



Research Article

# The Impacts of Integrated Health Hydroponic Planting on Green Space Exposure, Happiness, Anxiety and Stress among Secondary School Students: A Feasibility Quasi-Experiment

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## Abstract

**Background:** Mental health of adolescents have been exposing to risk factors associated with stress from a variety of sources. Previous studies identified that green space exposure might be effective for promoting mental health and reduction of stress. However, previous literature focused on adults, and for those which studied children and adolescents, the effects of planting and similar green activities remain to be explored. The aim of this study was to investigate the effects of a pioneer school-based program on green space use and satisfaction, and mental wellbeing indicators, among early adolescent students. **Method:** This was a feasibility quasi-experiment in which intervention and control groups were studied sequentially. Three secondary schools and 55 grade 7-8 students were sampled conveniently. In the intervention school, the green space program consists of (1) learning hydroponic planting; (2) learning green eating and tasting; (3) group practice in creating green areas at school. In the two control schools, the activities consisted of a standardized stress management program including (1) learning stress coping, (2) relaxation exercise, (3) green diet and green living activity in classroom. The activity schedule for each group (intervention and control) consisted of three one-hour sessions, each was conducted two to three weeks apart. Key outcomes were assessed with questionnaires at baseline and one month after the completion of the activity period as for each school. Data were fit with mixed model applying GEE. **Results:** At baseline, students were not sure whether they know how to plant herbs or prepare herbal tea. Control group at posttest had lower frequencies of using green facilities in the community and using school gardening facilities in the previous four weeks compared with intervention group and pretest. Females at posttest were associated with higher confidence in planting, and higher level of enjoyment from green activities. Other moderate to small but non-significant effects were also identified. **Conclusion:** In this study, the school based green space programme was found feasible for early adolescent students with statistically supported results. Limitations have also been identified and future study with larger scale, more frequent intervention, longer follow-up and RCT design are required.

**Keywords:** Adolescents; Hydroponic-planting; Stress management; Quasi-experiment; Green space; Anxiety; Stress; Happiness

## Introduction

Adolescent secondary school students are faced with multi-dimensional physical and psychological challenges that could impact on their mental well-being. They are at an adolescent development stage, and need to cope with abrupt changes in their physical bodies. They are often under inter-personal pressure in forming new social relationships [1]. Academic pressure is also an important source of stress which affect mental health [2,3]. Most local students seek to relieve stress through engagement in physical activities, seeking peer support or listening to or engaging in music [4]. Yet, green space, gardening, horticultural and similar activities were found having positive effects on mental health.

In the literature, there were a number of evidence which show the association between green space and its related human activities and health. Urban greenery and water were deemed important elements to improve indoor air quality, temperature and protection against heat and cold, which have effects on both physical and psychosocial health [5]. Research evidence with multiple angles in terms of neuroimaging data and supporting cellular and molecular animal studies indicated the interaction between social and environmental risk factors of mental health [6].

In the community, adults who lived closer to green space had lower perceived stress, better perceived health and related QoL, and were more likely to use green space for relaxation [7]. According to a review done in 2013 [8], adults with mental health issues had their depression and anxiety reduced, and benefited in physical, emotional, social, spiritual and even vocational domains after joining gardening activities. In Hong Kong, researchers found that horticultural activity could improve psychiatric patients' level of anxiety, depression and stress in a RCT [9]. The above evidence imply that human activities associated with plants for aesthetics could have positive effects on mental health.

Longitudinal evidence indicated that health benefits from green area appeared in different life courses between genders. In men, benefit of more green space emerged in early to mid-adulthood [10]. In women, but at older ages, moderate availability of green space was found contributing to better mental health. More benefits of green space might extend to physical health also. Previous study showed that cardiovascular disease and respiratory disease mortality rates decreased with increasing green space, but in men only [11]. Yet, women were found more active, saw greater aesthetic value, and had higher self-reported wellbeing in urban green spaces than men [12]. However, these gender differences were not confirmed in adolescents who would participate in green activities. Outdoor green space was found facilitating protective

factors of health such as increased free-time physical activity level in early adolescents [13]. Previous study also showed that neighborhood parks was associated with reduced stress among adolescents regardless of SES [14]. Nonetheless, the mental health benefits of gardening, horticulture or similar activities on adolescents needed further studies.

Due to increasing urbanization and densification in Hong Kong, most students live far away from green space. Hydroponics is a method of plants growing in a flexible scale with the use of water-based, nutrient-rich solution. With proper care, the plants can grow fast and strong by using less water; and hydroponics plants are more environment friendly than soil-based plants [15,16]. Hydroponics in the green roof systems are potentially applicable in Hong Kong building for example the schools in which adolescents spent most of their time [17].

Whether having green space at schools could provide them, however, a means for stress reduction or help them develop a green-living attitude and behavior remained unclear. Earlier studies investigated the effects of green space programs holistically, but the specific effects had remained unexplored to date. There was also limited research on the relationships between green spaces, Gender differences on mental health in secondary school students. Thus, the aim of this study was to investigate the impact of a pioneer school green space program on selected mental health indicators in secondary school students after participating in either the designed program or control activities with follow up.

## Hypothesis

It is hypothesized that after participation in the green space programme, students' will have their green space exposure and mental wellbeing in terms of 1) green space use and satisfaction, 2) anxiety and stress symptoms, 3) level of happiness improved compared with those who joined control activities.

## Methods Design

This was a feasibility quasi-experiment in which there was one intervention school and two control schools. Activities were conducted in each school sequentially.

## Eligibility criteria and sampling

The eligibility criteria of schools were 1) secondary schools in Hong Kong, 2) having a potential venue for hydroponic planting, 3) allowing students to participate in extracurricular activities. The eligibility criteria of students were 1) secondary school students (grade 7-8), 2) able to communicate in Chinese, 3) no allergy to soil, pollens or plants, 4) no G6PD deficiency.

Convenience sampling was done to sequentially recruit the first control school in Feb 2018, and the second control school and the intervention school in Sep 2018. The intervention school was

the one which showed interest in installing hydroponic planting system. One control school comprised three classes for each grade, and the other schools consisted of four classes for each grade. Each class contained 33 students. One class from grade 7 and one class from grade 8 were randomly recruited by the teacher in each school. Students in each recruited class were then conveniently recruited. Before the study activities, students with consents were screened for eligibility criteria on a checklist. Those who did not satisfy any one of the criteria were not included.

## **Intervention**

In the intervention group, the program, run by undergraduates who were trained by hydroponic planting therapist, consisted of (1) learning hydroponic planting; (2) learning green eating and tasting; (3) Group practice in creating green areas at school. The content included the introduction of basic techniques of planting, including material choosing, seeding, and watering; with materials provided for students to do hands-on planting. The theory part was taught in classroom and the practice session was held in the playground. The school was provided with hydroponic planting devices for the practice sessions. In addition, one teacher was trained for the technique of planting and the management of green plants, in order to guide the students for a sustainable green space at school. The control group consisted of a standardized stress management program of (1) learning stress coping, (2) relaxation exercise, (3) green diet and green living activity in classroom. The students were supervised and guided by trained undergraduates from The Hong Kong Polytechnic University.

The activity schedule for each group (intervention and control) consisted of three one-hour sessions, each was conducted two to three weeks apart. The research activity period for the first control school was from Mar 2018 to Jun 2018; the period for the second control school and intervention school was from Oct to Dec 2018.

## **Outcomes**

Key outcomes which were assessed at baseline and posttest included 1) green space use and satisfaction, 2) anxiety and stress, 3) happiness. Questionnaires which measure all targeted outcomes were distributed to both groups at baseline and one month after the completion of the activity period as for each school. Another outcome assessed at baseline was the green dietary habits. Students were blinded to study hypothesis though not blinded to activities they have participated in.

### **Green space use and satisfaction**

Green space use and satisfaction was assessed in three domains, they were 1) level of exposure to green space (four items); 2) perceived benefits of green activities (three items); 3) satisfaction of green space available (four items). Each item was

measured by a four-point ordinal scale. Higher score indicates more frequent green space use in the past four weeks or level of agreement. The instrument was developed by the research team based on literature review. Its content validity was assessed by three experts in occupation health, mental health nursing, and community health nursing, respectively, who had extensive experiences in promoting healthy lifestyle at school. They independently rated the relevance of each item by using a four-point scale. The Content Validity Index for Items (I-CVIs) was high (I-CVI = 0.98). Test-retest reliability was assessed on ten participants who completed the same questionnaire two weeks apart. The reliability was satisfactory ( $r = 0.764$ ). The scale reliability (internal consistency) at baseline was acceptable (Cronbach's  $\alpha = .755$ ,  $n=55$ ).

### **Anxiety and stress**

The self-reported anxiety and stress symptoms of the participants were measured by the corresponding subscales in the DASS (21 items) which was freely provided by the Psychology Foundation of Australia [18,19]. Each subscale comprised seven items which measure either anxiety, stress or depressive symptoms in the past week. Respondents were asked to rate each statement on a four-point ordinal scale from 0= not applicable to 3=most applicable. Higher score indicates more severe symptoms. DASS-21 showed satisfactory internal consistency and three-factor structure in Asian [20] including Chinese young populations [21].

### **Happiness**

Happiness was measured by the Delighted-Terrible Faces (DT-Faces) Scale which is a seven-point ordinal VAS [22]. The score ranged from 1=most happy (face A) to 7=most unhappy (face G).

### **Green dietary habits**

Green dietary habits were assessed with five items at baseline, they were the level of agreement on knowing how to grow edible plants, understanding, habit and promotion of green diet. Each item was measured with a four-point ordinal scale. Higher score indicates better habits.

### **Data Analyses**

Questionnaires at baseline and posttest were matched using the class and class number of students in each school. Categorical demographic characteristics included sex, cohabitants, religion and housing. Between groups differences in these characteristics were tested with Fisher exact tests [23]. Continuous demographic characteristics included age, years living in Hong Kong, and amount of pocket money got per week. Between groups differences in these variables were tested with independent t tests [24]. Between groups differences in green dietary habits at baseline were tested with Wilcoxon rank sum tests [25]. The group, time, sex effects and their interactions on green space use and satisfaction and mental

wellbeing in terms of stress, anxiety and happiness were tested with generalized estimating equations [26]. Error distribution was assumed following the Gaussian family. The correlation structure between time points was specified as AR1. Significance level (alpha) was set at .05. All analyses were done on R version 4.0.3 on RStudio 1.4.1103.

**Ethical Considerations**

Ethical approval for this study was obtained (*ID: HSEARS20160618002*) from the ethics committee of The Hong Kong Polytechnic University. Information sheets and parental consent forms outlining the details of the program were distributed to recruit students. This ensures participating students and their parents or guardians understood the potential risks and benefits of participation in the study. They were also informed of the rights to withdraw from the study at any time. Students who did not obtain parental consents were not included. Consent was also sought at the school level from a representative of each participating school. Both school representatives and participants were informed that data would be analyzed anonymously and in aggregate. At the end of the program in each school, all students received information and resources of counselling and mental health services.

**Results**

At baseline, 59 students were recruited in total. The period of recruitment and follow-up fell between Feb 2018 and Dec 2018. There were 18 students in the intervention school and 41 students in the control schools. At posttest, four students dropped out from the control group, hence the final number analyzed was 55.

Demographic characteristics were presented in Table 1. There were no significant between- group differences in sex, cohabitants, religion, housing, age, years living in Hong Kong, except living with maternal grandmother and the amount of pocket money received per week. However, the number of those living with maternal grandmother was small. Though the mean pocket money in control group was higher, the dispersion was also greater. Overall, the mean age of the sample was 13.5 (SD = 0.81), 60% of the sample were males, and over 60% were living in public housing. Over three-fourths did not have religious belief. Above 90% were living with mother but only three-fourths lived with father. Sixty percent of the sample were living with siblings. A majority of the participants were not living with grandparents.

		<b>Intervention</b>	<b>Control</b>	<b>Fisher exact</b>
		N=18	N=37	p
Sex	1=male	8	25	0.14
	2=female	10	12	
Live with father	1=yes	14	27	1
	2=no	4	10	
Live with mother	1=yes	16	35	0.59
	2=no	2	2	
Live with siblings	1=yes	12	21	0.57
	2=no	6	16	
Live with number of siblings	0	6	16	0.059
	1	4	15	
	2	7	5	
	4	1	0	
Live with paternal grandfather	1=yes	3	1	0.098
	2=no	15	36	
Live with paternal grandmother	1=yes	7	7	0.19
	2=no	11	30	
Live with maternal grandfather	1=yes	0	1	1
	2=no	18	36	
Live with maternal grandmother	1=yes	3	0	0.031
	2=no	15	37	
Live with others	1=yes	1	1	1
	2=no	17	36	

Live with number of others	0	18	36	1
	1	0	1	
Religion	1=nil	13	29	0.66
	2=Buddhism	2	1	
	3=Catholic	0	1	
	4=Protestant	3	6	
Housing	1=public	11	23	1
	2=non-public	7	14	
		<b>Intervention</b>	<b>Control</b>	<b>Welch t test</b>
		Mean (SD)	Mean (SD)	p
Age		13.39 (0.92)	13.54 (0.77)	0.55
Years living in Hong Kong		9.67 (5.05)	11.35 (3.51)	0.21
Pocket money per week		27 (45.05)	120.41 (128.55)	0.00025

**Table 1:** Demographic characteristics.

In Table 2, it shows that the green dietary habits at baseline did not have significant between- group differences. Generally, both groups agreed that they could understand the importance of balanced diet, consume optimal portions of vegetables, and encourage the others to follow green eating. However, students in the intervention group were not sure whether they know how to plant herbs or prepare herbal tea. Participants in the control group disagreed that they know how to plant vegetables or herbs or prepare herbal tea.

	Intervention		Control		Wilcoxon
	Median	MAD	Median	MAD	p
I know how to plant vegetables	3	0	2	0	0.12
I know how to plant herbs and make herbal tea	2.5	0.74	2	0	0.080
I can eat three portions of vegetables per day	3	0	3	1.48	0.10
I know the importance of a balanced diet	3	0	3	0	0.067
I encourage others to follow green eating	3	0	3	0	0.81

MAD: Median Absolute Deviation

**Table 2:** Green dietary habits at baseline.

Table 3 shows the effects of group, time and sex and their interactions on green space use and satisfaction as well as mental wellbeing in terms of stress, anxiety and happiness scores. The group by time effect on the using green facilities in the community and the using school gardening facilities were significant; where control group at posttest had lower frequencies of these activities in the previous four weeks compared with intervention group and pretest. Other moderate to small but non-significant effects included those on other outcomes such as happiness level, satisfaction with the green facilities in the community, and feeling relaxed when using the green facilities. We also see significant sex by time effect on the confidence in planting correctly, feeling relaxed when using the green facilities, and feeling happy when looking at their own plants. Females at posttest were associated with higher confidence in planting, and higher level of enjoyment from green activities.

	(Intercept)	Control	Post-test	Female	Control at post-test	Female at post-test
	b (SE)	b (SE)	b (SE)	b (SE)	b (SE)	b (SE)
Use green facilities in the community in the past four weeks	0.66 (0.22)**	0.25 (0.25)	0.35 (0.34)	0.11 (0.26)	-0.74 (0.35)*	-0.13 (0.34)
Visit green space of your school in the past four weeks	0.55 (0.28)*	-0.09 (0.29)	-0.22 (0.31)	0.41 (0.28)	0.17 (0.33)	-0.01 (0.34)



Use school gardening facilities in the past four weeks	0.16 (0.14)	0.11 (0.18)	0.39 (0.2)	0.51 (0.22)*	-0.67 (0.24)**	-0.29 (0.25)
I know the location of the green space facilities at school	1.66 (0.23)***	-0.19 (0.25)	0.12 (0.32)	0.31 (0.27)	0.04 (0.32)	0.08 (0.32)
I have confidence in planting correctly	2.07 (0.06)***	0.11 (0.09)	-0.44 (0.14)**	-0.22 (0.1)*	-0.11 (0.15)	0.58 (0.16)***
I think that green living lifestyle can promote concentration	1.85 (0.2)***	0.08 (0.18)	-0.18 (0.24)	-0.03 (0.15)	-0.08 (0.23)	0.23 (0.21)
Green school program can promote communication	2.04 (0.12)***	-0.13 (0.14)	-0.32 (0.22)	0.03 (0.15)	0.02 (0.22)	0.17 (0.21)
I am satisfied with the current green space in school	1.67 (0.16)***	0.03 (0.18)	0.4 (0.17)*	-0.01 (0.18)	-0.2 (0.2)	-0.01 (0.21)
I feel relaxed when I use the green facilities	1.99 (0.17)***	0.09 (0.17)	-0.66 (0.26)*	-0.09 (0.17)	0.31 (0.25)	0.58 (0.22)**
I feel happy when I look at my plants	2.13 (0.14)***	-0.01 (0.14)	-0.37 (0.18)*	-0.03 (0.13)	0.09 (0.18)	0.37 (0.18)*
I am satisfied with the green facilities in the community	1.62 (0.22)***	0.3 (0.23)	0.25 (0.23)	0.08 (0.22)	-0.41 (0.26)	0.16 (0.25)
Mean of stress score	0.46 (0.15)**	0.14 (0.16)	0.31 (0.23)	0.04 (0.15)	-0.14 (0.24)	-0.15 (0.23)
Mean of anxiety score	0.46 (0.14)***	0.04 (0.15)	0.25 (0.22)	0.05 (0.13)	-0.13 (0.23)	-0.12 (0.22)
Happiness level	2.92 (0.33)***	-0.06 (0.35)	-0.52 (0.44)	-0.25 (0.35)	0.57 (0.47)	-0.06 (0.48)

b: regression coefficient of GEE model. \*p<.05, \*\*p<.01, \*\*\*p<.001.

**Table 3:** Green space use and satisfaction and mental wellbeing regressed on group, time and sex.

## Discussion Limitations

The major limitation in this study was that the sample size was not large, and the balance between groups was further complicated by group allocation as there was only one set of hydroponic planting device. As seen in the results, the number included in the intervention group was 18 and the number in control group was 37, though the sample size of 55 was considered for parametric tests. But, for example, in crosstabs, some cell counts were small that favor Fisher exact test over chi-squared. Another limitation related to smaller sample size was lower statistical power. For example, in the GEE model, some estimates with moderate effect

sizes (moderately strong coefficients) were non-significant.

Regarding the assessment of green space use and satisfaction, the number analyzed in test-retest reliability was small, and validities such as convergent, concurrent and factor structure validity require further study.

On the other hand, recall bias and effect contamination might exist since the posttest was done one month after the last day of activity period for each school. Participants in the community might be exposed to different confounders over time as research activities were not run in parallel for all schools. For example, control group participants might or might not join green

activities themselves in the window period. Therefore, future RCT is required.

### **Generalizability**

The generalizability of the study results and intervention might be compromised by non-random sampling, and the combined limitations of group allocation and sample size, and the limitations in assessment tool and schedule. However, the report of this study supports that hydroponic planting is a feasible intervention for adolescents in school setting with potential and statistical positive outcomes in terms of green space use, satisfaction, and mental wellbeing.

### **Interpretations**

The hypothesis regarding the improvements, after participating in hydroponic planting, in green space use and satisfaction was partially supported; and the hypothesis with respect to mental wellbeing requires further investigation. However, some of the results related to gender difference are somehow consistent with the literature that females, over time, were more emotionally and confidently engaged in green activities. The non-significant group by time effects for the variables in terms of mental wellbeing might support an interpretation that the effects of hydroponic planting might be comparable to those of control activities, as stress reduction intervention was also provided in the control group. Another reason that we did not find significant group by time effects on mental wellbeing might be that students recruited were from general population which were not patients or at-risk groups recognized. However, future studies could focus on these groups to examine the benefits of hydroponic planting on them. Further, the frequency and period of intervention could be lengthened. One-hour session for every two to three weeks for three times might not be frequent enough to allow significant differences between groups. In addition, there was no post-test for green dietary habits. Future studies should answer these related questions.

In the competitive education system worldwide, sources of pressure for school children could be from too much homework, long school hours and preparation for secondary school entry and/or unsatisfactory school performance [27,28]. Green space exposure and green activities could minimize the mental health risks. Previous evidence shows that during childhood, risk for subsequent mental illness in those who lived with the lowest level of green space exposure was higher compared with those who lived with the highest level of exposure [29]. Stronger association was observed in cumulative exposure compared with single-year exposure. A Dutch survey discovered that households with a high volume of green space within three km radius were less affected by experiencing stressful life event, and potentially the perceived mental health issues [30].

Nonetheless, the use of public green space could be affected by demographic factors such as gender, lifestyle, and family background. In a cross-sectional study of Dutch [31], adolescents reported that green environment was very important for them to visit green spaces frequently for physical and social activities. In particular, males, those who owned dogs, or those having educated father visited green spaces more often. However, the visits were not associated with the quantity of green space around the residential area. A German survey showed a non-linear (inverted U-shape) relationship between the amount of and distance to green space and life satisfaction in urban residents [32].

At school setting, school based green activities were considered feasible interventions for students' wellbeing. However, previous results, including findings in this study, render further investigations. For example, results in study with small sample size and without randomization might not be satisfactory. Researchers in England conducted six monthly intervention sessions allowing 36 children and young adolescents with mental and developmental difficulties to develop green space at school under the guidance of horticulturists and psychotherapist. However, the quantitative outcomes regarding mental wellbeing were not satisfactory in this pre and posttest design [33]. A RCT with larger sample size is warranted. In terms of other benefits, previous RCT also hypothesized that school gardening intervention, in combination with coordinated approach in school-based interventions, might promote healthy eating, physical activity and improve weight status in elementary students [34]. However, the results later published did not find significant differences in outcomes such as vegetable preference, exposure, intake and fruit intake between intervention groups and the control intervention (Coordinated School Health) [35]. That means the differences in outcomes between targeted gardening intervention and no intervention remain unclear and require further trials.

### **Conclusion**

In this study, the school based green space programme was found feasible for early adolescent students with statistically supported results of green facility use in the community and school gardening, as well as gender differences which echoed the findings in the literature. Limitations have also been identified and future study with larger scale, more frequent intervention, longer follow-up and RCT design are required. Nevertheless, our new findings support the implementation of integrating hydroponic planting techniques into the conventional planting to promote students' mental health at secondary schools. In the context of contemporary adolescent development, education should be holistic and should not be confined to academic achievement; additional out-of-classroom experiential learning activities that enable students to learn in real-life contexts, broaden their horizons and foster whole-person development should be encouraged. In the future, the

implementation of the integrated health green space programme with hydroponic planting in urban area could be a sustainable mode of promoting green space concepts and greenness exposure to benefit key stakeholders such as adolescents, schools and families.

## Author Contributions:

**Conceptualization:** C.S.T.W and Y.K.C; **Methodology:** C.S.T.W and Y.W.M; **Validation:** C.S.T.W and Y.W.M.

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23. (2021) RDocumentation. `fisher.test`: Fisher's Exact Test for Count Data.
24. (2021) RDocumentation. `t.test`: Student's t-Test.
25. (2021) RDocumentation. `wilcox.test`: Wilcoxon Rank Sum and Signed Rank Tests.
26. (2021) RDocumentation. `geeglm`: Fit Generalized Estimating Equations (GEE).
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