship are not well-understood. Identifying the drivers of this relationship is important as a means of informing changes in policy and good practice if UA is to be supported as a food systems solution. A plausible explanation is that UA simply provides greater access to fruits and vegetables, and this is an often-cited benefit of UA (Garcia et al., 2018). However, the individual differences and situational factors underpinning food choice are more complex than this, and other factors are likely involved (Connors et al., 2001; Prescott et al., 2002; Sobal et al., 2014).

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

UA may also serve as a way of reconnecting people with nature, which could, in turn, have health benefits. As population centres move away from rural areas, a disconnect with nature and green space may be experienced (Maller et al., 2006), which seems to be detrimental to well-being and associated with stress (Uhlmann et al., 2018). Stress has been identified as a driver of poor health and unhealthy dietary choices (Ng et al., 2014; Sominsky & Spencer, 2014). Conversely, exposure to nature appears to have benefits for sustainable behaviours, well-being and diet. Nature exposure promotes environmentally sustainable behaviour, as evidenced by more co-operative and sustainable harvesting strategies in an experimental task (Zelenski et al., 2015), whilst also having benefits for well-being and stress reduction (Bowler et al., 2010; Greiman, 2014; Hazer et al., 2018; Hunter et al., 2019; Pamela Pensini et al., 2016; Roe et al., 2013; South et al., 2018). Exposure to nature scenes has also been shown to increase healthier dietary choices by encouraging people to be more future thinking and delay short-term gratification (Kao et al., 2019). Therefore, as exposure to nature is likely to happen when engaging in UA, increased connection with nature and wellbeing may also be potential explanations for the relationship between UA and diet.

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

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

Addressing these gaps, the current study used a cross-sectional online survey to test if proximity to and engagement with UA is associated with better diet quality, and what mediates this relationship. We collected data from a large sample of adults across the UK and used a structural equation model to test the following hypothesis.

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

2. Method

2.1 Participants

Participants were recruited from the Qualtrics participant panel and by an opportunity sample of members of the general public. The Qualtrics participant panel is an online platform where individuals participate in online studies and are financially reimbursed for their time. Qualtrics distributed the survey to members of their panel, and were paid a fee by the research team for doing so. The survey was distributed to panel members aged 18 years and over, who were based in the UK. To ensure that our participant sample would include participants who were engaged or interested in urban agriculture (as this was critical to addressing our research questions), we supplemented the Qualtrics participant panel recruitment by specifically targeting study adverts to urban growing and home gardening groups based in the UK, such as allotment societies, horticultural groups, social media communities and discussion forums related to home food growing. We took this recruitment approach in order to capture the experiences of participants from a range of backgrounds.

We aimed to recruit 595 participants. A sample size calculation indicated that 475 participants were needed for 90% power at alpha .05 (H0, Root Mean Square Error of Approximation (RMSEA) = .01, H1 = RMSEA = .08 (Hu & Bentler, 1999; MacCallum et al., 1996)). We increased this by 20% to allow for attrition. We aimed to recruit 400 participants via the Qualtrics participant panel, plus 195 participants from the general public to ensure that our sample contained a mixture of participants who did and did not have experience of urban agriculture. Participants were eligible to take part in the study if they were aged 18 years or over and based in the UK.

2.2 Measures

2.2.1 Demographics

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

2.2.2 Urban Agriculture Proximity and Engagement (UAPE)

We devised a series of questions to measure participants' proximity to and engagement with urban agriculture on a continuous scale. Participants were presented with the following definition of UA: *"Urban agriculture is defined as growing fruits and vegetables in urban or suburban areas"*. They then completed a series of four questions to assess their proximity to (3 questions) and engagement (1 question) with UA. Proximity questions asked about participants' awareness of examples of UA, such as allotments, growing in gardens, growing on balconies, within their i) neighbourhood (defined as 1 mile/20-minute walk of their home), ii) within their town or city, or iii) elsewhere. Responses were scored so that higher scores reflected participants indicating awareness of higher number of UA examples in their proximity. Engagement questions asked if participants took part in any forms of UA and how frequently they engaged in this (daily to less often Scores reflected the number of examples of UA participants engaged in and the frequency they engaged in this, with higher scores representing greater engagement in UA. Scores for proximity and engagement were combined to give a total score; higher total scores indicated greater proximity to and engagement with UA. Further details of the questions and scoring are shown as Supplementary Material. Cronbach α value for the measure was .851.

2.2.3 Perceived accessibility of fruits and vegetables

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

2.2.4 Food Choice Questionnaire – Health and Ethics subscales

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

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

2.2.5 Nature Relatedness Scale (NR-6)

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

2.2.6 Depression Anxiety Stress Scales 21 (DASS-21)

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

2.2.7 Short Food Frequency Questionnaire (SFFQ)

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

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

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

2.3 Procedure

The survey was delivered through Qualtrics via a weblink. Participants viewed the Participant Information Sheet and provided informed consent at the start of the study. Then they were presented with the definition of UA and completed the UAPE. Next the NR-6, questions about perceived access to fruits and vegetables, FCQ-E, FCQ-H, DASS-21, SFFQ, Demographic and SES questionnaires were presented in a random order. Survey completion took approximately 20 minutes. Participants from the general public were offered entry to a prize draw at the end of the study to win a share of £250 shopping vouchers as thanks for their time. The £250 prize fund comprised of five prizes: a £100 voucher, two £50 vouchers, and two £25 vouchers. Winners were selected at random upon completion of all data collection. Participants recruited from the Qualtrics participant panel were paid by Qualtrics for the time spent completing the survey. The study was approved by the University of Liverpool Health and Life Sciences Research Ethics Committee, Reference 5383. Data were collected in July-August 2019.

2.4 Analysis

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

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

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

3. Results

3.1 Participants

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

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

Table 1. *Participant characteristics.*

	Mean	*Standard deviation*	*Range*
Age (y)	42.75	15.708	18 – 86
BMI kg/m^2*	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 Motivations	3.11	.67	1 – 4
Ethics-related Food Choice Motivations	2.72	.85	1 – 4
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

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

3.2 Structural model

The structural equation model is shown in Figure 2. The model was an acceptable fit of the data (SRMR = .070, CFI = .964, TLI = .942, RMSEA = .058). Although the TLI was slightly below the ≥.95 cut off described by Hu and Bentler (1999), other model fit indices were good. Direct associations between the variables are shown in Table 2.

Table 2. *Direct associations between the variables.*

Association	*b* (*SE*)	*p*	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

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

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

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

3.3 Mediation analysis

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

Table 3. *Hypothesised indirect effects.*

Association	*b* (*SE*)	*p*	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

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

3.4 Structural model adjusted for age and SES

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

3.5 Exploratory Analysis - Separate effects of Proximity and Engagement Scores

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

4. Discussion

This study explored the association between proximity to and engagement with UA and diet quality, and whether this relationship is explained by one or more of several mediating factors. Results indicated that greater proximity to and engagement with UA is associated with greater perceived access to fruits and vegetables, health and ethical-related food choice motivations, nature connectedness, and, unexpectedly, greater psychological distress. Mediation analysis revealed that the relationship between UA and higher diet quality was indirectly explained by health and ethical-related food choices motivations. There was also a counter-intuitive indirect effect whereby UA was associated with poorer diet quality via higher psychological distress. Adding potential confounders to the model, namely age and EHDI, and exploring separate effects of proximity or engagement with UA, did not alter these findings.

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

Contrary to our hypothesis, greater perceived access to fruits and vegetables was associated with a poorer quality diet. This is surprising as others have shown that such access is associated with increased fruit and vegetable consumption (Caldwell et al., 2009). One explanation could be that access to fruits and vegetables alone is not sufficient to improve diet quality. We quantified access to fruits and vegetables via numbers of local shops, supermarkets and farmers markets that sell such produce, however these retailers also likely sell other, less healthy foods that could contribute to lower diet quality scores. However, it should be noted that the mediation pathway between UA-perceived access to fruits/vegetables and diet quality was not significant, meaning that this finding and potential explanation should be interpreted with caution.

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

4.1 Limitations and Future Directions

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

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

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

4.2 Conclusion

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

5. Declarations

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

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

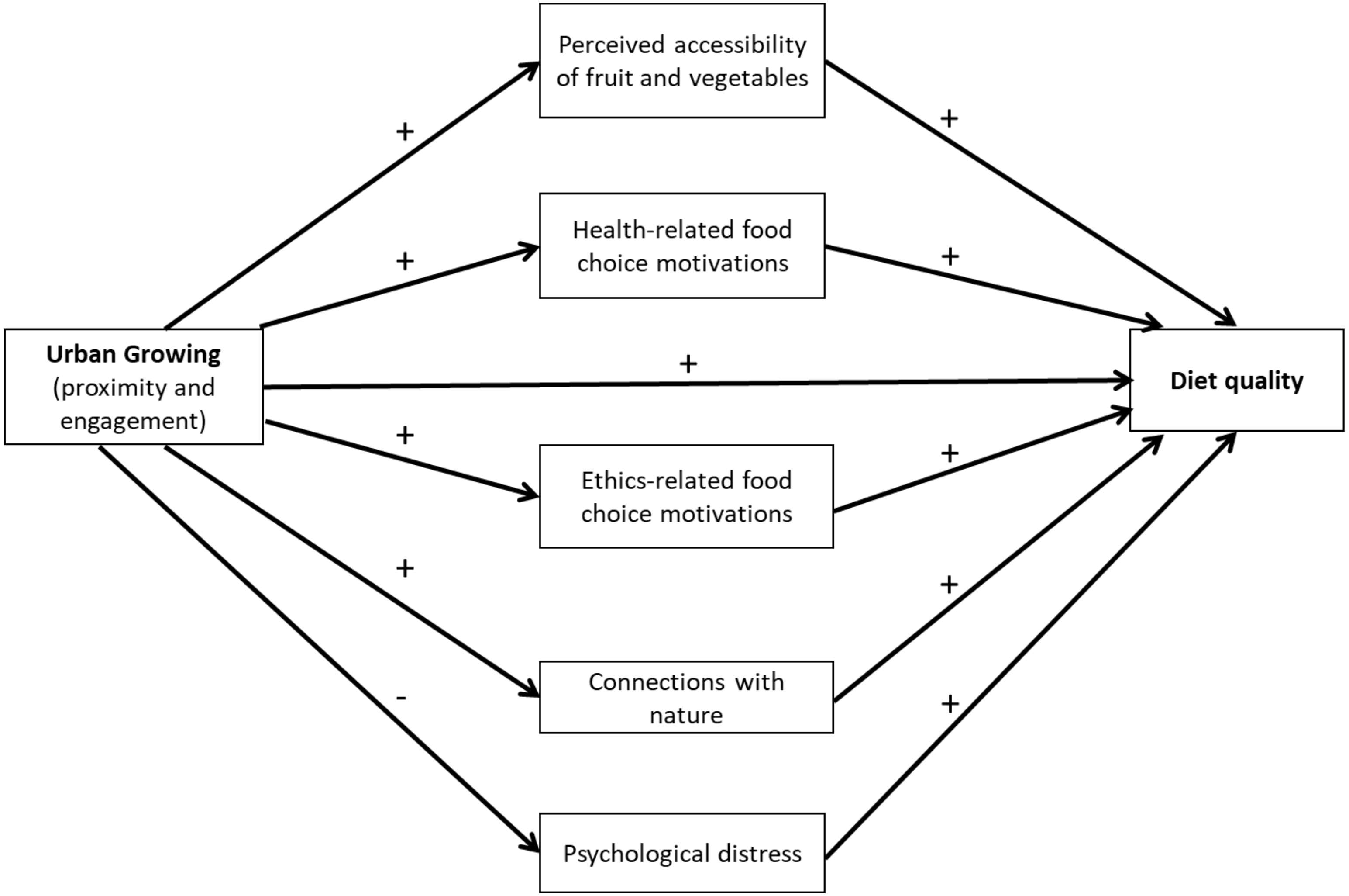

Figure 1. Hypothesised structural model of the associations between UA, potential mediators, and diet quality. Associations predicted to be positive are indicated by a + symbol; associations predicted to be negative are indicated by a - symbol.

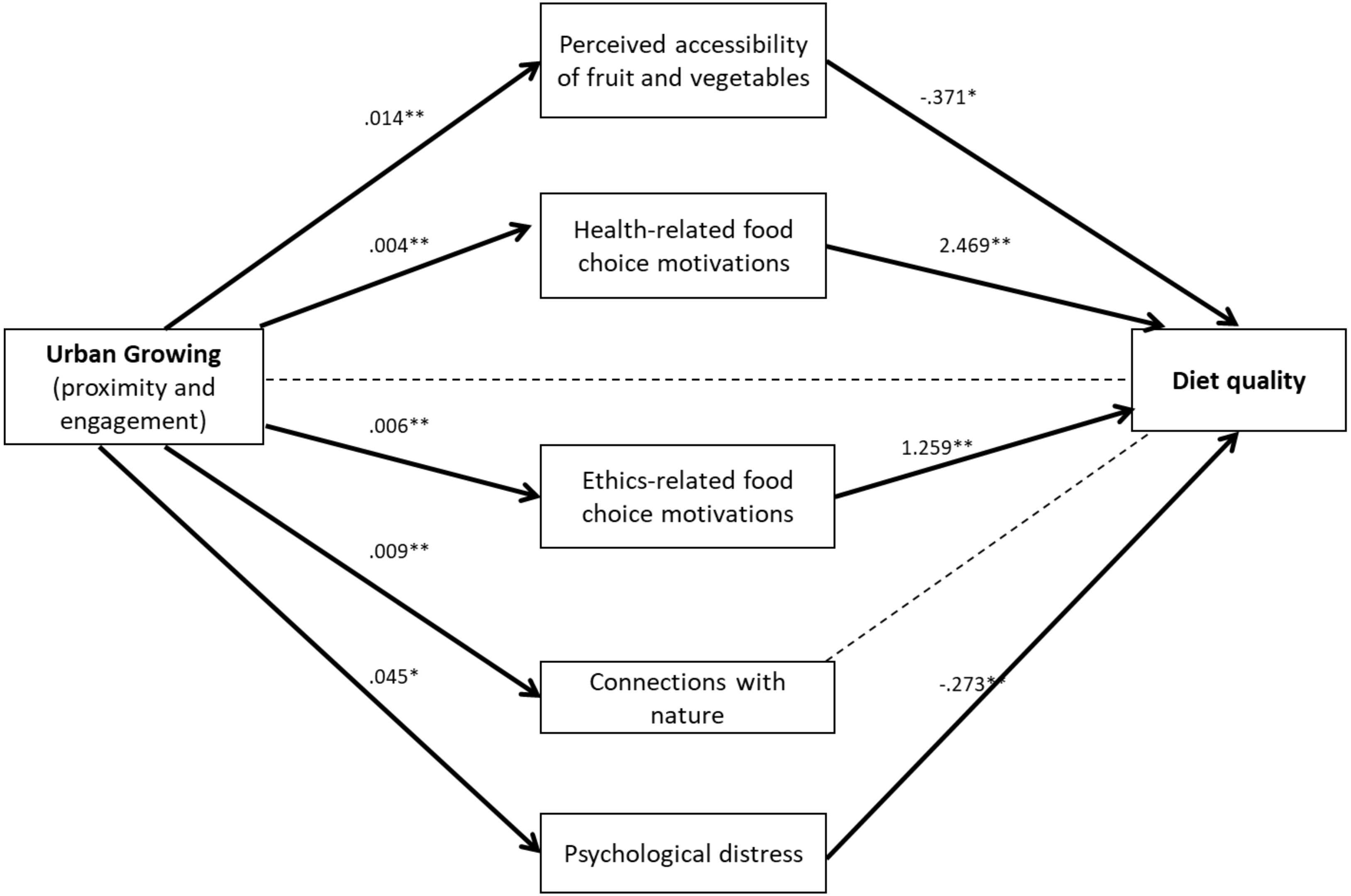

Figure 2. Associations between UA, potential mediators, and diet quality. Solid arrows indicate significant associations. Unstandardised regression coefficients are shown. **p*<.05, ***p*<.001.

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