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

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Research Highlights

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

Abstract

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

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

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

1. Introduction

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

Despite policy-makers having a growing understanding of the value of UGS from a health and well-being perspective, challenges remain as to where and what type of UGS should be incorporated into city planning. Previous research implies that factors including scale, accessibility, quality, biodiversity and activity within UGS influence the relative health benefits (Dallimer et al., 2012; Fischer et al., 2018; Keeler et al., 2019; Wood et al., 2018). Several reports suggest that larger (Mitchell et al., 2011), more naturalistic landscapes (Stott et al., 2015) with greater biodiversity (Cameron et al., 2020) promote more positive health effects. This might suggest that planners should prioritise larger, more informal parks or nature reserves over other forms of UGS, when considering 'therapeutic' or health-promoting landscapes (Cameron et al., 2020). Yet recent epidemiological studies also indicate health indices improve when homeowners possess a garden (Brindley et al., 2018; Dennis & James, 2017). This implies that smaller, more intimate and readily accessible green space may also have a role in promoting health for urban citizens, and provide an alternative strategy to providing therapeutic space within the urban matrix.

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

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

The research presented here aims to address the gaps in knowledge relating to private residential gardens and to help inform policy-makers and planners about their potential value in terms of well-being and socio-cultural relations. This is important because not only are gardens being omitted in some new developments, but existing gardens are also changing in terms of their land cover, with many being paved over to facilitate 'off-road' car parking or ease maintenance (Chalmin-Pui et al., 2019). In the UK, 87% of households have gardens (Davies et al., 2009) equating to 5,300 km^2 or 30% of the total urban area (Office for National Statistics, 2018), yet recent studies suggest as much as 38% of this area is now hard-surfaced, with some 'gardens' having no plants at all (Bonham, 2019). In reality, there is little understanding of how garden design, as well as type and extent of vegetation influences well-being (Lin et al., 2017). Our research specifically focused on small, residential front gardens associated with high-density housing stock as these are the ones most frequently paved over. It looked to investigate the effects of introducing ornamental landscape plants to paved front gardens and then determining effects on the residents' health and well-being. Ornamental plants were used exclusively, i.e. food crops were avoided, to ensure impacts related to aesthetics (Haviland-Jones et al., 2005) rather than additional material benefits, such as enhanced nutritional value or financial savings associated with growing the plants. Previous research has shown that there is a positive relationship between aesthetic preference and well-being (Hoyle et al., 2017a, 2017b). As the intervention was in front gardens, i.e. adjacent to the public streetscape, we were keen to determine if any wider socio-cultural benefits might accrue too, for example, any influence on neighbours.

The research examined diurnal profiles of the hormone cortisol, within the residents who took part. The physiological stress response in humans is regulated by the hypothalamic-pituitary-adrenal (HPA) axis and its synthesis of cortisol (Ryan, 2017). The circadian cortisol pattern in healthy individuals is typified by a rapid rise in cortisol production on waking in the morning, a steady decrease until mid-day, followed by a progressively slower decline until evening; with levels reaching their lowest point just prior to an individual falling asleep at night. Variations in this pattern can indicate HPA dysfunction, a consequence of a wide range of mental and physical health problems (Adam et al., 2017); for example, less rapid declines may suggest prolonged fatigue or exhaustion caused by chronic stress (Roe et al., 2013). Monitoring these diurnal profiles is important as simply calculating daily averages can be misleading – thus, for example, the assumption that high mean levels of cortisol correlate to enhanced stress and conversely low levels relate to stress-free conditions is an oversimplification (Smyth et al., 2013). We compared residents' cortisol diurnal profiles (i.e. the decline phase of the circadian pattern) here, in an attempt to determine if the garden intervention influenced physiological responses. Healthier cortisol patterns have been cited previously for those living in areas with higher levels of green space (Gidlow et al., 2016; Roe et al., 2013; Ward Thompson et al., 2012) and for participants exposed to a forest setting compared to an urban one (Lee et al., 2011).

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

Q1 Reducing perceived stress?

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

Q3 Improving subjective well-being?

Q4 Increasing physical activity?

Q5 Improving connectedness to nature?

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

2. Methods

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

2.1 Experimental design

Residents within Group A were provided with plants and containers first (May 2017), with Group B acting as a Control (i.e. a comparator group without plants/containers) over the subsequent summer and autumn. Residents within Group B received their intervention the following year (May 2018). Both groups were assessed on outcome measures pre- and post- the horticultural intervention (Figure 1). The experimental design followed Reichardt's (2006) "principle of parallelism" which recommends making multiple comparisons between groups over time (Mark & Reichardt, 2009). The quasi-experimental approach in a real-world setting acknowledged the lack of control over certain extraneous variables, including the lack of completely randomised groups (all residents showed some appetite to have a re-vegetated front garden).

2.2 Resident population and recruitment

The experiment was conducted in Salford, Greater Manchester, UK (Grid reference SJ 781999). Salford was chosen due to an abundance of 19th-century terrace houses, with small (10 m^2) paved-over (non-vegetated) front gardens. The local housing association aided recruitment, with residents informed about the intervention via door to door leaflet dropping followed up via in-person door to door calls. Residents who participated were all selected from the same neighbourhood (within 4 km of each other), but divided into the two groups based on the street they lived in. Thus Group A (n=25) was selected and pooled from 4 streets, and Group B (n=17) derived and pooled from 4 different streets. This provided geographic separation between the two groups to avoid either group influencing the other. There was no geographic or obvious socio-economic bias associated with the group distributions, with all residents within socio-economic classes 6-8 in the National Statistics Socio-Economic Classification (i.e. employment status that varies from semi-routine work to long-term unemployed), and the neighbourhood ranked as within the 10% most deprived in the UK (Rose & Pevalin, 2003). Residents were selected on the basis of willingness to take part in a garden intervention that involved placing containers and plants in their front gardens.

2.3 The intervention

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

2.4 Quantitative data sets and measured outcomes

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

Primary health outcome measures:

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

Secondary health outcome measures

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

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

2.4.1 Protocol for salivary data collection

Salivary cortisol data was collected following the procedures outlined by Roe et al. (2013). This data allows the modelling of trends and changes in the daily lives of research participants (Schlotz, 2018). Diurnal cortisol profiles (declines after waking - see Introduction) were monitored by collecting saliva samples four times a day (3, 6, 9, and 12 hours after waking) for each individual for two consecutive days with cotton swabs and Salivette collection tubes (Smyth et al., 2013). Participants were asked to confirm waking time on each day. To maximise participant adherence to the sampling protocol, they were subsequently sent SMS text reminders 30 minutes before a sample was due to avoid eating, drinking, or smoking (which can interfere with cortisol analyses), and when it was time to take the sample. Samples were stored in domestic refrigerators for up to 48 hours before collection, then stored at -20°C within a University laboratory prior to analysis. Cortisol concentration was determined by Enzyme Linked Immunosorbent Assay (ELISA) developed by Salimetrics LLC (USA). Assay characteristics: standard range =0.33-82.77 nmol L^{-1}, assay sensitivity =0.19 nmol L^{-1}(lower limit of detection), correlation with serum cortisol =0.91 (p<0.0001, n=47 samples). After centrifuging thawed samples at 3500 rpm for 10 min, duplicate analysis of samples was undertaken. The intra-assay coefficient of variation was <10% for all samples.

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

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

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

2.5 Additional questionnaire data

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

2.6 Qualitative data collection

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

2.7 Data analysis

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

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

Longitudinal qualitative data were analysed using interpretative phenomenological analysis (Smith et al., 1999) with time (pre- and post-intervention) as the main topic of inquiry. To maintain anonymity yet provide context, residents are cited using their gender and age to illustrate the emerging emotional themes.

3. Results

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

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

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

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

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

3.2 Cortisol measures

3.2.1 Diurnal salivary cortisol concentrations

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

3.2.2 Daily Average Concentration (DAC)

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

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

3.2.3 Total daily secretion (AUCg)

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

3.2.4 Diurnal cortisol decline (cortisol slope profiles)

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

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

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

3.2.5 Proportion of healthy diurnal cortisol profiles

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

3.3 Additional questionnaire data

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

3.4 Qualitative data collection

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

3.4.1 Motivation

The intervention motivated residents to engage with their new planters, add additional plants (10 residents) or garden furniture, and renovate other parts of the house/garden. One participant (male, 60) bought a paddling pool for his dog to play in, while spending time in the front garden. A participant with paranoid schizophrenia described the importance of seeing positive change for her home:

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

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

3.4.2 Relaxation

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

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

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

3.4.3 Pride

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

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

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

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

3.4.4 Positive emotions

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

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

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

"It's just nice to see the different colours. Otherwise, it looks dead bare. It made me feel brighter in myself" - Female, 86.

4. Discussion

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

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

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

Improvements in cortisol profiles were mirrored by significant increases in total daily cortisol secretion (AUCg) after the horticultural intervention. Very low values of AUCg are often associated with chronically low socio-economic status and poorer health (Desantis et al., 2015), and increases in this parameter also suggest improvements in health status. Finally, we noted an increase in the daily average concentrations (DAC) of cortisol after the intervention, again to levels consistent with populations of healthy individuals. Higher DAC is associated with a higher cortisol awakening response, which in turn has been linked to lower perceived stress (O'Connor et al., 2009).

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

Although there was no significant increase in SWEMWB scores *per se* (Q3), lower perceived stress and positive physiological responses after the planting intervention were supported by positive statements in the questionnaire. All 42 residents reported that their health or well-being had changed for the better due to the new front gardens; the gardens were also reported to help residents feel happier (52%), more relaxed (40%) or more connected to nature (26%) (Figure 6). Moreover, many or the qualitative personal statements clearly articulated the positive influence the gardens had on peoples' outlook on life, with strong themes developing around more positive attitudes in general, a sense of pride and an enhanced motivation to improve the local environment, as well as the gardens being valued as a place to relax. Therefore, there is some evidence the intervention provided socio-cultural benefits (Q6).

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

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

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

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

4.3 Implications for gardens and health

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

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

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

4.4 Limitations of the study

The key limitation was attrition in sample size over time; a common problem in longitudinal studies. The logistics of carrying out a longitudinal study in a deprived urban community included participants' failure to respond at specific sampling times, forgetting to take samples or meet for interviews (despite being prompted). Data was tested to ensure those residents who omitted samples/missed interviews were not atypical of the population in general. For example, residents who dropped out were not correlated with more irregular cortisol profiles than those who finished the evaluation. Further studies, however, should take care to ensure that later omissions are not in themselves associated with poorer health or greater stress levels. It is recommended that similar studies are conducted with larger sample sizes for higher sample power.

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

Finally, data from the connectedness to nature section of the questionnaire did not correspond well to some people's response to their own garden and this may relate to a mismatch between larger, theoretical components around nature and the more intimate feelings residents had for their familiar, small scale 'patch'. For example, residents may rarely have considered their garden when trying to address questions such as "When I think of my place on Earth, I consider myself to be a top member of a hierarchy that exists in nature". Perhaps a stratified or modified questionnaire is required when attempting to assess affinity to green space or urban nature *per se*?

5. Conclusions

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

Statement on Research Ethics

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

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

Table 2. Sample sizes for questionnaires and cortisol evaluations.

	Subjective well-being/socio-cultural (n=42)		Diurnal Cortisol (n=31)	
Complete responses	Pre and Post	Only Pre or Post	Pre and Post	Only Pre or Post
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	*P*-value
	N=42	n=25	n=17	
Gender				0.74
Female	27 (64%)	17 (68%)	10 (59%	
Male	15 (36%)	8 (32%)	7 (41%)	
Age				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%)	
Ethnicity				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%)	
Education				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%)	
Net Annual Income (£)				0.18
Less than 15,000	15 (36%)	11 (44%)	4 (24%)	

	Total	Group A	Group B	*P*-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%)	
Employment Status				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%)	
Tenure				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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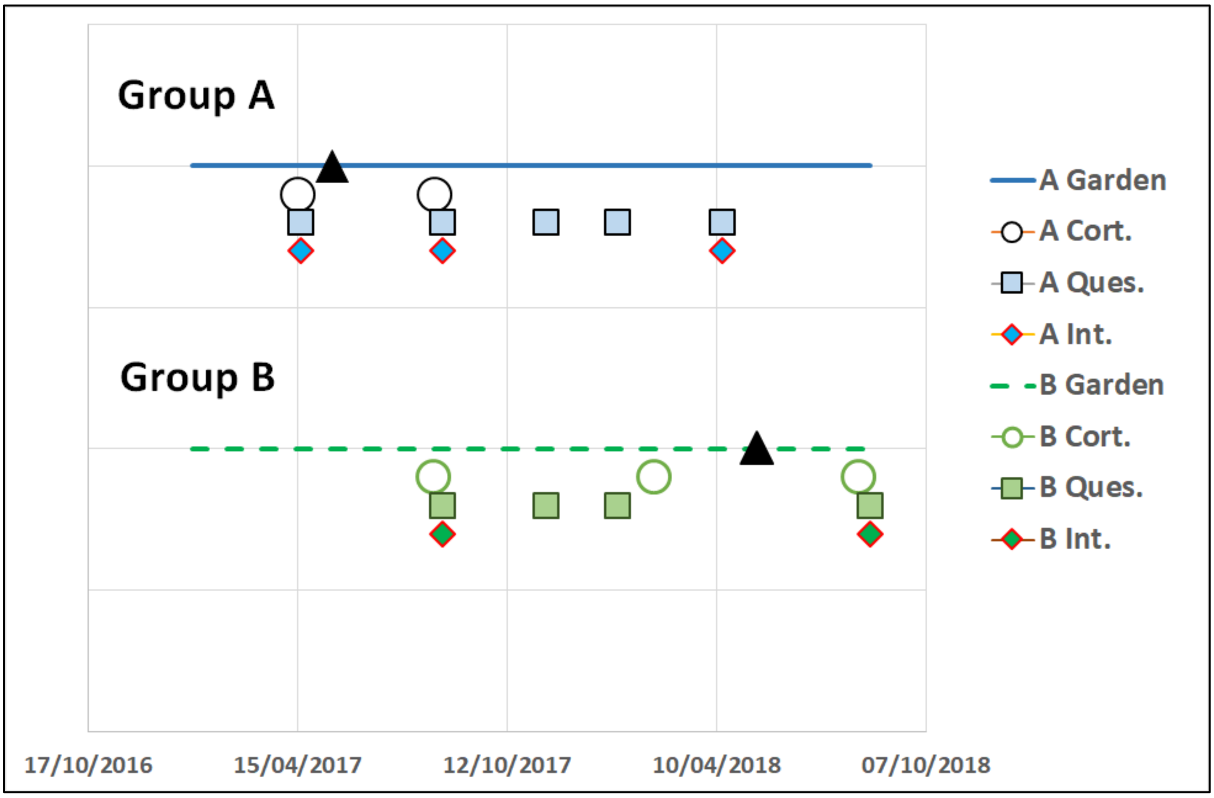

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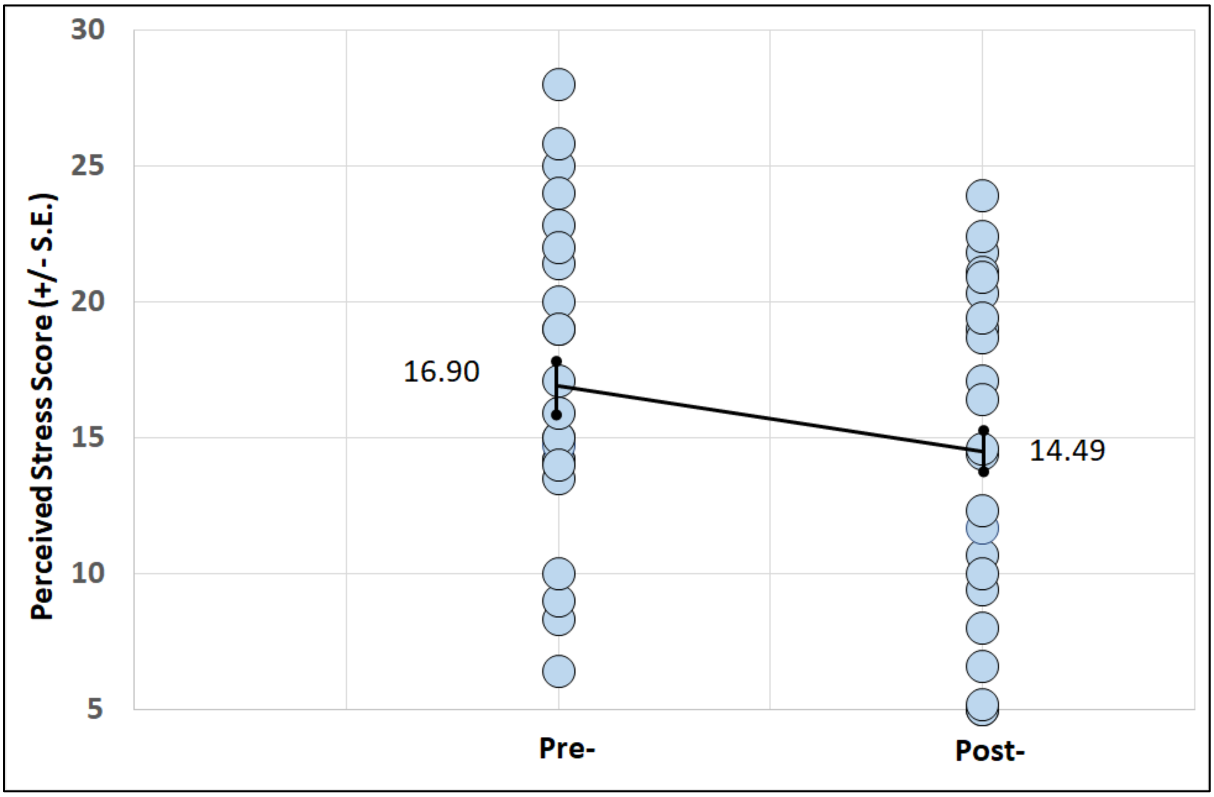

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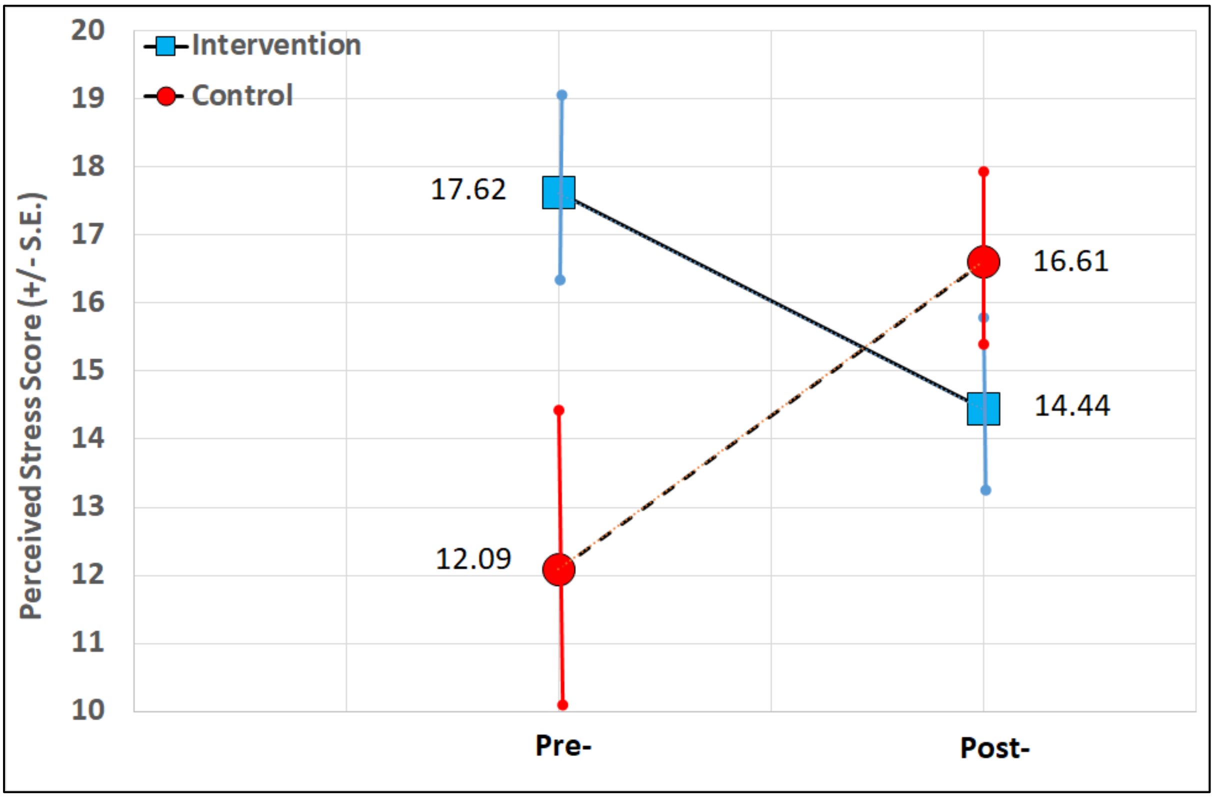

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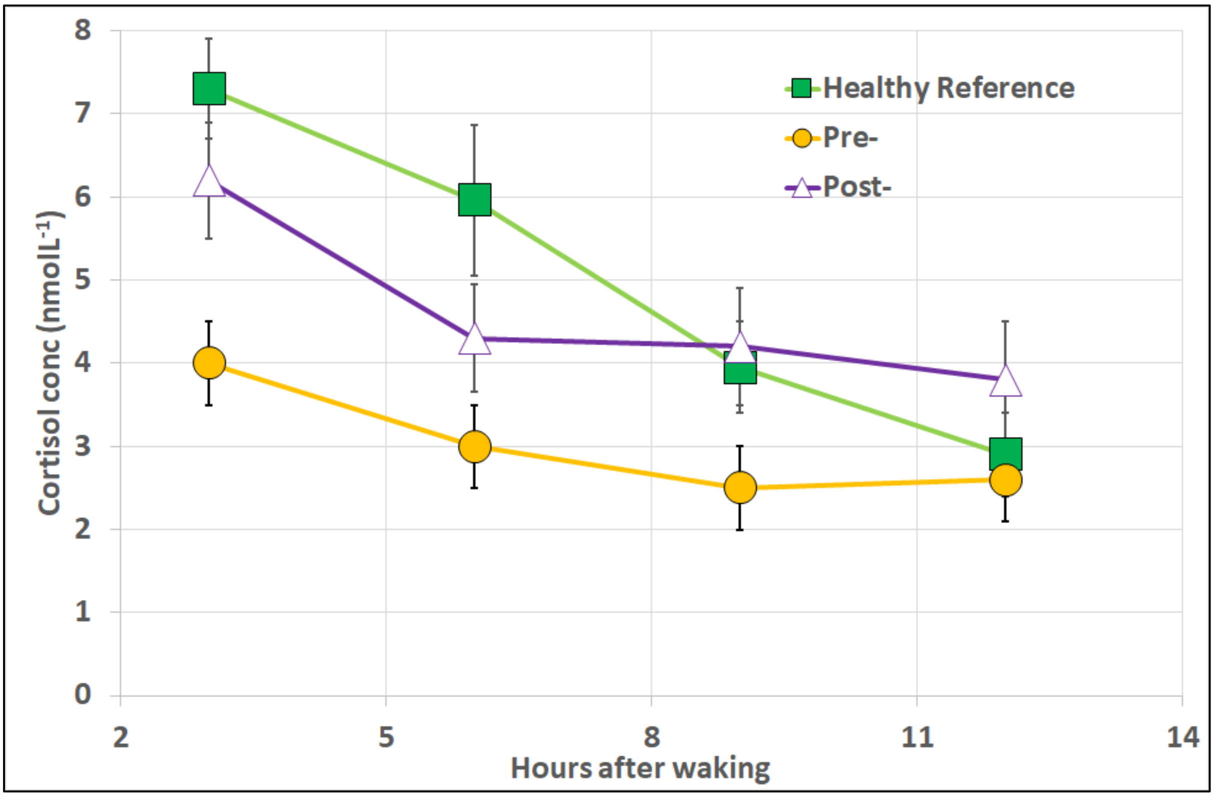

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