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Healthy Trees – Healthy People: A Model for Engaging Citizen Scientists in Exotic Pest Detection in Urban Parks

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Healthy trees – Healthy people: A model for engaging citizen scientists in exotic pest detection in urban parks

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ABSTRACT

Healthy Trees – Healthy People (HT-HP) is an outreach and education program created to enlist and train participants in exotic pest detection while providing them with structured opportunities to connect with urban nature and increase their physical and emotional health. HT- HP creates infrastructure to increase engagement by the urban populace in the urban tree canopy. The program solicits participants to engage in an 8-week intervention designed to expand capacity to detect non-native insect pests and pathogens, while increasing physical activity, raising awareness of healthy lifestyle choices, and improving the health of participants. Program participants were trained in tree and tree pest identification to provide 'eyes on the ground' that can contribute to exotic pest detection, reducing the risk of pest establishment, and increasing the sustainability of urban tree canopies. Participants in this pilot program reported significant improvements in their knowledge of tree identification and tree care, an awareness of, and ability to identify selected exotic invasive tree pests, and improved mindfulness. *Healthy Trees – Healthy People* is nimble, easily adaptable, and serves as a unique model that could include tailored tree identification and pest detection. The program can engage citizen scientists in exotic pest detection while increasing usage of urban parks.

1. Introduction

Trees are an essential component of urban nature, creating a vibrant aesthetic, contributing critical ecosystem services, and cultivating a sense of community safety. In urbanized areas, trees are proving essential to mitigate increasingly extreme conditions associated with climate change, playing a key role in reducing heat island effects (EPA, 2019). Urban trees also create a refuge for non-native, invasive, potentially devastating insect pests and pathogens, which devalue the trees, compromise their contributions to ecosystem benefits such as stormwater mitigation, energy savings, and carbon sequestration (Peltzer et al., 2010; Lovett et al., 2016; Linders et al., 2019), and threaten their sustainability.

Tree canopy coverage in many Kentucky communities is well below the recommended 40 % (Lexington 25 %, Louisville 30 %; Davy, 2012, 2015). Given the importance of urban trees and the challenges associated with maintaining them in the face of human development and associated abiotic stressors, coupled with persistent threats due to species' invasions, it is essential that we develop strategies to protect, maintain, and enhance the urban tree canopy. Organizations and government agencies tasked with maintaining tree health and mitigating the impacts of invasive species are increasingly turning to education and outreach to engage urban dwellers for invasive species detection and mitigation. One artifact of a more engaged populace may be improved human health outcomes.

A rapidly accumulating body of evidence demonstrates that exposure to nature and green spaces improves physical and emotional health and improves quality of life for urban populations (Hartig et al., 2011; Frumkin et al., 2017 and references therein). Globally, over half of humans and 80 % of US citizens live in urbanized areas (United Nations, 2019), increasingly disconnected from nature and green spaces, and deprived of the mental, physical, and social benefits of contact with nature. Urban parks serve an important role by providing opportunities to experience nature and engage in physical activity and social interaction in urban communities. Many urban dwellers fall far short of the recommended 150 min per week of physical activity (US DHHS, 2018), and the relatively recent realization of the importance of nature to human health is increasingly informing streetscape and urban planning decisions to support active living (Jackson, 2003; Shanahan et al., 2015). In addition, exposure to nature during physical and recreational

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activities provides urban users additional benefits compared to the same activities indoors that translate to higher scores in self-reported quality of life, and lower reports of anxiety and mental distress (Konijnendijk et al., 2013; Yuen and Jenkins, 2019). The connection between engagement with nature and increased mindfulness is well established (Barbro and Pickett, 2016; Schutte and Malouff, 2018), but some studies are starting to show there is a unique relationship between exposure to nature, mindfulness, and increased likelihood of engaging in pro-environmental behaviors (Barbaro and Pickett 2016). Although the specific mechanisms that link exposure to nature with positive health impacts are unclear, positive dose responses have been observed between nature exposure and several parameters of mental, social, and physical health. People enjoy greater emotional and physical health benefits with greater exposure and access to nature, and nature itself may serve as a motivator for engaging in physical activity (Cox et al., 2017; Velarde et al., 2007; Bowler et al., 2010; APHA, 2016).

Kentucky ranks 45th out of 50 states in overall human health (UHF, 2018), and 48th in the frequency of mental distress. Many of the physical health metrics driving this ranking are directly linked to physical inactivity, including cardiovascular deaths (44th), diabetes (44th), and obesity (43rd). Protecting and engaging with our urban trees is key to enhancing their health benefits to humans (Karjalainen et al., 2010; Donovan et al., 2013). To fully realize the benefits to ecosystem and human health that urban trees provide, it is essential that the risks associated with invasive insect pests and pathogens be minimized, prompting development of novel approaches to encourage and involve community members to engage in local parks with a focus on urban trees.

The *Healthy Trees – Healthy People* (HT-HP) outreach and education program was developed as a mechanism to increase public engagement in the urban tree canopy and provide a programmatic model for initiatives with similar aims. The primary objective of HT-HP was to expand capacity of community residents to detect non-native insect pests and pathogens and assess tree health within local urban parks, assessed in this study by tree knowledge and pest identification. Program participants were trained to provide "eyes on the ground" that can contribute to pest detection, minimizing establishment of invasive species, enhancing tree canopy health, and increasing the sustainability of urban tree canopies within local parks. As a result of increased engagement in nature through the setting of parks, secondary objectives of the program include human health-related behaviors and outcomes as measured by physical activity levels, weight, blood pressure, and mindfulness. Incorporating human health promotion within the intervention was also leveraged as a recruiting mechanism to increase interest and participation in the program which has a primary focus on tree health and pest identification. Program activities were developed to encourage and engage a more active populace, thereby enhancing the health and well-being of our urban populations.

2. Materials and methods

2.1. Program structure

Healthy Trees – Health People (HT-HP) was developed as a pilot outreach and education program to help increase engagement of urban populations in their urban forests in one Kentucky city; it was not developed or advertised as a weight loss program. The structure of the program included several months of program development, a mandatory orientation session, followed by an 8-week walking intervention that included brochures highlighting the featured trees in five urban parks, weekly newsletters, and voluntary guided walks. The program concluded with a mandatory closing session (Fig. 1).

Participants' tree knowledge, tree pest identification awareness, body weight, blood pressure, self-reported miles walked, self-reported fruit and vegetable consumption, mindfulness, and stress levels were measured before and after the pilot study. All study protocols and data collections tools were approved by the Institutional Review Board.

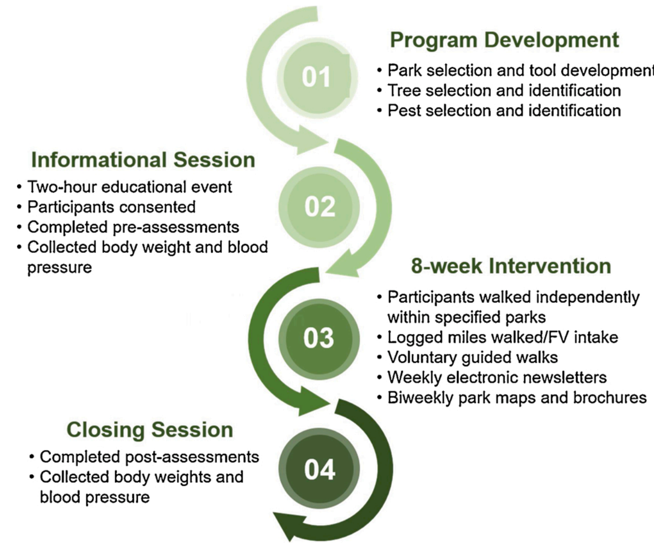

Fig. 1. "Healthy Trees – Healthy People" program structure and overview.

2.2. Program development

2.2.1. Park selection and tool development

Selection of parks and development of tools occurred 4–6 months prior to implementation of the program to provide ample time for materials development. Five public parks in Lexington, Kentucky were selected based on their geographic spread across the city, walking paths less than 1 mile in length, accessibility, and ease of walking (e.g., paved, low grade), in order to increase inclusivity and accommodate various physical abilities of participants.

For each park, a series of brochures were developed (Fig. 2) with a map of the walking path and the three selected trees for that brochure highlighted. Brochures were distributed electronically via email at two-week intervals, and highlighted three trees per park, so that participants received four brochures per park over the course of eight weeks. In total, 12 trees were featured in each park for a total of 48 trees. However, some redundancy in species selection occurred, in part to reinforce learning, so across all parks, 37 distinct tree species were featured over the course of 8 weeks (Table 1).

2.2.2. Tree selection and identification

Using existing walking paths, trees adjacent to the paths were selected based on their size, stature, prevalence, and pest risk. Featured trees were numbered, identified, and the height and diameter at breast height (DBH; 1.37 m above ground level) was measured. Each tree's contribution to ecosystem services was assessed using the National Tree Benefit Calculator (NTBC, 2017), which provides a simplified estimate of the overall benefits of individual trees, including contributions to storm water interception, energy savings, air quality, carbon sequestration, and property value. This information was included as an educational component within program brochures. The general health and pest status of each tree was assessed using a level one assessment (ANSI A300 2017), where the tree stem, branches, and canopy were visually examined for insect pests, pathogens, and any physical anomalies. Based on species and size, the risks of featured trees to known non-native, invasive insect pests were estimated.

Selected trees were numbered and photographed, and the identifying characteristics described. Information was provided on species identification and characteristics, size of selected tree, its relative health, pest threats, ecosystem benefits, and conservation status. Brochures taught users to focus on common characteristics used in tree identification (e.g.,

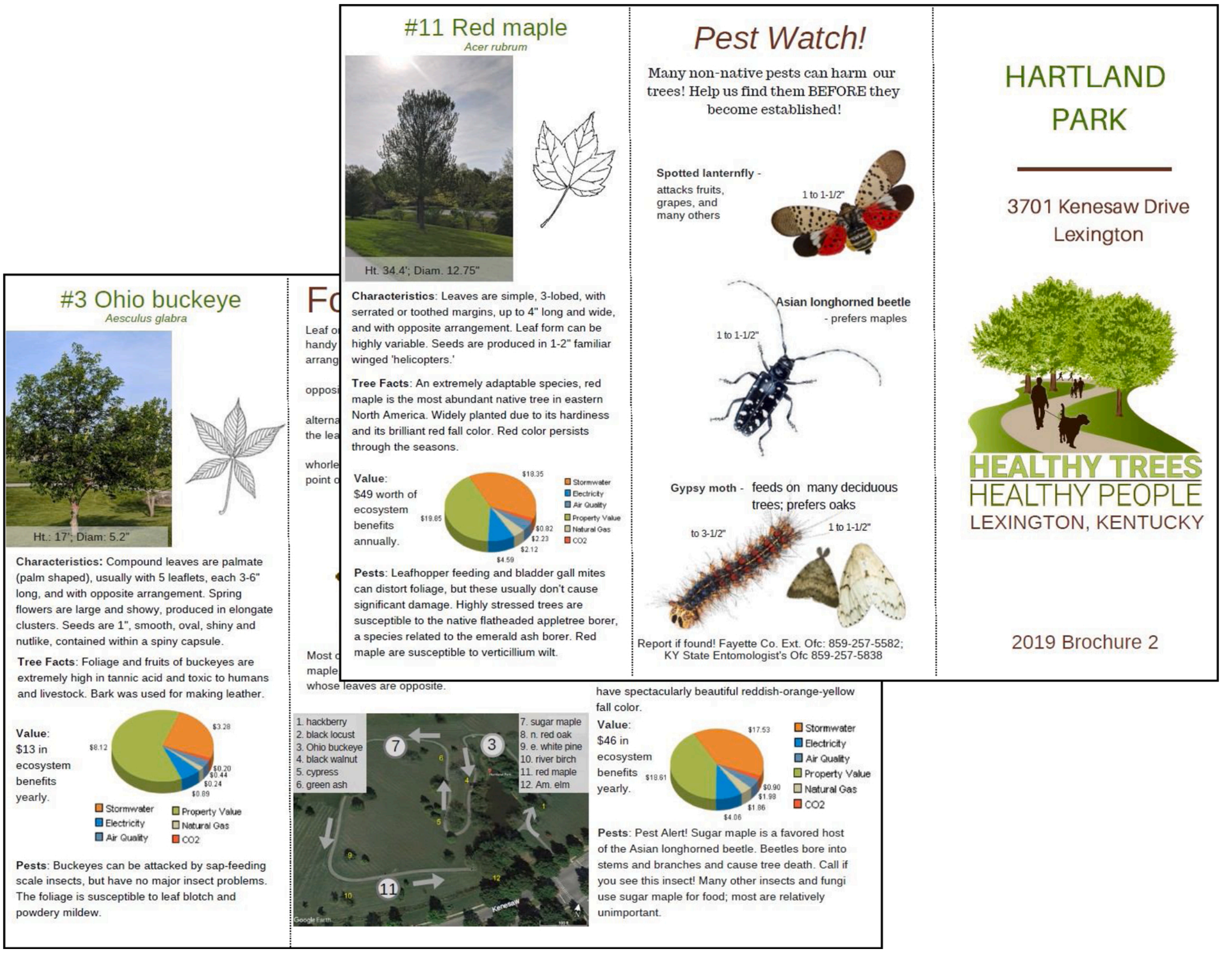

Fig. 2. Each brochure contained a map of featured trees and a "Pest Watch!" panel summarizing focal pests of concern and were distributed to participants every other week (4 brochures per park).

conifer vs. deciduous, simple vs. compound leaves, seed form), and provided tips to reduce confusion with tree identification (Fig. 2).

2.2.3. Pest selection and identification

Participants were also trained to identify selected non-native, invasive insect pests currently not found in Kentucky but that serve as imminent threats to urban trees. Each of these pest species have federal quarantines restricting their movement to guard against expansion of their invaded range in the US. The exotic pests in the "Pest Watch!" facet of the HT-HP program included the gypsy moth, *Lymantria dispar* (Lepidoptera: Erebidae), a non-native defoliator of oak trees that is the target of extensive regulatory efforts and whose invaded range is encroaching toward Kentucky (http://ky-caps.ca.uky.edu/). Among the featured trees in the HT-HP program were five selected oak species that could serve as preferred hosts of the gypsy moth. Also included was the Asian long-horned beetle, *Anoplophora glabripennis* (Coleoptera: Cerambycidae), an exotic wood-boring beetle that is encroaching on Kentucky and threatening its urban trees (http://ky-caps.ca.uky.edu/). Sugar maple is the preferred host of Asian long-horned beetles, and the HT-HP program included three sugar maples among the five parks. The third 'Pest Watch!' species was the spotted lanternfly, *Lycorma delicatula* (Hemiptera: Fulgoridae), which is posing an immediate and urgent threat to Kentucky (http://ky-caps.ca.uky.edu/). The preferred host plant is tree of heaven, *Ailanthus altissima*, but spotted lanternfly will also attack many other tree species, as well as grapes, stone fruits, and apples.

Each brochure generated for HT-HP contained a "Pest Watch!" panel depicting these exotic invaders and included phone numbers of appropriate regulatory officials to report positive finds or aid in identification, so that participants always had resources in hand to help identify any potential sightings (Fig. 2).

2.2.4. Participants

Healthy adult volunteers, 18–85 years old, were recruited with flyers, newsletters, radio announcements, and social media communications. Those who fell outside the specified age range or had been advised by their doctor to avoid physical activity were ineligible. No prior knowledge of trees or pests was expected of participants. Two cohorts were enrolled (summer 2018 and summer 2019), and the same intervention and study design was used for both years. Target enrollment was 50 individuals for each year. Participants who completed the program by providing pre- and post-intervention data were compensated $40.

2.2.5. Intervention

Recruited participants attended a mandatory 2 -h informational session, which included collection of written consent, an explanation of the study, initial data collection and completion of pre-assessment questionnaires, and an educational presentation. New and existing programmatic materials were utilized to train recruited participants in assessing tree health and tree maintenance needs, including general observations on insects and pathogens and specific exotic pest species (Fig. 3). Featured trees for the program were highlighted during the presentation and relevant tree pests and tips on exotic pest detection were provided.

At the close of the information session, participants were

Table 1
Park characteristics and featured trees for *Healthy Trees – Healthy People.*

Park	Acreage	Paved walkingtrail	Featured trees
Belleau Woods	18.10	0.48 mi; 10' elevation gain	Black cherry, Black walnut, Box elder, Bur oak, Eastern redbud, Hackberry, Lacebark elm, Shagbark hickory, Sugar maple, Swamp white oak, Sycamore, Tulip poplar
Castlewood	32.40	0.5 mi; 9' elevation gain	American basswood, Austrian pine, Bald cypress, Bitternut hickory, Black walnut, Blue ash, Bur oak, Chinkapin oak, Hackberry, Osage orange, White oak, Eastern white pine
Harrods Hill	12.57	0.45 mi; 17' elevation gain	Black cherry, Black locust, Black walnut, Bradford pear, Eastern white pine, Japanese chestnut, Northern catalpa, Northern red oak, Red mulberry, River birch, Sugar maple, Sweetgum
Hartland	17.13	0.48 mi; 9.3' elevation gain	Bald cypress, Black locust, Black walnut, Eastern white pine, Green ash, Hackberry, Northern red oak, Ohio buckeye, Red maple, River birch, Slippery elm, Sugar maple
Kirklevington	32.20	0.8 mi; 41' elevation gain	Bald cypress, Black cherry, Black locust, Black walnut, Eastern white pine, Hackberry, Japanese chestnut, Loblolly pine, Northern red oak, Red mulberry, Scots pine, Tulip poplar

encouraged, but not required, to walk in any one of the five designated urban parks while practicing tree identification for eight weeks. Those who wished to could walk at independent locations. Regardless, participants were asked to walk a minimum of 2–3 times per week. Participants were provided diet and exercise logs to record fruit and vegetable intake in cups per day and time spent walking in 15-minute increments over the course of the 8-week intervention. Participants also received the brochures mapping the trees in each park with additional information for each of the featured trees.

Study personnel offered 2–3 guided walks each week at rotating parks to visit, identify, and discuss highlighted trees, provide accountability, and generate a sense of community (Fig. 4). Participation in guided walks was voluntary, and substitute walking locations were acceptable.

To maintain engagement and provide encouragement, participants received a weekly electronic newsletter highlighting aspects of tree health and pest detection, human health, physical activity, healthy food choices, and times and locations of upcoming guided walks (Fig. 3). At each 2-week mark during the intervention, participants received the next set of electronic brochures that featured new trees in each park. After eight weeks, participants were invited to a closing session where post-assessments and final data collection was completed (Fig. 1). At the program closing session, participants were encouraged to continue utilizing the program brochures and maintain their engagement in their urban tree canopy.

2.2.6. Assessments

At the initial information session, demographics, body weight, and blood pressure were collected and recorded for each participant by study personnel. Pre-intervention questionnaires were administered recording self-reported physical activity levels and fruit/vegetable (F/V) consumption and mindfulness using validated survey tools (Topolski et al., 2006; Baer et al., 2008; Harden et al., 2016). Self-reported levels and patterns of physical activity were measured using the International Physical Activity Questionnaire Short Form (IPAQ-SF). For mindfulness, the Five Facet Mindfulness Questionnaire (FFMQ) was used which evaluates the five factors that are associated with current concepts of mindfulness, including observing, describing, acting with awareness, non-judging of inner experience, and non-reactivity to inner experience. In the second cohort, perceived stress was measured using a validated instrument (Cohen et al., 1983). In addition, pre-program knowledge of tree identification, urban tree benefits, and urban tree health threats (exotic pests) were assessed using program-specific surveys. Post-intervention questionnaires using the same assessment tools were administered at the closing session after completion of the 8-week intervention.

2.3. Analysis

When appropriate, descriptive statistics were used for proportions and averages. Paired-sample t-tests were conducted to compare tree and pest identification, mindfulness, perceived stress scales, blood pressure, body weight, time spent walking, and fruit and vegetable consumption before and after completion of the program. For survey scores, (i.e., mindfulness, tree, and pest identification), scores were included only if the assessment tools were entirely complete for the participant. The analysis was performed in SAS 9.4.

3. Results

In the first cohort, 45 enrolled and 38 completed the study. In the second cohort, 26 individuals enrolled and 22 completed. In sum, 71 participants enrolled in the program and 60 participants completed the program (84.5 % completion rate) over the course of two summers. Over 93 % of participants were Caucasian and 65 % were female (Table 2). The average participants were highly educated Caucasian females, 55−74 years old, with highly variable annual incomes. The majority (55 %) perceived themselves as "very healthy" and 53.4 % had normal BMIs (body mass index 18.5–25). A relatively small number (1.7 %) described themselves as "not healthy," and 18.3 % had BMI $>$ 30.

3.1. Tree and pest knowledge

Tree and pest knowledge and identification were the primary outcomes of this study. Participants reported strongly significant improvements in tree knowledge (Table 3A). In the pre-intervention assessment, participants demonstrated a weak understanding of tree identification and tree care, and a weak grasp of the ecosystem services that trees provide; the mean for tree knowledge prior to intervention was 64.4 % (16.1 correct out of 25 possible). Post-intervention tree knowledge scores improved considerably (20.6 correct out of 25) and were ~1.25x greater than pre-intervention knowledge. An even greater improvement occurred with respect to awareness of and the ability to recognize selected exotic tree pests, which was a major impetus for implementing the program. Prior to the intervention, participants scored only 32 % (3.2 correct out of 10) on questions associated with selected exotic insect tree pest identification and damage recognition. But awareness of and the ability to recognize the same selected exotic insect tree pests increased 2.4x over the course of the intervention (7.8 correct out of 10), a strongly significant gain (Table 3B).

3.2. Human health behaviors

Human health outcomes and behaviors were secondary outcomes of this study. As an indication of physical activity levels, time spent walking was self-reported. Over the course of the intervention participants reported no differences in the time spent walking; time walking (days walking × time walking per day) was equivalent pre- and post-intervention (404 vs. 407) (Table 3C.*i*). In contrast, participants self-reported an increase in fruit and vegetable consumption from 3.5 to 4.1 servings per day, a significant increase of 0.53 servings (Table 3C.*ii*).

Fig. 3. Newly developed (a) brochures and newsletters, and (b) pre-existing programmatic materials were used to educate, engage, and incentivize.

There was no difference between pre- and post- measurements of participants' weight (Table 3D.*i*). Also, systolic and diabolic blood pressure levels (Table 3D.*ii-iii*) did not change over the intervention. However, participants demonstrated substantial and significant increases in mindfulness; scores on the FFMQ increased significantly between pre- and post-assessments (Table 3D.*iv*). We found no difference in perceived stress levels evaluated in participants in the second cohort only (Table 3D.*v*).

Weather permitting, guided group walks were offered 2–3 times per week during evenings and Saturday mornings; the location rotated among the parks. Attendance ranged from 1 to 8 participants (Fig. 4), with an average of 3 participants per walk and an average duration of 1 h. A total of 43 participants took part in at least one guided walk, which provided study personnel a gauge on participant engagement. Weather (e.g., rain, heat index) was frequently a factor in determining the occurrence, attendance, and duration of the guided walks.

HT-HP participants anecdotally reported greater engagement with their city parks, including first-time park visits and/or visiting with greater frequency. The positive reception of the HT-HP program by participants was reflected by the program's selection for an Environmental Commission Award, given annually by the Lexington-Fayette Urban County Government in recognition of projects that significantly contribute to the improvement of the local environment in an effective or unique way.

4. Discussion

The urban tree canopy is an essential component of urban green spaces and represents a primary means for city dwellers and the urban populace to connect with nature. Despite the obvious benefits to human

Fig. 4. Guided walks highlighting selected trees were offered 2-3 times per week for the duration of the 8-week program.

Table 2
Demographics of participants that completed the program (n = 60).

	N = 60 (%)
Gender	
Male	21 (35.0)
Female	39 (65.0)
Age	
18–34	8 (13.3)
35–54	13 (21.7)
55–74	35 (58.3)
75+	4 (6.7)
Ethnicity	
Caucasian	56 (93.3)
Indian	1 (1.7)
Hispanic/Latino	1 (1.7)
Native American	2 (3.3)
Education	
High school Diploma/GED	2 (3.3)
Some College	4 (6.7)
College Graduate	19 (31.7)
Some Graduate School	11 (18.3)
Completed Graduate School	24 (40.0)
Annual Household Income	
<$25,000	15 (25.0)
$25,000-$49,999	18 (30.0)
$50,000-$99,999	15 (25.0)
≥$100,000	12 (20.0)
BMI	
Underweight (>18.5)	2 (3.3)
Normal (18.5-<25)	32 (53.4)
Overweight (25.0-<30)	15 (25.0)
Obese (>30)	11 (18.3)
Perceived Overall Health	
Extremely Health	4 (6.7)
Very Healthy	33 (55.0)
Somewhat Healthy	22 (36.7)
Not Healthy	1 (1.7)

health and urban ecosystems that these trees provide (Karjalainen et al., 2010), they also serve as a conduit and refugia for invasive insect pests and pathogens (Sweeney et al., 2019). Preventive regulatory measures aimed at reducing invasive species introductions have been adopted (Haack et al., 2014), but the rate of introductions remains steady, and

Table 3
Pre- and post-intervention parameters (mean (s.e.)) evaluated during the 8-week Healthy Trees-Healthy People program. Paired t's were assessed on Confidence Limits for means.

	Intervention			
	Pre-	Post-	tdf; $P > t$	N1
A. Tree knowledge	16.1 (0.7)	20.6 (0.5)	t59 = 8.31; $P <$ 0.001	60
B. Pest knowledge	3.2 (0.4)	7.8 (0.4)	t54 = 10.00; $P <$ 0.001	55
C. Human behaviors				
i. Time walking[2]	403.9 (69.3)	407 (64.2)	t54 = 0.53; $P =$ 0.60	55
ii. Fruit + vegetable consumption[3]	3.5 (0.2)	4.1 (0.2)	t59 = 2.29; $P =$ 0.03	60
D. Human health				
i. Weight	164.6 (4.1)	163.3 (4.6)	t59 = -0.42; $P =$ 0.68	60
ii. BP – systolic	121.8 (2.0)	119.2 (2.5)	t59 = -1.95; $P =$ 0.06	60
iii. BP – diastolic	78.9 (1.3)	78.1 (1.3)	t59 = -0.45; $P =$ 0.66	60
iv. Mindfulness score	136.0 (2.0)	142.3 (2.2)	t39 = 3.23; $P =$ 0.003	40
v. Stress	15.2 (1.2)	15.1 (1.2)	t18 = -0.22; $P =$ 0.83	19

the pressures of live insect introductions has not been alleviated (Brockerhoff and Liebhold, 2017; Seebens et al., 2017). The risks that urban trees represent with respect to invasive species introductions and establishment must be balanced with the essential roles that they play in providing ecosystem services and in enhancing human health (Sweeney et al., 2019 and references therein). Striking this balance is reflected in the growing realization of the need for community-based monitoring programs that allow citizen scientists to positively contribute to the environment in their communities (Conrad and Hilchey, 2011).

Since the mid 1990's, government agencies responsible for biosafety and biosecurity, including those responsible for exotic pest detection and interception, have increasingly relied on outreach and education programs to encourage citizen input (Thomas et al., 2017). Citizen scientist-driven programs can potentially provide broad spatial and temporal input regarding tree health and pest presence. However, data quality can vary (Crall et al., 2011), and participant retention can be problematic (Lewandowski and Specht, 2015). We addressed this by maintaining regular contact via emails containing tree and pest information and healthy choice reminders. Participants were also provided frequent opportunities to reinforce learning through face-to-face interactions via our guided walks.

In this pilot study, our findings suggest that the HT-HP program may serve as a model for outreach programming that effectively enhances tree knowledge and pest identification among community members in an urban environment. HT-HP provides a mechanism for supporting urban tree health and managing persistent tree health challenges in urban communities, while balancing the pervasive global threat of invasive pests.

HT-HP is unique in the fact that it provides evidence for the potential positive influence of community-based monitoring programs on the environment and exhibits a positive impact on the health of participants themselves. Participants demonstrated significant improvements in mindfulness, yet the specific component of the intervention that contributed to this effect was not determined. Likely due to the relatively short duration of the study and the overall health status of the cohorts at the time of the pre-assessments, there were no significant changes in body weight or blood pressure. Further, there was no increase in self-reported physical activity among participants. This finding may be attributable to the fact that participants recruited for this study were already active walkers, and the program provided no additional impetus and no benefits to them with respect to additional physical activity.

Based on the existing literature connecting physical activity to increased mindfulness (Roberts and Danoff-Burg, 2010; Kennedy and Resnick, 2015), it would be expected that our improvements in mindfulness may be a result of increased physical activity within parks. However, in this study, we saw improvements in mindfulness without increased levels of self-reported physical activity, suggesting that the setting and location within urban parks and/or the focus on trees and pest identification, may have contributed to increased mindfulness regardless of physical activity. It should also be noted that the increases in mindfulness were observed even without reinforcement in the weekly newsletters, further suggesting these results may be a product of participation in activities in nature rather than educational materials.

Healthy eating practices, with an emphasis on fruit and vegetable consumption, were highlighted during the informational session, and subsequently reinforced in the weekly newsletters. Interestingly, participants showed a significant increase in self-reported daily cups of fruits and vegetables consumed. This affirms that information and guidance within the newsletters was supportive of this behavior change, and is perhaps a reflection of increased mindfulness among participants. It may seem illogical to evaluate this healthy living practice within this study, yet these findings reinforce existing literature that states healthy lifestyle choices are synergistic and are interwoven within practice (Jayawardene et al., 2016). These secondary outcomes may seem detached from the tree and pest focus of the project, but they suggest that further studies should examine the connection between environmental monitoring practices and increased desires in participants to also implement healthy practices and behaviors in their own personal lives. This finding would be insightful for dual-purpose community-based monitoring programs and outreach projects that emphasize both environmental and human health.

4.1. Limitations

Although the HT-HP program is a novel approach to engage urban populations in local parks, the pilot project has limitations. First, participants were demographically homogenous; they were generally healthy, physically active, and highly educated. Future adaptations of the program should recruit from populations with greater demographic variability that are less likely to self-select. To improve sampling, strategic recruitment through community-based organizations or groups interested in environmental monitoring may be ideal. Second, data related to health behaviors was self-reported; self-reported data is notoriously skewed and for statistical validity requires a much larger sample size than what our study provided. Third, the study was of a short duration and with no control group. Eight weeks is insufficient to generate meaningful and lasting changes in physical health metrics, though our increases in mindfulness and tree and pest knowledge provides hopeful baseline data for future investigations.

4.2. Considerations for implementation

HT-HP provides a framework for use in other communities to train citizens to assist in detection of exotic urban tree pests, increase use of urban parks, and enhance community engagement of urban populations. While conceptually the HT-HP program is easily transferable to other communities, the materials produced in our pilot study are unique to Lexington, Kentucky, and cannot be generalized to other communities. For example, the structure of the program and the deliverables were easily modified to respond to evolving pest concerns within urban trees over the course of the two-year study. In the first year, an exotic pest in the "Pest Watch!" of HT-HP was the walnut twig beetle, *Pityophthorus juglandis* (Coleoptera: Curculionidae), which is part of an exotic insect – fungal complex and carries the fungus that causes thousand cankers disease on black walnut (https://forestry.ca.uky.edu/tcd). There were five black walnuts among the selected trees at the five parks. By the second year of the study, the walnut twig beetle was deemed less of a forest health concern by regulatory officials and was dropped from the "Pest Watch!" brochures. This demonstrates that the HT-HP model is flexible, and nimble enough to respond to changing tree pest concerns, depending on the urban tree species and relevant pests in a given geographic region.

Adapting the program and methodology to other communities would require initial inputs for materials development, unique collaborations between stakeholders invested in tree and human health, and community engagement. Necessary tools to be adapted include logos, marketing materials, informational presentations, brochures, newsletters, or other forms of communication relevant to the target population. This novel approach of bridging tree and human health may be of interest to community organizations and stakeholders interested in programs that creatively enhance community-based environmental monitoring. In addition, this program provides a unique approach to provide experiential learning and professional development opportunities for aspiring tree specialists, environmental educators, health professionals, and urban parks departments, who may be willing to manage the program, develop the regionally appropriate tools and materials, and facilitate guided walks.

4.3. Future directions

Future iterations of HT-HP should examine how programs engage and support citizens in community-based environmental monitoring initiatives. Using qualitative feedback from participants would be insightful for understanding how to increase participation in similar volunteer initiatives, garner program buy-in and support from the community, and showcase the value of the program to stakeholders that is not captured in quantitative methods. Future directions may include a program with a duration greater than 8 weeks, and other creative strategies to reinforce learning and behavior change. This may include using web-based apps or other forms of technology and tracking methods.

5. Conclusion

The aim of this pilot study was to develop a program infrastructure to expand community tree engagement and increase capacity for exotic pest detection, while promoting healthy lifestyle among participants. While initial input is high, implementation of the *Healthy Trees – Healthy People* program provides a dual advantage; communities will benefit from training citizen scientists in exotic pest detection and promotion of healthy tree canopies, while encouraging physical and emotional health. This program allows for novel and unique collaborations between community stakeholders to emphasize the link between tree and human health and encourages and engages a more involved populace.

Declaration of Competing Interest

The authors report no declarations of interest.

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