

1 **“It made me feel brighter in myself”- The health and well-**
2 **being impacts of a residential front garden horticultural**
3 **intervention**

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22 **Research Highlights**

- 23 • Significant improvement in self-reported health were recorded after the introduction
24 of the plants.
- 25 • Residents reported significant decreases in perceived stress post-intervention.
- 26 • A significant increase in the proportion of ‘healthy’ diurnal cortisol patterns from
27 24% to 53% post-intervention suggests better health status in those individuals.
- 28 • The role of residential gardens in influencing health and well-being needs greater
29 prominence in the public health agenda.

30

31 **Abstract**

32 Residential gardens make up 30% of urban space in the UK, yet unlike many other green
33 space typologies, their role in the health and well-being agenda has largely been overlooked.
34 A horticultural intervention introduced ornamental plants to 38 previously bare front gardens
35 ($\approx 10\text{m}^2$) within an economically deprived region of North England, UK. Measures of
36 perceived stress and diurnal cortisol profiles (as an indicator of health status) were taken pre-
37 and post-intervention (over 3 months). Residents reported significant decreases in perceived
38 stress post-intervention. This finding was aligned with a higher proportion of ‘healthy’
39 diurnal cortisol patterns post-intervention, suggesting better health status in those individuals.
40 All residents derived one or more reported socio-cultural benefits as a result of the front
41 garden plantings, although overall scores for subjective well-being did not increase to a
42 significant level. Further qualitative data suggested that the gardens were valued for
43 enhancing relaxation, increasing positive emotions, motivation, and pride of place. The
44 results indicate that adding even small quantities of ornamental plants to front gardens within
45 deprived urban communities had a positive effect on an individual’s stress regulation and
46 some, but not all, aspects of subjective well-being. The research highlights the importance of

47 residential front gardens to human health and well-being, and thus their contribution to the
48 wider debates around city densification, natural capital and urban planning.

49

50 **Key Words: Cortisol; Deprivation; Socio-cultural Benefits; Stress Regulation; Urban**
51 **Green Space; Wellbeing**

52

53 **1. Introduction**

54 An increasing body of research demonstrates that urban green space (UGS) has
55 therapeutic value by allowing city dwellers to relax and engage with nature (Frumkin et al.,
56 2017; Hartig et al., 2014). Especially in urbanised societies, exposure to green space has been
57 shown to generate positive benefits in emotional well-being (Ballew & Omoto, 2018; Roe &
58 Aspinall, 2011), cognitive functioning (Bratman et al., 2019), behaviour (Guéguen & Stefan,
59 2016) and physiological responses, including heart rate variability, pulse rate, blood pressure,
60 skin conductance, cortical brain activity and diurnal cortisol profiles (Haluza et al., 2014;
61 Neale et al., 2019; Roe et al., 2017, 2013; Toda et al., 2013). Exposure to green space/nature
62 has been linked to enhancement of the immune system (Hansen et al., 2017) and encouraging
63 physical activity (Cameron & Hitchmough, 2016; de Vries, 2010).

64 Despite policy-makers having a growing understanding of the value of UGS from a
65 health and well-being perspective, challenges remain as to where and what type of UGS
66 should be incorporated into city planning. Previous research implies that factors including
67 scale, accessibility, quality, biodiversity and activity within UGS influence the relative health
68 benefits (Dallimer et al., 2012; Fischer et al., 2018; Keeler et al., 2019; Wood et al., 2018).
69 Several reports suggest that larger (Mitchell et al., 2011), more naturalistic landscapes (Stott
70 et al., 2015) with greater biodiversity (Cameron et al., 2020) promote more positive health
71 effects. This might suggest that planners should prioritise larger, more informal parks or

72 nature reserves over other forms of UGS, when considering ‘therapeutic’ or health-promoting
73 landscapes (Cameron et al., 2020). Yet recent epidemiological studies also indicate health
74 indices improve when homeowners possess a garden (Brindley et al., 2018; Dennis & James,
75 2017). This implies that smaller, more intimate and readily accessible green space may also
76 have a role in promoting health for urban citizens, and provide an alternative strategy to
77 providing therapeutic space within the urban matrix.

78 Surprisingly, the value of residential gardens (also known as ‘domestic’, ‘private’ or
79 ‘home’ gardens) as a health intervention has largely been overlooked (Cameron et al., 2012).
80 In a review of UGS and mental health, only approximately 1% of studies involved residential
81 gardens (Wendelboe-Nelson et al., 2019) and more information is required on the merits of
82 this landscape type. Moreover, in the context of ever-increasing urbanisation and city
83 densification, there is evidence that some city planners see residential gardens as a
84 dispensable luxury (Haaland & Konijnendijk van den Bosch, 2015). Residential garden size
85 is getting smaller, and some planners/developers are omitting gardens in new housing
86 schemes completely (Tahvonen & Airaksinen, 2018). Yet this may be folly if such features
87 are enhancing human health and well-being. Moreover, residential gardening is a common
88 pastime with 49% of UK adults (Department for Culture Media and Sport, 2017) and 78% of
89 USA homeowners taking part in regular garden activities (Clayton, 2007). Thus, gardening
90 holds much promise as an intervention for health and well-being. Indeed, the value of private
91 residential gardens as therapeutic landscapes was brought to the fore during the Covid-19
92 virus outbreak (Sofa & Sofa, 2020), where residents were socially isolated and the only green
93 space that could be accessed for long periods of time, were private gardens (for those that
94 possessed them).

95 Despite the dominance of *residential* gardening as an activity, much of the literature
96 on gardening with respect to health and well-being actually relates to *communal* gardening on

97 public or semi-public land, possibly because this is easier for researchers to access.
98 Communal gardening covers community garden schemes, allotments, hospices, prison
99 gardens and horticultural therapy interventions. Although the data is still not extensive, there
100 is a greater evidence-base for benefits associated with communal gardening. These include
101 improvements in: physiological relaxation (Hassan et al., 2018), stress relief (Genter et al.,
102 2015), mental health (Soga, et al., 2017b), mood (Grahn & Stigsdotter, 2010), social skills
103 (Himmelheber et al., 2018), self-esteem (Cammack et al., 2002), confidence (Eum & Kim,
104 2016), creativity (Exner and Schützenberger, 2018), diet (Hale et al., 2011), and opportunity
105 for physical exercise (Soga et al., 2017a). Although it would be logical to assume that
106 benefits associated with communal gardening translate across to residential gardening
107 (Cervinka et al., 2016), this needs testing, not least as a number of reports suggest that much
108 of the benefits of communal gardening relate to social interactions, encouragement from
109 peers and pride in producing produce. Aspects that perhaps, may not be so relevant to private
110 residential gardening, although residential gardens that are overlooked and enjoyed by
111 neighbours or passers-by may have their own distinct socio-cultural influences.

112 The research presented here aims to address the gaps in knowledge relating to private
113 residential gardens and to help inform policy-makers and planners about their potential value
114 in terms of well-being and socio-cultural relations. This is important because not only are
115 gardens being omitted in some new developments, but existing gardens are also changing in
116 terms of their land cover, with many being paved over to facilitate ‘off-road’ car parking or
117 ease maintenance (Chalmin-Pui et al., 2019). In the UK, 87% of households have gardens
118 (Davies et al., 2009) equating to 5,300 km² or 30% of the total urban area (Office for
119 National Statistics, 2018), yet recent studies suggest as much as 38% of this area is now hard-
120 surfaced, with some ‘gardens’ having no plants at all (Bonham, 2019). In reality, there is little
121 understanding of how garden design, as well as type and extent of vegetation influences well-

122 being (Lin et al., 2017). Our research specifically focused on small, residential front gardens
123 associated with high-density housing stock as these are the ones most frequently paved over.
124 It looked to investigate the effects of introducing ornamental landscape plants to paved front
125 gardens and then determining effects on the residents' health and well-being. Ornamental
126 plants were used exclusively, i.e. food crops were avoided, to ensure impacts related to
127 aesthetics (Haviland-Jones et al., 2005) rather than additional material benefits, such as
128 enhanced nutritional value or financial savings associated with growing the plants. Previous
129 research has shown that there is a positive relationship between aesthetic preference and well-
130 being (Hoyle et al., 2017a, 2017b). As the intervention was in front gardens, i.e. adjacent to
131 the public streetscape, we were keen to determine if any wider socio-cultural benefits might
132 accrue too, for example, any influence on neighbours.

133 The research examined diurnal profiles of the hormone cortisol, within the residents
134 who took part. The physiological stress response in humans is regulated by the hypothalamic-
135 pituitary-adrenal (HPA) axis and its synthesis of cortisol (Ryan, 2017). The circadian cortisol
136 pattern in healthy individuals is typified by a rapid rise in cortisol production on waking in
137 the morning, a steady decrease until mid-day, followed by a progressively slower decline
138 until evening; with levels reaching their lowest point just prior to an individual falling asleep
139 at night. Variations in this pattern can indicate HPA dysfunction, a consequence of a wide
140 range of mental and physical health problems (Adam et al., 2017); for example, less rapid
141 declines may suggest prolonged fatigue or exhaustion caused by chronic stress (Roe et al.,
142 2013). Monitoring these diurnal profiles is important as simply calculating daily averages
143 can be misleading – thus, for example, the assumption that high mean levels of cortisol
144 correlate to enhanced stress and conversely low levels relate to stress-free conditions is an
145 oversimplification (Smyth et al., 2013). We compared residents' cortisol diurnal profiles (i.e.
146 the decline phase of the circadian pattern) here, in an attempt to determine if the garden

147 intervention influenced physiological responses. Healthier cortisol patterns have been cited
148 previously for those living in areas with higher levels of green space (Gidlow et al., 2016;
149 Roe et al., 2013; Ward Thompson et al., 2012) and for participants exposed to a forest setting
150 compared to an urban one (Lee et al., 2011).

151 Based on the above evidence the research examined the following key questions
152 Will a front garden horticultural intervention - introducing plants to paved front gardens
153 overtime (3 months) affect residents by:

154 Q1 Reducing perceived stress?

155 Q2 Improving diurnal cortisol profiles, suggesting better HPA function/health status?

156 Q3 Improving subjective well-being?

157 Q4 Increasing physical activity?

158 Q5 Improving connectedness to nature?

159 Q6 Providing socio-cultural benefits such as enhanced community cohesion?

160

161 **2. Methods**

162 A front garden intervention was carried out in an economically deprived region of
163 North England, UK with plants and planted containers being introduced to resident's
164 properties. Pre- and post- well-being measures (subjective well-being, perceived stress,
165 diurnal cortisol) were captured over a 2-week data collection period prior to and for at least 3
166 months after each intervention, with the experiment being repeated over a two-year period,
167 using two sub-populations of residents (i.e. Groups A and B, Figure 1).

168

169 *2.1 Experimental design*

170 Residents within Group A were provided with plants and containers first (May 2017),
171 with Group B acting as a Control (i.e. a comparator group without plants/containers) over the

172 subsequent summer and autumn. Residents within Group B received their intervention the
173 following year (May 2018). Both groups were assessed on outcome measures pre- and post-
174 the horticultural intervention (Figure 1). The experimental design followed Reichardt's (2006)
175 “principle of parallelism” which recommends making multiple comparisons between groups
176 over time (Mark & Reichardt, 2009). The quasi-experimental approach in a real-world setting
177 acknowledged the lack of control over certain extraneous variables, including the lack of
178 completely randomised groups (all residents showed some appetite to have a re-vegetated
179 front garden).

180

181 *2.2 Resident population and recruitment*

182 The experiment was conducted in Salford, Greater Manchester, UK (Grid reference
183 SJ 781999). Salford was chosen due to an abundance of 19th-century terrace houses, with
184 small (10 m²) paved-over (non-vegetated) front gardens. The local housing association aided
185 recruitment, with residents informed about the intervention via door to door leaflet dropping
186 followed up via in-person door to door calls. Residents who participated were all selected
187 from the same neighbourhood (within 4 km of each other), but divided into the two groups
188 based on the street they lived in. Thus Group A (n=25) was selected and pooled from 4
189 streets, and Group B (n=17) derived and pooled from 4 different streets. This provided
190 geographic separation between the two groups to avoid either group influencing the other.
191 There was no geographic or obvious socio-economic bias associated with the group
192 distributions, with all residents within socio-economic classes 6-8 in the National Statistics
193 Socio-Economic Classification (i.e. employment status that varies from semi-routine work to
194 long-term unemployed), and the neighbourhood ranked as within the 10% most deprived in
195 the UK (Rose & Pevalin, 2003). Residents were selected on the basis of willingness to take

196 part in a garden intervention that involved placing containers and plants in their front
197 gardens.

198

199 *2.3 The intervention*

200 Participants received the same style of containers, range of plants and growing
201 information, although the layout could vary based on the actual dimensions of individual
202 front gardens or activities therein. For example, access to domestic bins, often situated in
203 front of the property, had to be maintained. Residents were consulted on the types of plants
204 they preferred and a standard list developed (Table 1), which were then used in the
205 intervention (Figure 2); all residents receiving the same plant taxa, the exception being choice
206 of tree species - *Amelanchier* or *Juniperus*, or ability to decline a tree completely. Residents
207 received one tree, one shrub, one climber, and enough sub-shrubs, bulbs, and bedding plants
208 to fill the two containers. This provided diversity in structure, colour, and seasonality for each
209 resident. Containers were planted by the researcher with no obligation for the resident to be
210 involved with planting or subsequent management of these. All containers were ‘self-
211 watering’ with a 22 L in-built reservoir of water. Although residents were not obliged to
212 maintain the plants, active participation was encouraged and access to horticultural advice
213 provided through the Royal Horticultural Society Advisory team. Residents were also given
214 an information booklet written in a style accessible to non-gardeners.

215

216 *2.4 Quantitative data sets and measured outcomes*

217 A number of parameters were measured as indicators of health status through
218 questionnaires and cortisol sampling and are linked to our original questions (Q1-4). These
219 were-

220 Primary health outcome measures:

- 221 • Perceived stress scale (Cohen et al., 1983) a 10-item scale scored on a Likert ranking
222 of 5 (indicating higher stress) to 1 (indicating lower stress) (Q1).
- 223 • Diurnal cortisol levels and profiles (Adam & Kumari, 2009 and see protocol outlined
224 below) (Q2).

225 Secondary health outcome measures

- 226 • Subjective well-being: Short Warwick and Edinburgh Mental Well-Being Scale -
227 SWEMWB (Tennant et al., 2007); widely used in the health service sector with self-
228 reported scores ranging from 7 (low) to 35 (high) mental well-being (Q3).
- 229 • Physical activity levels (Likert 1-5 scale, 1 being inactive, 5 being fully active) (Q4).

230

231 The questionnaires were also used to provide additional information on connectedness
232 to nature (Mayer & Frantz, 2004). This was a 14 item scale scored on a Likert ranking of 5
233 (completely agree) to 1 (completely disagree) relating to experiences of nature (Q5).

234

235 *2.4.1 Protocol for salivary data collection*

236 Salivary cortisol data was collected following the procedures outlined by Roe et al.
237 (2013). This data allows the modelling of trends and changes in the daily lives of research
238 participants (Schlotz, 2018). Diurnal cortisol profiles (declines after waking - see
239 Introduction) were monitored by collecting saliva samples four times a day (3, 6, 9, and 12
240 hours after waking) for each individual for two consecutive days with cotton swabs and
241 Salivette collection tubes (Smyth et al., 2013). Participants were asked to confirm waking
242 time on each day. To maximise participant adherence to the sampling protocol, they were
243 subsequently sent SMS text reminders 30 minutes before a sample was due to avoid eating,
244 drinking, or smoking (which can interfere with cortisol analyses), and when it was time to
245 take the sample. Samples were stored in domestic refrigerators for up to 48 hours before

246 collection, then stored at -20°C within a University laboratory prior to analysis. Cortisol
247 concentration was determined by Enzyme Linked Immunosorbent Assay (ELISA) developed
248 by Salimetrics LLC (USA). Assay characteristics: standard range =0.33-82.77 nmol L⁻¹,
249 assay sensitivity =0.19 nmol L⁻¹(lower limit of detection), correlation with serum cortisol
250 =0.91 ($p<0.0001$, n=47 samples). After centrifuging thawed samples at 3500 rpm for 10 min,
251 duplicate analysis of samples was undertaken. The intra-assay coefficient of variation was
252 <10% for all samples.

253 Cortisol samples that indicated possible non-compliance with the sampling schedule
254 were excluded following recommendations by Dmitrieva et al. (2013). These were extremely
255 high values (≥ 60 nmol L⁻¹) or samples that demonstrated a rapid increase from the previous
256 value (≥ 10 nmol L⁻¹). Four aggregate measures were calculated:

- 257 1. Daily Average Concentration (DAC) (Nicolson, 2004), calculated as the daily mean of
258 the four samples.
- 259 2. Daily total secretion - Area Under the cortisol Curve with respect to ground level
260 (AUCg), calculated using the trapezoid formula (Pruessner et al., 2003).
- 261 3. Diurnal cortisol decline (slope profiles of cortisol curves)(Adam et al., 2006). Slope
262 was calculated as the difference between cortisol concentrations at 12 and 3 hours post-
263 awakening.
- 264 4. Proportion of healthy 'i.e. normal' diurnal cortisol profiles (Miller et al., 2016). Using
265 discrete cortisol profiles (Dmitrieva et al., 2013), this assesses the proportion of
266 curves that fit the normal diurnal cortisol profile. A cortisol profile is considered to be
267 healthy if it peaks within the first hour of awakening, declines rapidly over the
268 morning hours, and tapers off through the rest of the day, reaching its lowest point at
269 night (Saxbe, 2008). Cortisol reference ranges were used to determine healthy diurnal
270 cortisol profiles. Each resident's raw diurnal cortisol profiles pre- and post-

271 intervention were classified into one of four categories following Miller et al. (2016):
272 1) normal or healthy slope, 2) low slope, 3) irregular slope, 4) elevated evening slope.
273 Changes in the number of samples showing a healthy profile were related to pre-/post-
274 intervention times.

275

276 *2.5 Additional questionnaire data*

277 In addition to the formal scores generated for perceived stress, well-being, level of
278 physical activity and connectedness to nature, the questionnaire also posed further questions
279 relating to feelings of happiness, relaxation, anxiety or depression experienced over the
280 period of the intervention (Q3); and any changes in social-cultural aspects such as
281 perceptions about the local community or neighbourhood (Q6) or connectedness to nature
282 (Q5). These complemented qualitative data collected via interview (see below).

283

284 *2.6 Qualitative data collection*

285 Qualitative data was collected through semi-structured in-depth interviews, before and
286 after the intervention. Data included how residents felt about their lives, well-being, mental
287 and physical health, street, neighbourhood, community, engagement with nature and
288 gardening, attitudes towards the intervention, motivations for participation in the research and
289 expectations regarding the outcomes of the intervention. Throughout the study period,
290 additional qualitative data was collected about alterations to gardens (both experimental and
291 otherwise) and based on informal conversations with passers-by and neighbours.

292

293 *2.7 Data analysis*

294 Residents were inconsistent in their responses to requests for questionnaire or salivary
295 cortisol data, resulting in a larger population in Group A, than Group B (Table 2). As such,

296 data for cortisol was pooled across both groups before comparing profiles pre- (2 weeks
297 before) to those post-intervention (3 months after). Similarly, for well-being and perceived
298 stress, data was pooled across the groups to allow for robust analysis of pre- and post-
299 intervention effects. Missing datasets did not fit a pattern, and tended to be related to
300 individuals forgetting to provide samples or not being at home when interviews had been
301 arranged. There was no evidence that any particular socio-economic or health factors were
302 influencing the data sets (e.g. missing values were not restricted to those with the poorest
303 health), so although statistical power was reduced, no obvious bias was linked with this loss
304 of data. A range of statistical tests (using 'R' version 3.4.3) were employed, as appropriate to
305 the data, to determine statistical significance of the intervention. These included paired t-
306 tests, McNemar's test, linear modelling, single and repeated measures ANOVA for pre- and
307 post-intervention evaluation; a difference-in-difference regression model was used to
308 compare results from intervention and control groups across different times. (Table 3
309 summarises the tests used for each parameter). Where appropriate to do so, statistical power
310 was increased by augmenting with additional individuals who provided data at relevant time
311 points or restricted comparisons (see n values below for each specific statistical test/model
312 used in the results section).

313 In the process of this statistical analysis, model checking was performed by
314 consideration of standardised predicted values, standardised residuals and whether the data
315 met the assumptions of homogeneity of variance and linearity. Transformations were carried
316 out where appropriate to ensure compliance with these assumptions. For example, to correct
317 for a positive skew in the cortisol data, data was log-transformed prior to statistical analysis.

318 Longitudinal qualitative data were analysed using interpretative phenomenological
319 analysis (Smith et al., 1999) with time (pre- and post-intervention) as the main topic of

320 inquiry. To maintain anonymity yet provide context, residents are cited using their gender
321 and age to illustrate the emerging emotional themes.

322

323 **3. Results**

324 After a total of 237 house-approaches, 42 (13%) residents took part in the research
325 with the majority of residents (93%) being white (Table 4). Four residents who took part, co-
326 habited, thus there were 38 horticultural interventions in total. Only 17 residents chose to
327 have a tree planted (40%). Beyond watering, 14 residents actively engaged with their new
328 gardens, such as deadheading flowers or adding plants (33%). In terms of data collection, 28
329 residents in total (14 Group A; 14 Group B) completed pre- and all post-
330 interviews/questionnaires and 16 (8 Group A; 8 Group B) provided complete cortisol profiles
331 pre- and post- the intervention.

332

333 *3.1 Quantitative data - Perceived stress, well-being (SWEMWB), physical activity and* 334 *connectedness to nature scores*

335 Pooling data across both groups (n=28) showed there was a significant decrease in
336 perceived stress post-intervention, (paired t-test, $t(27)=-2.44$, $p=0.021$; Q1)(Figure 3). There
337 were no significant effects though on subjective well-being (Q3), physical activity (Q4) or
338 connectedness to nature scores (Q5).

339 Restricting data to a single period (Aug 2017) when Group A (after the intervention)
340 could be compared to Group B (control, i.e. no intervention) at the same time, resulted in
341 mean perceived stress levels of 13.4 and 16.9, respectively. ANOVA showed this to be only
342 significant, however at a 10% level, i.e. $p=0.092$; possibly partially attributed to low
343 replication (n=17).

344 A difference-in-difference regression model showed that perceived stress levels
345 overall decreased by 3.18 in the intervention group, whereas stress levels actually rose by
346 4.52 in the control group (Figure 4). Although this result is not statistically significant
347 ($p=0.129$), it does suggest that the engagement with the researcher alone (control group) had
348 no positive effect on perceived stress scores.

349

350 *3.2 Cortisol measures*

351 *3.2.1 Diurnal salivary cortisol concentrations*

352 A repeated-measures ANOVA factoring sample day and sample time revealed no
353 significant order effect for day 1 or 2 of sampling using log-transformed values ($n=31$). There
354 was a significant main effect of sampling time ($F=4.39$, $df=1$, $p=0.037$), indicating that
355 cortisol means varied across the day. Both results suggested participant adherence to the
356 required sampling protocol and legitimised averaging cortisol variables (DAC, AUCg and
357 diurnal decline) across the two sampling days to give the most reliable measures (Roe et al.,
358 2013).

359

360 *3.2.2 Daily Average Concentration (DAC)*

361 A paired t-test run on the residents with measures both pre- and post-intervention
362 ($n=16$) showed a marginally non-significant effect, with pre-intervention concentrations (3.01
363 $\text{nmol L}^{-1} \pm 0.51$) lower than post-intervention ones (4.51 ± 0.59), $t(15)=1.99$, $p=0.065$. Further
364 evaluations using simple linear regression (log-transformed values) indicated a significant
365 relationship between the pre-/post- factor and DAC ($t=-2.805$, $p=0.006$). DAC increased by
366 21% from pre- to post-intervention, and the adjusted r^2 value showed that 6.9% of the
367 variation in DAC can be explained by the model, ($p=0.006$). Before the intervention cortisol
368 levels tended to be very low ($\approx 3\text{-}4 \text{ mol L}^{-1}$), but were higher post-intervention ($\approx 4\text{-}6 \text{ mol L}^{-1}$)

369 (Figure 5). These post-intervention values were closer to reference ranges from healthy
370 participants of similar age and socio-economic status as this sample (Smyth et al., 2019).

371

372 3.2.3 Total daily secretion (AUCg)

373 A paired t-test on AUCg data (n=14) showed residents significantly increased their
374 total secretion post-intervention (AUCg=28.37±3.63), compared to pre-intervention
375 (AUCg=18.60±2.98); $t(13)=2.27, p=0.041$. Again linear regression showed a significant
376 relationship between the pre-/post- factor and AUCg ($t = -3.488, p < 0.001$) with 13% of the
377 variation in AUCg being explained by the model ($p < 0.001$).

378

379 3.2.4 Diurnal cortisol decline (cortisol slope profiles)

380 A paired t-test (n=13) conducted on the diurnal decline (difference between
381 concentrations at 12 and 3 hours post-awakening) indicated that declines were significantly
382 steeper post- (-3.40 ± 1.09) than pre-intervention (-2.52 ± 0.534); $t(12) = -2.34, p = 0.038$. Linear
383 regression though, did not show a significant relationship between the pre-/post- factor and
384 cortisol decline ($t = -1.79, p = 0.078$).

385 A two-way repeated measures ANOVA (n=13) was also conducted to determine the
386 effects of time (pre-or post-intervention) and sample (3 or 12 hours post-awakening) on
387 cortisol. This showed there was a significant two-way interaction between the effects of time
388 and sample on cortisol: $F(1, 13) = 5.112, p = 0.042$; suggesting values were different at 3 hours,
389 but not necessarily at 12 hours post-awakening (Figure 5).

390 The cortisol decline post-intervention was strongly-negatively correlated with well-
391 being scores. This was significant ($r = -0.67, n = 14, p = 0.006$); cortisol profiles in participants
392 with higher well-being scores showed a steeper decline in cortisol concentration and in line
393 with what would be expected in healthy individuals.

394

395 *3.2.5 Proportion of healthy diurnal cortisol profiles*

396 For residents providing both pre- and post- diurnal cortisol profiles (n=16), the
397 proportion of healthy slopes rose from 24% pre-intervention to 53% post-intervention. An
398 exact McNemar's test showing this change to be significant, $\chi^2=5.56, p=0.018$.

399

400 *3.3 Additional questionnaire data*

401 Analysing all post-intervention questionnaires (n=42, i.e. pooling data across those
402 that had and had not completed a pre-intervention questionnaire) indicated all residents
403 (100%) felt somewhat or extremely happy with their new front garden, and 100% also
404 reported that their health or well-being had improved as a result of the intervention. Twenty-
405 two residents (52%) reported that the garden helped them to feel happier, 17 residents (40%)
406 reported that the garden helped them to relax, and 11 residents (26%) reported that the garden
407 made them feel more connected to nature (Figure 6). Relatively few residents (3), however,
408 reported that the gardens directly reduced feelings of depression, worry or anxiety. Moderate
409 numbers reported an increased sense of pride (9) and more social contacts (9) through the
410 questionnaire.

411

412 *3.4 Qualitative data collection*

413 Four key themes emerged from the qualitative data analysis (interviews). Introducing
414 plants elicited feelings related to motivation, relaxation, pride and positive emotions.

415

416 *3.4.1 Motivation*

417 The intervention motivated residents to engage with their new planters, add additional
418 plants (10 residents) or garden furniture, and renovate other parts of the house/garden. One

419 participant (male, 60) bought a paddling pool for his dog to play in, while spending time in
420 the front garden. A participant with paranoid schizophrenia described the importance of
421 seeing positive change for her home:

422 *“It's the one part of the house that's nice at the moment, so it makes a difference. It definitely*
423 *makes you think about the rest of the house and getting on top of things, so I'm having the*
424 *back garden done next week. It's started me off; if you get a lift up, it sort of spurs you on. It*
425 *definitely gets you motivated a bit more”* - Female, 42.

426 Residents also stated they were encouraged by the responsibility to care for the plants.
427 This was especially the case for residents with chronic depression and other mental illnesses,
428 who appreciated change in small steps. One participant described feeling *“like a normal*
429 *human being”* when seeing the plants outside her door (female, 51). The intervention
430 influenced neighbours who had not directly participated in the research, and these purchased
431 plants, containers and artificial grass for their own properties. One resident requested a ‘plant
432 list’ so she could have a matching display for her own front garden.

433

434 3.4.2 Relaxation

435 The majority of residents reported that it was relaxing to view the plants, come home
436 to them, and watch them grow.

437 *“One of the big things that I've noticed, is when I come back from work and see all the*
438 *daffodils, it switches me into home mode. It's like a buffer zone between work and home.”* -
439 Male, 37.

440 One participant caring both for her ill mother and granddaughter amidst her own
441 relationship problems, explained that sitting on her front step, next to the plants, with her
442 morning coffee helped her cope when she did not otherwise have time for herself (female,
443 42).

444

445 3.4.3 Pride

446 The new plantings gave residents a sense of pride in their home. The interventions
447 took place in areas with frequent fly-tipping and theft. A large proportion of participants
448 explained that the “nice planters” would improve people’s perception of the area, as well as
449 their own.

450 *“You don't want visitors to think you live in a dump, you don't want them to pity you. [...] It*
451 *gives you pride, not just in your house but in the whole area. It makes it look like your area*
452 *has not just been left to rot.” - Male, 40.*

453 Residents noted that the colourful planters became an indicator of care, and a catalyst
454 to pay more attention to the neighbourhood. One resident (male, 47) was inspired to become
455 a local council ‘street champion’ and took part in litter picks. This improved ‘sense of pride’
456 was cited as improving communication between residents and contributing to a genuine sense
457 of community. Some residents also felt an increased sense of responsibility for the plants
458 themselves.

459 *“It is quite relaxing, but I never thought I'd say this. I'm quite attached to them now. It*
460 *sounds weird because they're only plants, but they're not. They're mine. And they are living*
461 *things, so you've got to look after them. It's like having a little pet.” Female, 37.*

462

463 3.4.4 Positive emotions

464 All residents reported that the plants made them feel more cheerful and lifted their
465 emotions when viewing them. They talked about better moods upon leaving/returning to the
466 house. Though experienced by all, qualitative assessment of emotional intensity during
467 interviews suggested that this was most acutely appreciated by people struggling with poor
468 mental health.

469 *“It’s lovely. It really cheers me up, honestly [...] I love nature, and I see so little of it. So*
470 *every time I get out of the house, I get a little wave of pride. It gives me a lift, a little swing in*
471 *my step. Every time.”* - Female, 51.

472 The importance of the visual impact/flower colour was explained by several residents,
473 and residents’ home visitors also noticed the changes.

474 *“It’s just nice to see the different colours. Otherwise, it looks dead bare. It made me feel*
475 *brighter in myself”* - Female, 86.

476

477 **4. Discussion**

478 *4.1 Results that support health, well-being and socio-cultural benefits*

479 Results from the intervention support the notion that small-scale ornamental plantings
480 improved residents’ mood and self-reported health with respect to perceived stress (Figure 3).
481 Improvements in participant self-reported data were supported by aggregate measures of
482 salivary cortisol concentrations, with a number of cortisol parameters suggesting significant
483 improvements in cortisol patterns and traits associated with better health (Q2) (6 out of 8 of
484 our cortisol analyses showed a statistically significant difference at the 5% level).

485 The significantly steeper declines in cortisol slopes observed post-intervention
486 indicate better health through more effective regulation of circadian and hormonal
487 mechanisms, i.e. a likely consequence of reduced stress. The proportion of cortisol curves
488 showing a healthy pattern increased significantly (by 29%) after plants were provided to
489 residents. Indeed, empirical values post-intervention (53% normal) were comparable to other
490 studies for healthy individuals in similar demographic groups (Ice et al., 2004; Ryan, 2017;
491 Smyth et al., 1997).

492 Improvements in cortisol profiles were mirrored by significant increases in total daily
493 cortisol secretion (AUCg) after the horticultural intervention. Very low values of AUCg are

494 often associated with chronically low socio-economic status and poorer health (Desantis et
495 al., 2015), and increases in this parameter also suggest improvements in health status. Finally,
496 we noted an increase in the daily average concentrations (DAC) of cortisol after the
497 intervention, again to levels consistent with populations of healthy individuals. Higher DAC
498 is associated with a higher cortisol awakening response, which in turn has been linked to
499 lower perceived stress (O'Connor et al., 2009).

500 Overall our data suggests that for this population cortisol levels and profiles were
501 considered 'healthy' post-intervention, but indicated poor health status pre-intervention
502 (Smyth et al., 2019). Indeed, the 'blunted' cortisol levels below reference ranges encountered
503 pre-intervention are linked to depression (Adam et al., 2017), post-traumatic stress disorder
504 (Bechara, 2017), suicide attempts (Keilp et al., 2016) and childhood adversity (Koss &
505 Gunnar, 2018) through the down-regulation of the hypothalamic-pituitary-adrenal (HPA) axis
506 after prolonged exposure to chronic stress. Overall, the increase in the number of cortisol
507 curves with a healthy pattern after the intervention suggests that more residents were
508 experiencing less HPA fatigue, stress, anxiety, sleep disturbances, or irritability. Comparing
509 the data on perceived stress in this study to others, the positive effects due to the horticultural
510 intervention were approximately equivalent to 8 weekly mindfulness sessions (as measured
511 after 6 months) (van Wietmarschen et al., 2018). Thus, the data addresses Q1 and Q2,
512 indicating the intervention reduced perceived stress levels, improved cortisol profiles and
513 thereby had a positive effect on the residents' health status.

514 Although there was no significant increase in SWEMWB scores *per se* (Q3), lower
515 perceived stress and positive physiological responses after the planting intervention were
516 supported by positive statements in the questionnaire. All 42 residents reported that their
517 health or well-being had changed for the better due to the new front gardens; the gardens
518 were also reported to help residents feel happier (52%), more relaxed (40%) or more

519 connected to nature (26%) (Figure 6). Moreover, many of the qualitative personal statements
520 clearly articulated the positive influence the gardens had on peoples' outlook on life, with
521 strong themes developing around more positive attitudes in general, a sense of pride and an
522 enhanced motivation to improve the local environment, as well as the gardens being valued
523 as a place to relax. Therefore, there is some evidence the intervention provided socio-cultural
524 benefits (Q6).

525

526 *4.2 Results that do not support health, well-being and socio-cultural benefits*

527 The intervention did not show any significant differences on either subjective well-
528 being (SWEMWB) (Q3), enhanced physical activity (Q4) or connectedness to nature
529 outcome measures (Q5). The lack of direct relationship between the horticultural intervention
530 and subjective well-being score is surprising; especially as it is at odds with the data on stress, a
531 potential precursor of certain aspects of poor mental health (Toussaint et al., 2016). This
532 suggests that the intervention might relieve stress, but not necessarily be influencing other
533 aspects of well-being, such as feeling loved or having increased confidence (aspects covered
534 within the SWEMWB scoring). Certainly, other studies on therapeutic gardens and
535 engagement with nature have suggested that there can be misalignment between the positive
536 effects on day to day stress management and such activities being an antidote to deeper or
537 longer-term mental health problems (Toussaint et al., 2016).

538 The lack of any enhancement in connectedness to nature score (Q5) from the
539 intervention is interesting too. This may partially be due to the fact that the residents who chose
540 to take part, already had some desire to have plants in their garden, possibly suggesting a
541 higher nature connection level than a genuinely random control group. This skew in
542 participants may be one reason why the nature connection measure did not change from pre-
543 installation to post.

544 It is also possible that an interest in gardening and nature connectedness are not
545 exactly aligned. Although on the one hand, gardening, is by definition, working and being in
546 close proximity to nature through the medium of plants (and predominately cultivated forms
547 of plants), it is not necessarily engagement with ‘wild nature’ *per se*. We saw no strong
548 evidence of residents showing wider engagement with other aspects of urban wildlife, or
549 mentioning taxa other than plants. It is possible that the horticultural intervention was
550 inducing positive affect, as indicated by the qualitative data, but not necessarily just that
551 associated with biophilic responses (Wolf et al., 2017) or biodiversity (Richardson, 2019).
552 Gardens have been linked to an enhanced sense of self-worth through the opportunity for
553 increased creativity, and self-expression (Clayton, 2007). As mentioned above, they can also
554 be a source of pride (Clayton, 2007) or improve a sense of place (Freeman et al., 2012) as this
555 study confirms. These positive aspects of gardens in socio-cultural terms require further
556 investigation using additional outcomes measures that capture these dimensions.

557

558 *4.3 Implications for gardens and health*

559 As far as we are aware, this is the first study to evaluate the health benefits of a small-
560 scale front garden horticultural intervention. Moreover, the research was innovative in that
561 ornamental landscape plants were used exclusively in an attempt to differentiate responses
562 based on emotion to those of material need (i.e. food). Many previous garden studies indicate
563 food crops were grown, yet the motivations to grow food and non-food plants may be
564 different. The focus here was purely on an aesthetic transformation to the front garden.

565 Taken in the round, these datasets indicate the horticultural intervention reduced the
566 level of stress in residents (as captured by both self-reporting Q1 and a physiological
567 biomarker Q2) at least in the short-medium term (over a 3 month period).

568 The positive findings from this study have wider implications for urban planning. As
569 outlined above, there is a trend in urban planning to save space by providing housing with
570 little or even no garden space (Brook Lyndhurst Ltd, 2007). Most research on salutogenic
571 aspects of UGS have focussed on parks (Wolf & Wohlfart, 2014), nature reserves (Adjei &
572 Agyei, 2015) and urban forests (Panagopoulos et al., 2016), including trees close to
573 residential properties (Taylor et al., 2015) and policy makers are beginning to acknowledge
574 the value of such spaces in this respect (Lee et al., 2015). Policymakers and planners should
575 not feel, however, that such places can necessarily directly substitute for private gardens and
576 the health benefits they provide. Private gardens are distinct from other forms of UGS in a
577 number of important ways. They provide an opportunity for citizens to engage with the
578 natural world in an immediately accessible manner, while also being imbued with social and
579 cultural elements. The privacy component alone allows autonomy and opportunities to be
580 creative or reflective in a way that would rarely be feasible in public UGS. Even the social
581 dynamics around domestic gardens may be different from that of communal gardens or
582 allotments, despite the physical activities being very similar. They are also intrinsically linked
583 with the domestic property and can enhance (or if poorly maintained, undermine) the sense of
584 pride that can be aligned with homeownership. One of the principal findings from this
585 research was the capacity for ornamental gardens to provide an immediate, accessible and
586 easily sought place for relaxation. In effect, an important location for some ‘down time’ and a
587 place to find respite from the stress and strains of urban life. The surprising element, perhaps,
588 was how little green space was actually required to accrue these benefits.

589

590 *4.4 Limitations of the study*

591 The key limitation was attrition in sample size over time; a common problem in
592 longitudinal studies. The logistics of carrying out a longitudinal study in a deprived urban

593 community included participants' failure to respond at specific sampling times, forgetting to
594 take samples or meet for interviews (despite being prompted). Data was tested to ensure those
595 residents who omitted samples/missed interviews were not atypical of the population in
596 general. For example, residents who dropped out were not correlated with more irregular
597 cortisol profiles than those who finished the evaluation. Further studies, however, should take
598 care to ensure that later omissions are not in themselves associated with poorer health or
599 greater stress levels. It is recommended that similar studies are conducted with larger sample
600 sizes for higher sample power.

601 The horticultural intervention relied on a relatively small volume of new plantings,
602 and was facilitated by both the local housing association and the Royal Horticultural Society.
603 Questions remain as to the impact of the number of plants used, garden style adopted, and
604 social context (community grassroots initiatives vs. top-down local authority programmes). It
605 should also be noted that although our data showed a positive trend between the garden
606 intervention and i. perceived stress, ii. cortisol profiles that relate to less stress and iii.
607 improvements in mood (trends not found in our control population), sample sizes were small,
608 and we cannot categorically claim 'cause and effect'; other factors external to the project
609 could also have been influencing these trends. Although our groups A and B were chosen to
610 be similar in socio-demographics, and by and large were, there was a higher proportion of
611 homeowners in group A than B (as compared to tenants), and this may have influenced
612 results. Further research is required to note any particular influences in owning a garden as to
613 managing one that is part of a rented property.

614 Finally, data from the connectedness to nature section of the questionnaire did not
615 correspond well to some people's response to their own garden and this may relate to a
616 mismatch between larger, theoretical components around nature and the more intimate
617 feelings residents had for their familiar, small scale 'patch'. For example, residents may

618 rarely have considered their garden when trying to address questions such as “When I think
619 of my place on Earth, I consider myself to be a top member of a hierarchy that exists in
620 nature”. Perhaps a stratified or modified questionnaire is required when attempting to assess
621 affinity to green space or urban nature *per se*?

622

623 **5. Conclusions**

624 The data presented suggests that adding plants and containers to residents’ front
625 gardens was associated with significant reductions in perceived stress (Q1) which was
626 reflected in improved diurnal cortisol patterns (Q2) post-intervention (i.e. steeper diurnal
627 declines, increased daily average concentration and total secretions compared to ‘blunted’
628 levels pre-intervention). Qualitative data also showed residents being happier, more relaxed,
629 and having greater motivation to improve and feel a sense of pride in their living
630 environment. We did not detect a significant improvement, however, in the subjective well-
631 being scale – SWEMWB post-intervention (Q3). In reality, it may be that certain components
632 of well-being were improved but not others. Data from the study also indicated that there
633 were some socio-cultural benefits associated with the intervention (Q6), for example being
634 more motivated and taking a greater sense of pride in the home-environment and
635 neighbourhood. Gardening has been quoted as ‘therapeutic’, but we believe this is the first
636 empirical study to demonstrate that enhancing a *residential* garden through planting has a
637 positive impact on stress regulation. The study highlights the importance of residential
638 gardens as a potential resource for public health and the need for gardens to be brought more
639 forcefully into the debates around housing, city densification, and the value of different types
640 of green infrastructure. On a national, regional, and city scale, residential gardens could
641 provide a public health benefit by contributing to preventing mental ill-health.

642

643 **Statement on Research Ethics**

644 The research project was compliant with UK and Data Protection Acts (1998, 2018)
645 and was approved by the University's Research Ethics Committee.

646

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650

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Table and Figure Captions

Table 1. Plant species/cultivar used in each garden.

Table 2. Sample sizes for questionnaires and cortisol evaluations.

Table 3. Specific statistical tests applied to the different measured parameters.

Table 4. Demographics (number and percent) of residents and significance level for comparisons within factors (p-values).

Figure 1. Timeline of engagement with residents. Group A (n=25) received the garden intervention first (May 2017), with Group B (n=17) acting as a Control. Group B received their own garden intervention in May 2018, allowing for a pre- and post- evaluation of this group, as well as for Group A. (▲=garden intervention; ○=cortisol samples; ■=questionnaires and ◆=interviews). Data was pooled for pre- and post-questionnaires due to not all residents completing questionnaires on each occasion. Where an individual resident repeated the questionnaire, e.g. after the intervention, then mean scores were used in the subsequent analyses.

Figure 2. Typical garden design pre- (April 2017) and post-intervention (August 2017 & March 2018) with additional planted-up containers providing seasonal interest, and the option for residents to have one small tree planted.

Figure 3. Mean perceived stress pre- and post-intervention (n=28). Bars represent standard error (S.E.).

Figure 4. The effect of the front garden intervention on participants using differences-in-differences estimation (n=23). Bars represent standard error (S.E.).

Figure 5. Salivary cortisol concentrations (mean \pm standard error) pre- and post-intervention (n=16). Data for healthy participants from laboratory reference data and included for illustrative purposes; n=26, 15 women and 11 men aged 48.6 ± 11.7 years (but also see Smyth et al., 1997; Smyth et al., 2013; 2019). Bars represent standard error (S.E.).

Figure 6. Responses from residents to the questionnaire (n=42) following the horticultural intervention.

Tables

Table 1. Plant species/cultivar used in each garden.

Plant type	Species/cultivar
Deciduous tree	<i>Amelanchier canadensis</i> 'Glenn Form'
Evergreen tree	<i>Juniperus scopulorum</i> 'Blue Arrow'
Shrubs	<i>Rhododendron</i> 'Wombat'
Climbers	<i>Clematis</i> 'Jackmanii' <i>Clematis</i> 'Ville de Lyon'
Sub-shrubs	<i>Lavandula angustifolia</i> 'Hidcote' <i>Rosmarinus officinalis</i> Prostratus Group
Geophytes (bulbs)	<i>Galanthus nivalis f. pleniflorus</i> 'Flore Pleno' <i>Crocus sativus</i> <i>Narcissus</i> 'Tête-à-tête'
Bedding plants (annuals)	<i>Petunia</i> 'Surfinia Sky Blue' <i>Viola</i> 'Sorbet Series'

Table 2. Sample sizes for questionnaires and cortisol evaluations.

	Subjective well-being/socio-cultural (n=42)		Diurnal Cortisol (n=31)	
	Pre and Post	Only Pre or Post	Pre and Post	Only Pre or Post
Complete responses				
Group A	14	11	8	8
Group B	14	3	8	7
Total	28	14	16	15

Table 3. Specific statistical tests applied to the different measured parameters.

Parameter Measured	Statistical Test Employed
Demographics data	Fisher test for proportions
Perceived stress (PSS) (Q1)	Paired t-test One way ANOVA to compare Aug 2017 data only A difference-in-difference regression model to compare the two populations over time
Subjective well-being (SWEMWB) (Q3)	Paired t-test
Physical activity (Q4)	Paired t-test
Connectedness to nature (Q5)	Paired t-test
Diurnal salivary cortisol concentrations (Q2)	Repeated measures ANOVA (Log-transformed)
Salivary cortisol - Daily Average Concentration (DAC) (Q2)	Paired t-test Simple linear regression (Log-transformed)
Salivary cortisol – Total daily secretion (AUCg) (Q2)	Paired t-test Simple linear regression Two-way repeated measures ANOVA (to determine effects of sampling time)
Salivary cortisol concentration decline correlated with mental well-being (SWEMWB) (Q2 & Q3)	Simple linear regression
Proportion of normal diurnal cortisol profiles (Q2)	McNemar's test

Table 4. Demographics (number and percent) of residents and significance level for comparisons within factors (*p*-values).

	Total	Group A	Group B	<i>P</i> -value
	N=42	n=25	n=17	
<i>Gender</i>				0.74
Female	27 (64%)	17 (68%)	10 (59%)	
Male	15 (36%)	8 (32%)	7 (41%)	
<i>Age</i>				0.70
18 - 24	2 (5%)	1 (4%)	1 (6%)	
25 - 34	7 (17%)	6 (24%)	1 (6%)	
35 - 44	13 (31%)	6 (24%)	7 (41%)	
45 - 54	11 (26%)	6 (24%)	5 (29%)	
55 - 64	6 (14%)	4 (16%)	2 (12%)	
65 - 74	2 (5%)	1 (4%)	1 (6%)	
85 or older	1 (2%)	1 (4%)	0 (0%)	
<i>Ethnicity</i>				1.0
African/Caribbean/ Black	1 (2%)	0 (0%)	1 (6%)	
Arab	2 (5%)	1 (4%)	1 (6%)	
White	39 (93%)	24 (96%)	15 (88%)	
<i>Education</i>				0.71
GCSE	11 (26%)	7 (28%)	4 (24%)	
A Levels	7 (17%)	5 (20%)	2 (12%)	
Foundation degree	4 (10%)	2 (8%)	2 (12%)	
Other qualification (e.g. teacher training, nursing...)	6 (14%)	3 (12%)	3 (18%)	
Bachelors degree	3 (7%)	1 (4%)	2 (12%)	
Masters degree	1 (2%)	0 (0%)	1 (6%)	
Doctorate	1 (2%)	0 (0%)	1 (6%)	
No response given	9 (21%)	7 (28%)	2 (28%)	
<i>Net Annual Income (£)</i>				0.18
Less than 15,000	15 (36%)	11 (44%)	4 (24%)	

	Total	Group A	Group B	<i>P</i> -value
15,000 - 25,999	10 (24%)	4 (16%)	6 (35%)	
26,000 - 34,999	7 (17%)	5 (20%)	2 (12%)	
More than 70,000	1 (2%)	0 (0%)	1 (6%)	
No response given	9 (21%)	5 (20%)	4 (24%)	
<i>Employment Status</i>				0.75
Employed full time	16 (38%)	8 (32%)	8 (47%)	
Employed part time	12 (29%)	7 (28%)	5 (29%)	
Self-employed	2 (5%)	2 (8%)	0 (0%)	
Retired	5 (12%)	3 (12%)	2 (12%)	
Unemployed	7 (17%)	5 (20%)	2 (12%)	
<i>Tenure</i>				0.015
Resident owner	18 (43%)	7 (28%)	11 (65%)	
Tenant	23 (55%)	18 (72%)	5 (29%)	
Lodger	1 (2%)	0 (0%)	1 (6%)	

Figures

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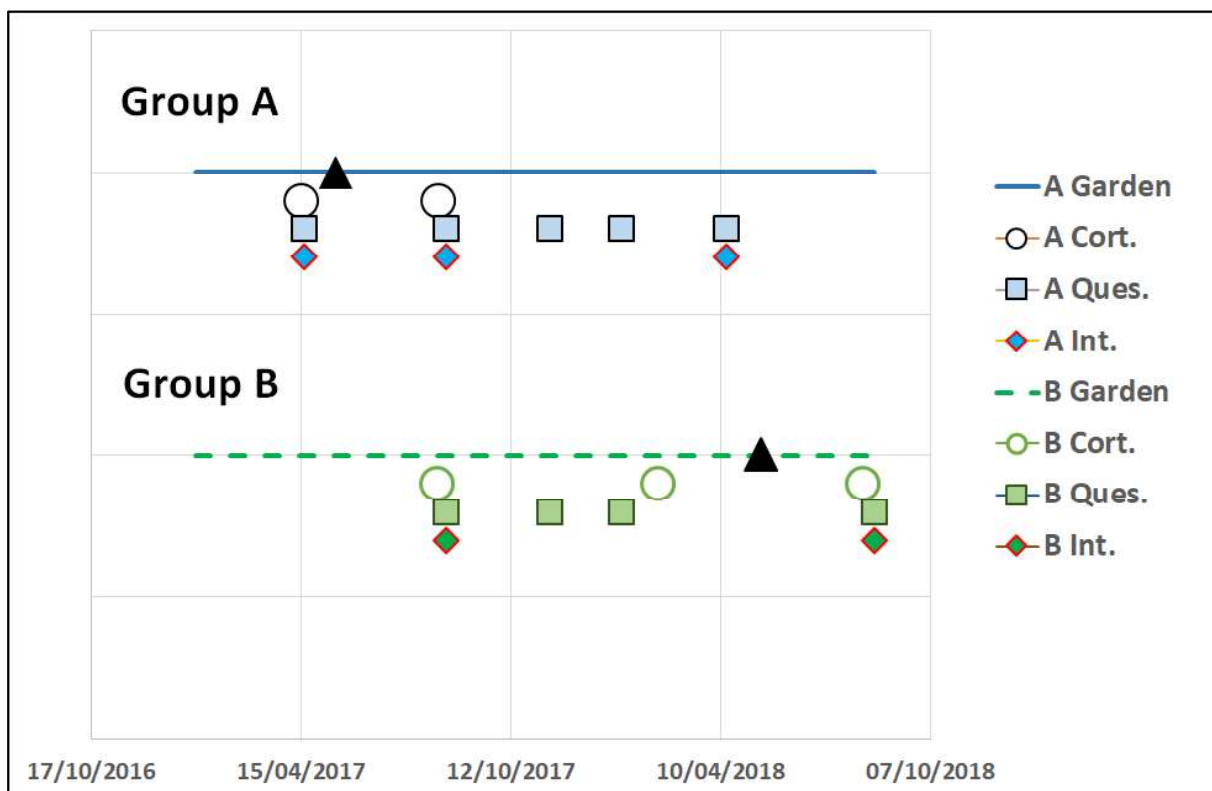


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April 2017



August 2017



March 2018

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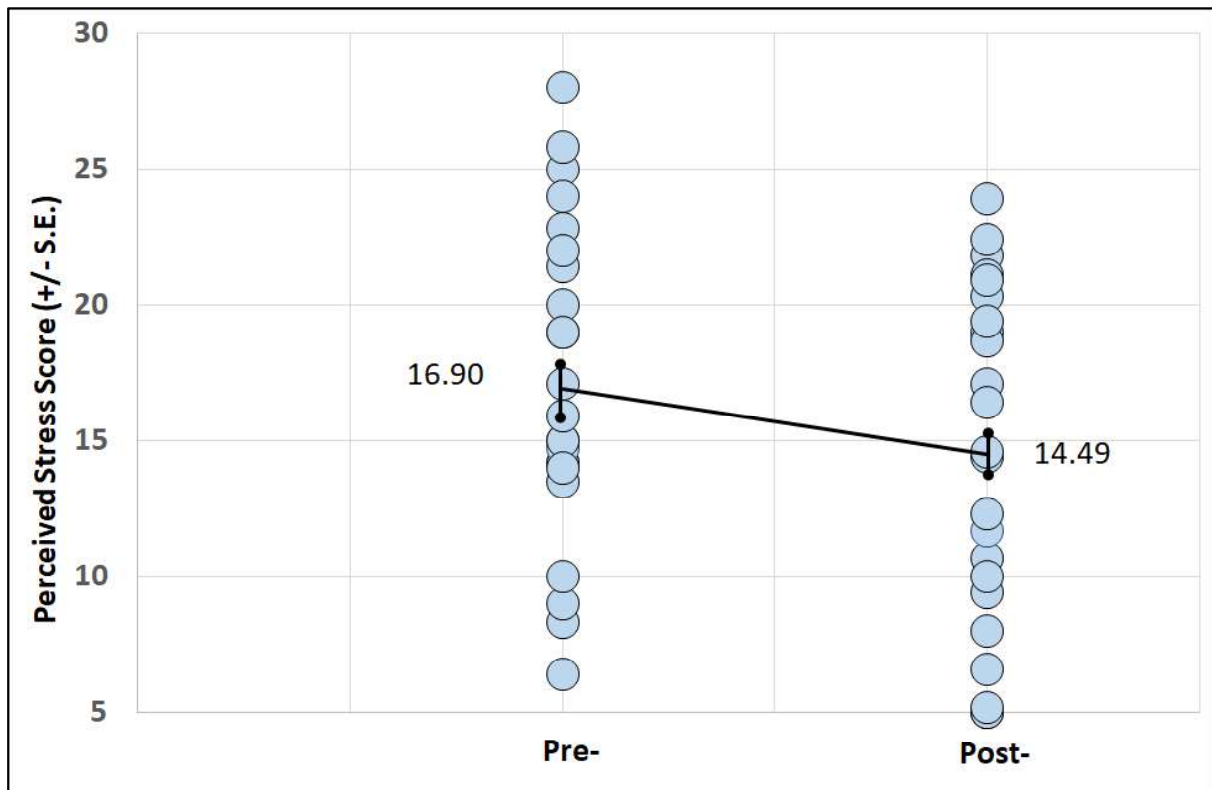


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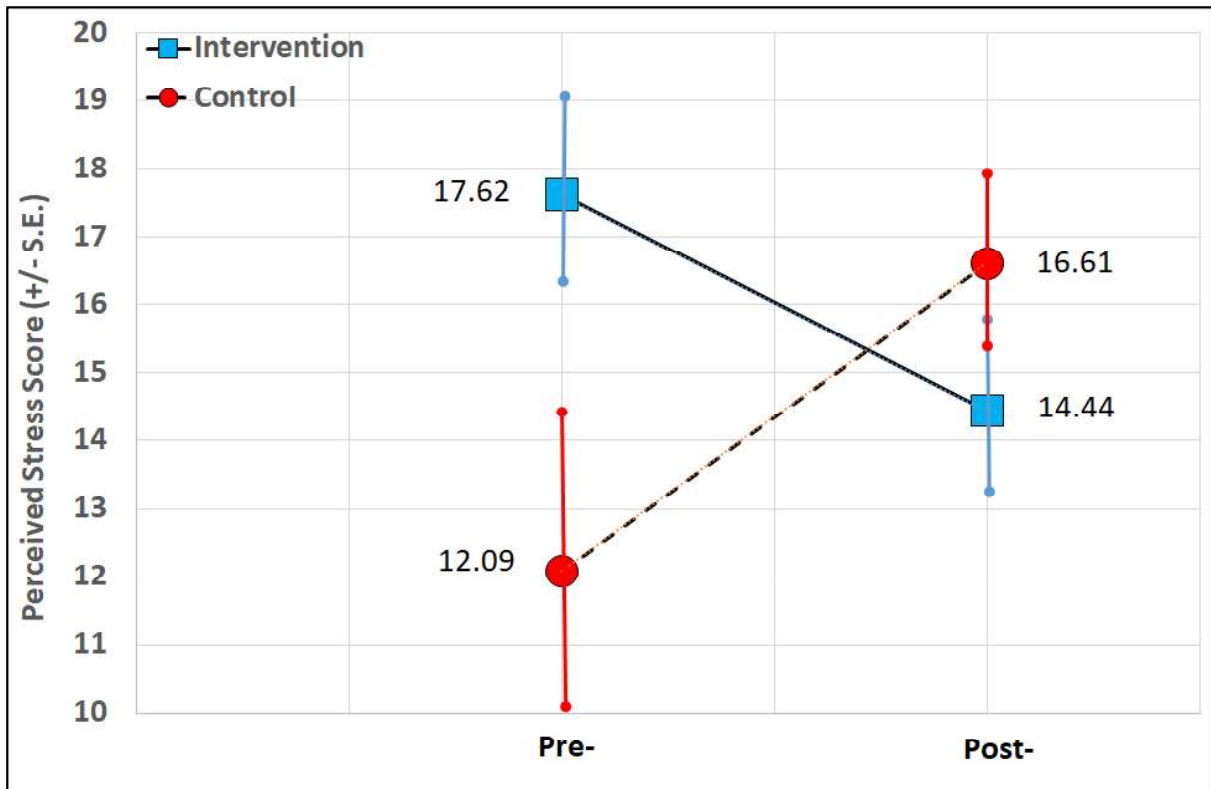


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