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Examining Healthy Community Design Characteristics and Its Influence on Physical Health

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THESIS

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EXAMINING HEALTHY COMMUNITY DESIGN CHARACTERISTICS AND ITS INFLUENCE ON PHYSICAL HEALTH

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Abstract

Current trends in obesity rates associated with the community layout constitutes research towards understanding the interaction between the two in order to improve the public's physical health. Successes in healthy community planning studies for the public can be harnessed and implemented within the microcosm of military bases to yield similar results. Four factors were recognized through an in-depth academic literature review that showed positive influence on physical health and physical activity. They are access to green space, highly connected pedestrian and bicycle networks, access to public transportation, and integrated mixed land use. The four healthy planning strategies formed the necessary background to analyze the Healthy Base Initiative survey. A priori data from the Air Force Civil Engineer Center was examined for reliability, validity, and consistency. The results uncovered the fact that the exploratory nature of the Healthy Base Initiative survey was too wide-ranged in its questions leading to an inconclusive and undesirable outcome. The new DoD Healthy Activity Public Planning Investigative survey addresses the issues of the Healthy Base Initiative survey by reducing the most applicable healthy planning factors to the four strategies highlighted from the literature review. The novel survey combines questions pertaining to existing healthy base infrastructure with a validated World Health Organization Global Physical Activity Questionnaire to examine the causal relationship between physical health and environment. Altogether, the significance of this research presents four concise healthy planning strategies for the Air Force Civil Engineer Center and the Department of Defense, as well as a recommendation for a way forward on understanding how to improve base occupant's physical health through healthy community planning.

I would like to thank my all of my classmates at AFIT. They have been my family away from home. To my family, thank you for their tremendous support when days seemed impossible. I thank my committee members for their expert knowledge on the subject. Most importantly, I give thanks to my thesis advisor Lt Col Andrew Hoisington. Without his guidance and passion for mentoring I would not have accomplished this academic feat. Their combined support has allowed me to improve as an individual and I will carry this achievement with me proudly wherever I go.

Alvin T. Yip

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EXAMINING HEALTHY COMMUNITY DESIGN CHARACTERISTICS AND ITS INFLUENCE ON PHYSICAL HEALTH

I. Introduction

Background

The World Urbanization Prospects has reported that 66% of the global population will live in an urban environment by 2050 [1]. Urban growth and sprawl has a detrimental effect on physical activity and public health due to vehicular dependency, reduced rates of exercise, and decreased walking due to poor street connectivity [2; 3]. The health issues, particularly obesity, associated with physical inactivity has impacted over 160 million people in the United States. This is a cause for concern for community planners as more rural land is being converted into urban environments every year and currently 55% of the world population resides in urban areas [4]. The negative effects of obesity has accounted for $147 billion dollars in U.S. healthcare costs and led to 39.2 million days of lost work yearly. These trends have extended to the military as the number of individuals with a body mass index (BMI) over 30 has increased by 5.7% between 1995 and 2008 [5]. Furthermore, in 2015, the Armed Forces Health reported that 113,958 active duty service members had at least one obesity-related diagnose compared to the 86,186 individuals in 2010 [6]. The relationship between physical health and the urban environment is not completely known but it has been theorized that select factors in the community design may have an effect on obesity.

Community planning researchers have sought to alter the negative effects of urban-

ization into a positive aspect by studying different factors of community design. While there are countless community design factors, this paper focuses on specific strategies applicable to Department of Defense installations based on established healthy design factors in larger city and urban communities. The four fixated aspects are: access to green space and recreational areas, highly connected pedestrian and bicycle networks, integrated mix land use, and access to public transportation and transit facilities [7–11]. These four factors may not dramatically influence a person's physical activity but the synergistic combination of the healthy designs may contribute to healthier individuals. To gain a deeper understanding of healthy community planning and its impact to physical health, researchers have often used a survey to explore the causal relationship between the two.

Problem Statement

The Air Force Civil Engineer Center gathered information from community planners with the intent to explore areas of healthy planning most applicable to Air Force bases as well as discern the level of healthy planning across all bases. Their Healthy Base Initiative (HBI) survey data was provided to this study as a starting point to investigate community layout characteristics and its impact on physical health. As global urbanization is increasing and limiting individual's potential for physical activity; this research concentrates on examining healthy community designs and its influence on physical fitness and seeks to contribute to the Department of Defense by providing a survey which investigates the causal relationship between the community environment and physical activity.

Research Objective

Given the intent of this thesis is to provide and understand the impact the community layout has on public health, the research objectives are as follows:

1. Determining the established community layout factors in current literature that influence physical activity.
2. Analyze the Healthy Base Initiative Survey for reliability, validity, and consistency.
3. Develop a survey for the Department of Defense to assess healthy community design and examine public perception of physical health impacted by the base community layout.

Thesis Organization

This thesis follows a scholarly format in which chapters 2, 3, and 4 accomplish the three research objectives and chapter 5 is a summation of the whole study. Chapter 2, "Factors of Healthy Community Design" details an in-depth review of healthy community planning factors in current literature accompanied by a discourse of the Department of Defense's publications on the same. Four strategies of the community layout are identified to have an impact on the public's physical health: (1) green space access, (2) connected and safe pedestrian and bicycle infrastructure, (3) integrated mixed land use, and (4) access to public transit and transit facilities. Chapter 2 also addresses the Department of Defense's design documents, the Unified Facilities Criteria, and compares them with current public standards for healthy community planning.

Chapter 3 of this thesis, "A review of the Air Force Healthy Base Initiative Survey" builds upon the four healthy design strategies by investigating the survey tool's ability to measure the difference in planning and execution of healthy community designs. It also looks at the application of the four strategy healthy community layout model

on the HBI survey data to determine the reliability and validity of the survey tool. The third chapter will also present the descriptive statistics associated with the survey data and provide recommendations for changes to Air Force policy to improve healthy community design execution.

Chapter 4, "Development of the DoD HAPPI Survey" discusses standard research method procedure and how to apply them in development of a new survey. This chapter analyzes issues and limitations with the HBI survey and offers an explanation to readjust from a researcher's point of view. The DoD Healthy Activities Public Planning Investigative (HAPPI) survey was created through the combination of the in-depth literature review of chapter 2 and the HBI results of chapter 3. The novel survey is a combination of 13 questions that help the Air Force Civil Engineer target four specific facets of healthy design as well as 16 physical activity questions adopted from the WHO Global Physical Activity Questionnaire aimed at gaining an understanding of how base occupants feel their community layout is impacting their physical health. Finally, chapter 5 provides conclusions to this thesis and recommendations for future work.

Bibliography

1. D. of Economic, S. Affairs, and P. Division, *2018 Revision of World Urbanization Prospects*, 2018. [Online]. Available: https://www.un.org/development/desa/publications/2018-revision-of-world-urbanization-prospects.html

2. "Urban sprawl and risk for being overweight or obese." *American journal of public health*, vol. 94, no. 9, p. 1574–9, Sep 2004. [Online]. Available: http://www.ncbi.nlm.nih.gov/pubmed/15333317

3. H. P. Hynes, "Obesity, physical activity, and the urban environment: public health research needs," *Environmental Health*, vol. 5, no. 1, p. 25, Dec 2006. [Online]. Available: http://ehjournal.biomedcentral.com/articles/10.1186/1476-069X-5-25

4. U. Nations, "The Speed of Urbanization Around the World," 2018. [Online]. Available: https://esa.un.org/unpd/wup/

5. C. M. Reyes-Guzman, R. M. Bray, V. L. Forman-Hoffman, and J. Williams, "Overweight and Obesity Trends Among Active Duty Military Personnel: A 13-Year Perspective," *American Journal of Preventive Medicine*, vol. 48, no. 2, pp. 145–153, Feb 2015. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0749379714005054

6. L. L. Clark and S. B. Taubman, "Update: Diagnoses of overweight and obesity, active component, U.S. Armed Forces, 2011-2015," *MSMR*, vol. 23, no. 9, pp. 9–13, sep 2016.

7. "Active community environments (aces) resource kit to prevent obesity," 2009. [Online]. Available: http://dhfs.wisconsin.gov/health/physicalactivity/index.htm

8. T. Community Preventive Services Task Force, "Task Force Finding and Rationale Statement - Physical Activity: Built Environment Approaches Combining Transportation System Interventions with Land Use and Environmental Design," 2016. [Online]. Available: https://www.thecommunityguide.org/sites/default/files/assets/PA-Built-Environments.pdf

9. E. T. McMahon and T. C. Thoerig, "Ten principles for building healthy places building healthy places initiative," *Urban Land Institute*, 2013. [Online]. Available: http://uli.org/wp-content/uploads/ULI-Documents/10-Principles-for-Building-Healthy-Places.pdf

10. "Intersections: Health and the built environment," *Urban Land Institute*, 2013. [Online]. Available: www.uli.org

11. *Active design*, 2018, transit and Parking: Ref 11, 24, 19-22, 23Grocery stores and fresh produce access: 53, 54, 55, 56Create vendiagram of 4 domains, UFC, and universal design.

II. Factors of Healthy Community Design

Abstract

Obesity is a problem that plagues physical health across the United States. An estimated 160 million people in the U.S. are overweight or obese and the issue is occurring within the active duty personnel as obesity rates climbed 5.7% for people with body mass index greater than or equal to 30 between 1995 and 2008 [1; 2]. The purpose of this paper is to investigate the impact of the community layout on public health. Based on an in-depth academic literature review, four strategies were identified that can impact physical health to include: (1) improving access to plazas, parks, green spaces, and recreational facilities, (2) designing accessible, pedestrian-friendly streets and bicycle infrastructure with high connectivity, and traffic calming features for recreation and transportation, (3) developing and maintaining mixed land use in neighborhoods incorporating availability of fresh produce, and (4) improving access to public transit and transit facilities. Incorporating the four strategies in the community layout at each installation can compound and improve the overall health of the public, therefore, shifting towards a healthier base. Additionally, a discourse will be presented on the Department of Defense's Unified Facilities Criteria guidelines and the incorporation of the four strategies within their documents.

Introduction

Obesity is a physical health issue with an estimated 160 million people that are overweight or obese in the United States [1]. Reported in 2019, the economic impact of obesity accounted for $147 billion dollars in U.S. healthcare costs (personal health care, hospital care, physician services, allied health services, and medication) and caused 39.2 million days of lost work per year (lost output due to reduction in pro-

ductivity associated with morbidity or mortality) [3; 4]. In the military specifically, there might be a trend of obese active duty personnel, as apparent in the body mass index (BMI) over 30 increasing by 5.7% individuals between 1995 and 2008 [2]. In 2015, the Armed Forces Health reported that 113,958 active duty service members had at least one obesity-related diagnose, a 27.7% increase from 86,186 in 2010 [5]. Additionally, in 2019, healthcare associated with obesity in the military totaled over $1.5 billion annually [6]. Therefore, there is a concern in relation to obesity for both the military's and the public's physical health and quality of life.

Physical health and urban environments have been associated with obesity and physical activity [7; 8]. Currently, 55% of the world population resides in urban areas [9]. Specifically, within North America, 82% in individuals dwell in an urban environment [10]. In the next 30 years, global urban growth is expected to increase another 18% [11]. The continual increase in global urbanization will likely increase obesity rates and physical health. To properly address obesity, it is important to understand the influences on the characteristic, namely genetics, diet, physical activity, and the physical environment [12]. Well established research of family studies, investigations of parent-offspring relationships, and the study of adopted children support the genetic contribution to body weight [13]. Diet and physical exercise are individually motivated factors that are most impactful on an individual's weight [14; 15]. Numerous studies have reinforced regular exercise as an enhancement to adaptation of a low-saturated-fat, low-cholesterol diet to help curb obesity [16]. In contrast, the physical environment is a field of study not yet matured and requires more research to uncover the potential to influence the physical health of individuals [17].

Select factors in the physical environment that may have an effect on obesity include the community layout, socioeconomic status, neighborhood safety, and transportation opportunities [18]. The community layout is the man-made surroundings

in which people live, work, commute, and interact within their daily lives and the environmental layout is suggested to be linked to improved or degraded health and wellness [12]. The socioeconomic status of an individual contributes to their well-being because in general, the higher their status, the better their surroundings and health [19]. For example, higher socioeconomic status leads to safer neighborhoods to walk around or affording the option of better fitness centers. However, on the other hand, lack of socioeconomic status can lead to disconnect from green space, limited access to fresh food, and increased consumption of fast food [20; 21]. Lastly, public transportation opportunities are associated with a person's well-being because it involves the individual walking from their place of residence to the transit stop and from the transit stop to their place of work [22].

Although there are multiple community layout characteristics, it is important to note that this research is centralized on identifying factors most applicable to Department of Defense (DoD) installations. Therefore, following an academic literature review, guidelines from large cities and urban communities were examined and the most common healthy design characteristics were highlighted to form the specific community factors discussed in this paper. They are: (1) improving access to plazas, parks, green spaces, and recreational facilities, (2) designing accessible, pedestrian-friendly streets and bicycle infrastructure with high connectivity, and traffic calming features for recreation and transportation, (3) developing and maintaining mixed land use in neighborhoods incorporating availability of fresh produce, and (4) improving access to public transit and transit facilities [23–27]. These four domains were selected because of its ability to be implemented within the microcosm of a DoD installation and yield similar results compared to the public. The synergistic combination of the four strategies work together to improve individuals' physical health.

An expanded discourse on the four strategies is accompanied with an analysis of

existing policies in DoD base design guides (Unified Facilities Criteria (UFC)). The UFC documents govern planning, design, construction, sustainment, restoration, and modernization of all Military Departments and the Defense Agencies infrastructure. It is a system that is used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and Bilateral Infrastructure Agreements (BIA). Table 1 consolidates the information on the four strategies of a healthy community layout within UFC publication. Analysis of the existing policy will explore the extent to which this literature review is incorporated into the UFC documents.

Table 1. Existing Healthy Planning Strategies in UFC Publication

WBDG Publication	Healthy Community Strategy			
	Green Space	Pedestrian and Bicycle Infrastructure	Mix Land Use	Public Transportation Infrastructure
UFC 2-100-01 Installation Master Planning (2019)		Section 2-4	Section 2-2.4 Section 2-2.5	Section 2-2.3
UFC 2-100-01 Installation Master Planning (2019)			Section 2-5.4	
UFC 3-101-01 Architecture (2019)			Section 2-1	
UFC 3-201-02 Landscape Architecture (2009)	Section B-4	Section B-3		

Strategy 1 – Improving access to green spaces and recreational facilities

Integrating green spaces (plazas or parks) and recreational facilities into community layouts is the first strategy to improve physical health and decrease obesity. Community green spaces have aspects that complement the appeal of an area, to include items such as trees and their shade, or park benches and other public amenities [28]. In order to efficiently incorporate green space into a community environment, it should be collocated within the proximity of other land use types (i.e. residential or

commercial) [29]. The quality of green space such as cleanliness or aesthetic appeal affects the amount of usage, therefore, it should be well maintained [30–32].

There is evidence from research that supports occupants who live near an area with rich green space have the benefit of numerous health advantages [29; 33–35]. For example, in a 2002 urban environment study of 3,144 senior citizens, participants living in environments within a concentration of green space such as small gardens or green scenery was connected with increased lifespan, lower deaths from strokes, and lower obesity rates [34; 36; 37]. Children also benefit by choosing physical pastimes (i.e. sports) when living near green space [38; 39]. Optimizing the amount of green space in a community layout is another important factor to consider to ensure residents can easily access the public space. A Dutch national survey of 250,782 participants reported a noticeable difference in perceived health when comparing the percentage of green space within a three-kilometer radius (Figure 1)[29].

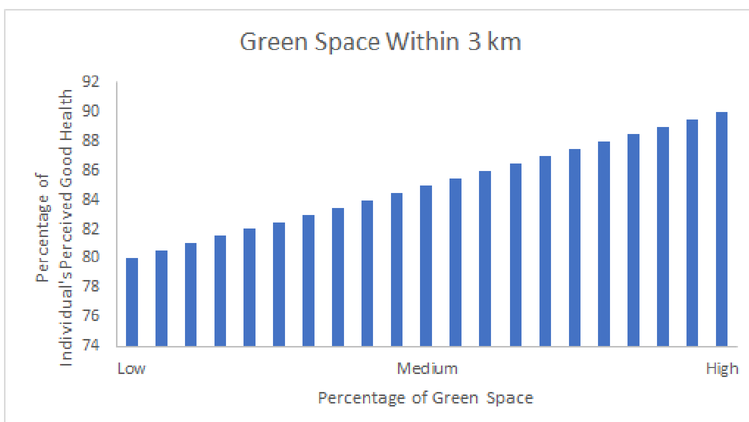

Figure 1. Relation between green space and self-perceived health. Adopted from [29]

The level of physical activity and health is also related to the distance required to reach a green area. Survey results from 11,238 participants reported that close proximity to green space fostered 26% more moderate and 11.3% more vigorous physical activity [40]. The relationship of proximity to green space and physical activity was also seen in a survey of 2,650 participants in Australia [41]. Furthermore, quality of

life improves with the addition of green space as concluded in a case study between green and non-green campus universities [42]. Students were more satisfied and had significantly higher perceived quality of life on a green campus. Individuals that perceive they are not close to a green space are less willing to walk for recreational purposes, therefore, a plausible relationship may be inferred between the increase of physical activity and physical health due to closeness to green space [43].

Current UFC standards comparison with green space standards

The Landscape Architecture UFC 3-201-02 governs the design and guidance of site improvements for DoD projects. The literature provides extensive requirements on grounds maintenance, urban forestry management, and brush management of base landscape. Section B-4 in the Landscape Architecture UFC regulates the common areas to include plazas, courtyards, parade grounds, recreational areas, landscape, monuments, and playgrounds. Although research suggests 96 square-feet of green space per person [44], there is no global minimum green space requirement to benchmark against, the UFC guides community planners to incorporate 4 – 12 square-feet per person of green spaces into the overall community layouts and contextual surroundings [45].

Another document that dictates DoD design is the Installation Master Planning UFC 2-100-01. It does not specifically outline a requirement for green space; however, it guides architects and community planners to contact local government offices when planning green space. Instead of keeping a separate document for landscaping, the Installation Master Planning UFC can improve its green space guidelines by incorporating the literature from the Landscape Architecture UFC document. Overall, the congruity between the DoD documents and the industry standards reflects accurate classification of green space as a healthy design characteristic. Both UFCs lack the

requirement to offer green space areas to occupants with regards to physical health. Detailed in the studies shown above, green space positively impacts individual's overall physical fitness and well-being, therefore, the DoD can improve its UFC guidance by pointing out the importance for green space in community environments.

Strategy 2: Designing accessible, pedestrian and bicycle-friendly infrastructure

The second impactful healthy community layout strategy incorporates pedestrian streets and bicycle infrastructure with high connectivity [36]. There are proven health benefits of a physically active lifestyle but, over 60% of American adults do not achieve these benefits and an estimated 25% do not conduct physical activities during their free time [9; 46] This may be due to the community characteristics of proximity to recreational facilities or street design and its role in motivating or discouraging physical activity [47].

Quantifying the walkability of an area can help associate walking with health benefits [48]. One of many methods to identify walkability is the objective scoring index. It measures walkability through z-score normalization of net residential density, retail floor area ratio, mix land use, and intersection density [49]. Environments with interconnected sidewalk infrastructure induce more walking [50]. Although there is research supporting socioeconomic status as an influential factor on walking, another impactful factor is the connected sidewalk infrastructure of an area [51]. Using the walkability index, 16 regions in King County, WA, and Baltimore, MD were selected for their neighborhood quality of life study. The study controlled for socioeconomic status and reported that participants walked 4% - 7% more in high walkable neighborhoods than low walkable neighborhoods [49; 52]. The results from a walkability study in Brisbane, Australia are similar, with an increase of physical health through

the influence of environment walkability and not by a neighborhood's socioeconomic status [53].

A longitudinal study named the RESIDEntial project (RESIDE) evaluated the impacts of the Western Australian government's new sub-division design code on walking, cycling public transportation use, and sense of community [43]. The RESIDE study sampled 1,813 residents before displacing them into 74 new housing developments, of which eighteen followed the new livable neighborhood development design code. Post-relocation results showed that participants in the eighteen new neighborhood developments walked for recreational (52.6%), transport (36.1%) than outside the neighborhood (13.2%) [43]. The unique contribution of this study was the opportunity to measure the resident's change in travel behavior (walking or biking times) while living in a low walkability area and after moving to an area with higher walkability. Conducting additional longitudinal intervention studies can help measure the different strategies of the community layout and its influence on physical health.

An integral part of pedestrian-friendly streets is a well-connected bicycle network with routes to parks and public spaces. A highly connected pedestrian and bicycle infrastructure network coupled with mix land use and green spaces helps to encourage physical activity by providing easy access to walking, running, and bicycling [54]. Nations like Australia, Canada, Ireland, the United States, and the United Kingdom only utilize bicycle as transportation between 1% to 3%, compared to Denmark, Germany, the Netherlands, and Sweden with 10% to 27% even though bicycling to destinations offers health benefits [55–57]. Safety, in terms of cycling routes and supporting infrastructure, limits the use of bicycling to destinations [58] therefore, one successful implementation for bikeway design is bicycle lanes in addition to automotive roadways. By separating bicycles and cars, cyclists feel safer and conflicts between the two are less likely to occur [59].

Drawing the public's attention to the health benefits of bicycle routes encourage more usage. Cities such as Sydney, Barcelona, Malmo, Sofia, and Freiburg have found both the economic and health benefits of bicycling in their urban environments [60]. The City of Sydney increased its bicycling travel behavior by producing guides for recommended routes to hospitals through rail stations and bus stops. Sydney further encouraged bicycling by investing in attractive and enjoyable bicycle routes as well as rewarding destination points of interest [61]. Furthermore, cities such as Melbourne, Brisbane, Washington, D.C., London, and Minneapolis/St. Paul have found success with implementation of a bike share system. These cities are among 800 other ones where users of bike share systems have benefited physically from the transition of automobile related travel to active transportation [62]. Bike share programs achieve success when they are conveniently located, reasonably priced, and well advertised in the community for users [63; 64]. From an economic perspective, a health economic assessment tool in the Netherlands estimated savings of $19 billion per year from bicycling which prevents about 6,500 deaths per year and leads to the Dutch population having an additional half-a-year longer life expectancy [65]. As a whole, changing the community layout to support bicycle infrastructure can improve physical health.

Current Air Force UFC standards comparison with street and bicycle infrastructure connectivity

The DoD Installation Master Planning UFC 2-100-01 section 2-4 governs healthy community planning. Section 2-4.1 guides community planners to create conditions that encourage physical activity through highly connected sidewalks, and bikeways. The guide recognizes the safety of pedestrians and bikers by integrating continuous infrastructure buffered from the street by a row of bushes or strip of plants

[66]. Section 2-4.2 highlights the benefits of connecting transportation networks as an alternate method of travel between origins and destinations. Furthermore, long stretches of sidewalks should incorporate mile markers for fitness activity tracking. Lastly, the guide recommends coordinating with the local transportation plan to ensure the installation's transportation network is appropriately linked with the surrounding community. The master plan takes into consideration the positive effects of well-designed pedestrian and bicycle infrastructure and how the decrease of auto dependence will lead to increased levels of walking, running, and cycling.

The Landscape Architecture UFC 3-201-02 section B-3 provides information on walkways and bikeways design standards and emphasizes the community characteristic importance of connecting centers of activities [45]. Section B-3.4 specifically objectifies walkways and bikeways to connect continuous pathways where possible, reduce safety conflicts between pedestrian, bicyclists, and automobiles, provide amenities for pedestrian and bicyclists. Section B-3.4.4 on bikeway designs states additional considerations such as pavement width, bikeway clearances, street crossings, and signage. Overall, the plans in-place for bicycling infrastructure planning are similar to literature on designing connected sidewalk and bicycle networks.

Strategy 3: Developing and maintaining mixed land use in neighborhoods

The third strategy is developing and maintaining mix land use in a community layout [67]. The term mix land use can be viewed as horizontal, vertical, or a combination of the two [68]. The vertical mix land has two or more different uses, occupying the same building. The horizontal mix land use describes two or more different types of functionalities that are placed within close proximity to each other. Both vertical and horizontal mix land utilize the proximity and connecting infrastructure to

increase walking and decrease driving, illustrated in Figure 2 [68; 69].

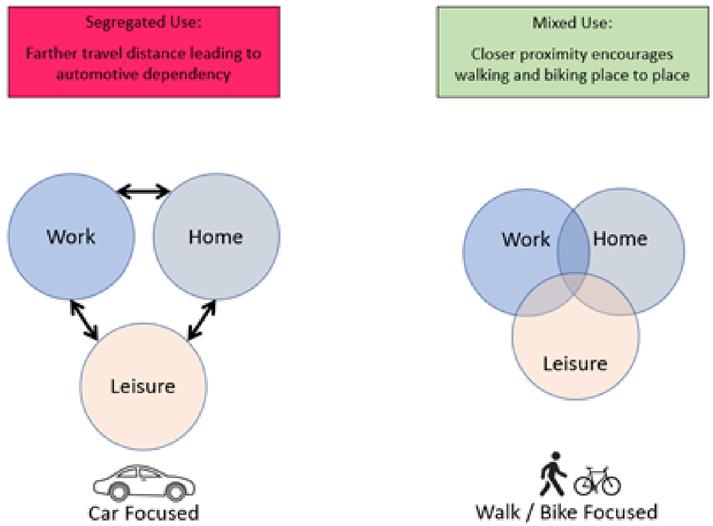

Figure 2. Influence of mixed land use on daily life. Adopted from [68]

The variety of mixed land use types in the community influences the level of walking in the area. For example, in the RESIDE project (mentioned above), researchers measured the volume of transportation via walking, based on the amount of mix land use types. The study noted that more mix land use types led to more time spent walking per week [70; 71].

Walking and bicycling between the different mixed land use area can also benefit physical health by decreasing the risk of heart disease. In 2005 study, the correlation between community layout, obesity, and coronary heart disease risk among 2,692 low-income women was assessed. By quantifying mix land use through different public facilities, it was observed that areas with more destinations of interest led to more exercising such as biking, walking, and running. Women who lived in a highly mixed land use area had a 2.6 lower BMI with 20% less risk for coronary heart disease compared to women in a low mixed land use area [72].

Another aspect of mixed land use's influence on physical health is travel behavior which can fluctuate due to the mix land use environment [68]. The variation in

mix land use can change the destination of trips, trip length, frequency of trips, and the mode of travel. Therefore, incorporating different mix land use types can help change travel behavior and motivate individuals to walk or bike as the method of transportation [67]. A study in 2002 studied the correlation in travel patterns between walking and transportation in a car with an individual's weight in Atlanta, Georgia. Using 10,878 participants in a cross-sectional travel survey, high mix land use participant's BMI decreased by 12.2% compared to subjects in a low mix land use environment [73]. The probability of an individual's obesity increased as time spent traveling by car increased [73]. In contrast, by walking at least one kilometer per day, the likelihood of obesity reduced by 4.8% [73]. Overall, incorporation of the mix land use strategy into community layouts improves physical health because individuals will walk and utilize more mass transportation options [52; 74].

While mix land use may benefit the community's healthiness, research warns of the negative impacts [68]. Mix land use can increase environmental air and noise pollution in residential areas [75]. It can also lead to heavy commercial vehicle activity in residential zones which can cause a blockage as the road width may not be designed for it [75]. Furthermore, a recent study by Wo (2019), showed that mix land use not only increases the traffic congestion of an area, it may also increase crime rates [76]. Lastly, the residential value may increase due to the different commercial uses in the local area and force low-income families to relocate [77].

Current Air Force UFC standards comparison with mix land use standards

Mix land use is one healthy community layout strategy covered in multiple UFCs. The DoD Installation Master Planning UFC 2-100-01 sections 2-2.4 and 2-2.5 provide guidance for horizontal and vertical mixed-uses [66]. The publication recommends

compact, synergistic, and integrated mix land use development. In other words, compatible land uses should be co-located. In the High Performance and Sustainable Building Requirements UFC 2-100-02, section 2-5.4 instructs designers to promote opportunities for occupants to voluntarily increase physical activity [78]. This overlaps with strategy 1 (improve access to recreational facilities) and can be interpreted as designing to include a small fitness center within or adjacent to the facility as well as a small court yard green space to allow for breaks throughout the day. Section B-1.3.1 of Landscape Architecture UFC 3-201-02 advises planners to site land uses with functional relationship to existing facilities and proximity to users [45]. The last document which covers mix land use is UFC 3-101-01 for Architecture. Section 2-1 generally requires planners to optimize the use of space within facilities [79]. Overall, the UFCs directs planners to incorporate mix land use practices while conducting master planning to promote walking and biking from one destination to another inside a 10-minute walking radius.

Strategy 4 – Access to public transit

Physical health research has shown that people can achieve the daily recommended physical activity time by walking to and from transit stops and are less likely to be overweight [22; 80–84]. In order to capitalize on these health benefits, the fourth strategy of this paper is to provide access to public transit and transit facilities. At least 75% of survey adults felt that it was reasonable to walk 10-minutes from place to place (Figure 3, [85]). Similarly quantified by P. Seneviratne (1985), people were more likely to walk to and from transit stops if it was within a quarter-mile and only 20% of participants were likely to walk further if the distance exceeded a quarter-mile walk [86; 87].

There are several methods to promote public transportation in a community. One

method involves communication with the community. Placing signs and information on the transit map to include time, route and calories burned to the nearest transit stop can encourage individuals to walk to their transit stop [27]. Other approaches to increase usage is through inclusion of bus shelters, seats at shelters, and wider sidewalks at transit stops to accommodate more users [27].

Figure 3. Reasonable Walking Periods. Adopted from [85]

As explained previously, people will walk to destinations if within reason and will opt to drive for the time savings, therefore, highlighting the health benefits of public transportation use can help reinforce travel behavior change. Worth mentioning is the economic and environmental savings of using public transportation versus personal owned vehicles. For example, public transportation has the potential to reduce CO2 emissions by 7.4 million tons per year within the U.S [88]. It can also help individuals from paying costs with vehicle parking and operation while alleviating traffic congestion [89]. As a whole, public transportation offers important benefits to a healthy community and incorporating this strategy within an Air Force installation may result in a healthier lifestyle.

Current Air Force UFC standards comparison with public transit standards

Compared to public standards, the Installation Master Planning UFC, section 2-2.3 transit-oriented development guide has a similar direction for DoD infrastructure. The publication dictates transit stops to be located at approximately half-mile intervals [66]. The addition of public transit on installations has advantages that include: 1) lowering traffic congestion and vehicular accidents, 2) reducing parking requirements, and 3) lowering CO2 emissions. Several bases such as Hill AFB (Utah), Fort Belvoir (Virginia), and Keesler AFB (Mississippi), have integrated public buses or vanpool services onto and around the installations. As a benchmark, employees at Keesler AFB who benefited from its public transportation service saved 144,360 commuter miles and 5,724 gallons of fuel in 2013 [90].

People that use transit services may spend a median of 19 minutes per day walking to pick-up locations [22]. Therefore, in addition to monetary savings, workers that utilized public transportation to and from Keesler AFB likely experienced the physical health benefits associated with walking to and from transit. Altogether, the Installation Master Planning document reflects similar design recommendations to literature examples for mass transit options in the DoD. Future bases that adopt a public transportation service can likely achieve a higher level of physical activity when walking to and from transit stops. [72; 91; 92].

Conclusion

To conclude, this literature review was able to investigate and simplify the factors in a community layout that impacts physical health down to four main characteristics. Incorporating green space within communities, providing interconnected and safe pedestrian and bicycle infrastructure, integrating mix land use concepts, and

improving access to public transportation are the elements which have the largest impact on individual's physical health. The unique contribution of this paper is to show that the DoD can achieve similar health benefits reported in academic studies if the four healthy design strategies are applied within bases. Based on this paper's academic review of industry standards on healthy community layouts, the four strategies provide a robust reference point for analyzing the Healthy Base Initiative Survey from the Air Force Civil Engineer Center.

Obesity is a problem that society must focus on together. The challenge is even more prevalent in the military as its members must be fit to fight. Small changes in the community layout at each installation can compound and improve the overall health of the public causing a shift towards a healthier base. Collectively, the issues of being obese can be reversed through time with enough public awareness, the collaboration between experts, and the incorporation of healthy activities into daily lifestyles.

Bibliography

1. C. J. Murray, M. Ng, and A. Mokdad, "The vast majority of American adults are overweight or obese, and weight is a growing problem among US children — Institute for Health Metrics and Evaluation," 2014. [Online]. Available: http://www.healthdata.org/news-release/vast-majority-american-adults-are-overweight-or-obese-and-weight-growing-problem-among

2. C. M. Reyes-Guzman, R. M. Bray, V. L. Forman-Hoffman, and J. Williams, "Overweight and Obesity Trends Among Active Duty Military Personnel: A 13-Year Perspective," *American Journal of Preventive Medicine*, vol. 48, no. 2, pp. 145–153, Feb 2015. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0749379714005054

3. G. A. Colditz, "Economic costs of obesity and inactivity." *Medicine and science in sports and exercise*, vol. 31, no. 11 Suppl, pp. S663–7, nov 1999. [Online]. Available: http://www.ncbi.nlm.nih.gov/pubmed/10593542

4. A. M. Wolf and G. A. Colditz, "Current Estimates of the Economic Cost of Obesity in the United States," *Obesity Research*, vol. 6, no. 2, pp. 97–106, mar 1998. [Online]. Available: http://doi.wiley.com/10.1002/j.1550-8528.1998.tb00322.x

5. L. L. Clark and S. B. Taubman, "Update: Diagnoses of overweight and obesity, active component, U.S. Armed Forces, 2011-2015," *MSMR*, vol. 23, no. 9, pp. 9–13, sep 2016.

6. C. f. D. Control, "UNFIT TO SERVE: Obesity is Impacting National Security," Tech. Rep., 2019. [Online]. Available: www.cdc.gov/nccdphp/dnpao

7. "Urban sprawl and risk for being overweight or obese." *American journal of public health*, vol. 94, no. 9, p. 1574–9, Sep 2004. [Online]. Available: http://www.ncbi.nlm.nih.gov/pubmed/15333317

8. H. P. Hynes, "Obesity, physical activity, and the urban environment: public health research needs," *Environmental Health*, vol. 5, no. 1, p. 25, Dec 2006. [Online]. Available: http://ehjournal.biomedcentral.com/articles/10.1186/1476-069X-5-25

9. A. L. Dannenberg, R. J. Jackson, H. Frumkin, R. A. Schieber, M. Pratt, C. Kochtitzky, and H. H. Tilson, "The impact of community design and land-use choices on public health: a scientific research agenda." *American journal of public health*, vol. 93, no. 9, pp. 1500–8, 2003. [Online]. Available: http://www.ncbi.nlm.nih.gov/pubmed/12948970{\%}0Ahttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC1448000

10. U. Nations, "The Speed of Urbanization Around the World," 2018. [Online]. Available: https://esa.un.org/unpd/wup/

11. D. of Economic, S. Affairs, and P. Division, *2018 Revision of World Urbanization Prospects*, 2018. [Online]. Available: https://www.un.org/development/desa/publications/2018-revision-of-world-urbanization-prospects.html

12. J. Wakefield and K. G. Thigpen, "Fighting Obesity Through the Built Environment," *Environmental Health Perspectives*, vol. 112, no. 11, aug 2004. [Online]. Available: http://www.niehs.nih.gov/drcpt/https://ehp.niehs.nih.gov/doi/10.1289/ehp.112-a616

13. M. C. Neale and L. J. Eaves, "Genetic and environmental factors in relative body weight and human adiposity," *Behavior Genetics*, vol. 27, no. 4, p. 325–351, 1997.

14. C. Abraham, C. Whittington, J. McAteer, and S. Gupta, "Effective techniques in healthy eating and physical activity interventions: A meta-regression." *Health Psychology*, vol. 28, no. 6, p. 690–701, 2009. [Online]. Available: http://doi.apa.org/getdoi.cfm?doi=10.1037/a0016136

15. F. Sacks, A. Trichopoulou, G. Drescher, A. Ferro-Luzzi, E. Helsing, and D. Trichopoulos, "Mediterranean diet pyramid: a cultural model for healthy eating," *The American Journal of Clinical Nutrition*, vol. 61, no. 6, pp. 1402S–1406S, Jun 1995. [Online]. Available: https://academic.oup.com/ajcn/article/61/6/1402S-1406S/4651234

16. M. L. Stefanick, P. T. Williams, and W. L. Haskell, "The effects on plasma lipoproteins of a prudent weight-reducing diet, with or without exercise, in overweight men and women," *New England Journal of Medicine*, vol. 325, no. 7, p. 461–466, Aug 1991. [Online]. Available: http://www.nejm.org/doi/abs/10.1056/NEJM199108153250703

17. T. H. Moore, J. M. Kesten, J. A. López-López, S. Ijaz, A. McAleenan, A. Richards, S. Gray, J. Savović, and S. Audrey, "The effects of changes to the built environment on the mental health and well-being of adults: Systematic review," *Health and Place*, vol. 53, no. July, pp. 237–257, 2018.

18. M. A. Papas, A. J. Alberg, R. Ewing, K. J. Helzlsouer, T. L. Gary, and A. C. Klassen, "The Built Environment and Obesity," *Epidemiologic Reviews*, vol. 29, no. 1, pp. 129–143, may 2007. [Online]. Available: https://academic.oup.com/epirev/article-lookup/doi/10.1093/epirev/mxm009

19. N. Adler and J. Ostrove, "Socioeconomic Status and Health: What We Know and What We Don't," 1999. [Online]. Available: https://www.researchgate.net/publication/12633380

20. V. Inglis, K. Ball, and D. Crawford, "Why do women of low socioeconomic status have poorer dietary behaviours than women of higher socioeconomic status? A qualitative exploration," *Appetite*, vol. 45, no. 3, pp. 334–343, dec 2005.

21. K. E. Smoyer-Tomic, J. C. Spence, K. D. Raine, C. Amrhein, N. Cameron, V. Yasenovskiy, N. Cutumisu, E. Hemphill, and J. Healy, "The association between neighborhood socioeconomic status and exposure to supermarkets and fast food outlets," *Health and Place*, vol. 14, no. 4, pp. 740–754, 2008.

22. A. L. Dannenberg, "Walking to public transit: Steps to help meet physical activity recommendations," *American Journal of Preventive Medicine*, vol. 29, no. 4, p. 273–280, Nov 2005. [Online]. Available: https://www.cdc.gov/healthyplaces/articles/besser_dannenberg.pdf

23. "Active community environments (aces) resource kit to prevent obesity," 2009. [Online]. Available: http://dhfs.wisconsin.gov/health/physicalactivity/index.htm

24. T. Community Preventive Services Task Force, "Task Force Finding and Rationale Statement - Physical Activity: Built Environment Approaches Combining Transportation System Interventions with Land Use and Environmental Design," 2016. [Online]. Available: https://www.thecommunityguide.org/sites/default/files/assets/PA-Built-Environments.pdf

25. "Intersections: Health and the built environment," *Urban Land Institute*, 2013. [Online]. Available: www.uli.org

26. E. T. McMahon and T. C. Thoerig, "Ten principles for building healthy places building healthy places initiative," *Urban Land Institute*,

2013. [Online]. Available: http://uli.org/wp-content/uploads/ULI-Documents/10-Principles-for-Building-Healthy-Places.pdf

27. *Active design*, 2018, transit and Parking: Ref 11, 24, 19-22, 23Grocery stores and fresh produce access: 53, 54, 55, 56Create vendiagram of 4 domains, UFC, and universal design.

28. "Advancing obesity solutions through investments in the built environment: Proceedings of a workshop in brief (2017)," *National Academy of Sciences*, p. 10, 2017. [Online]. Available: https://doi.org/10.17226/24963.

29. R. A. Verheij, P. P. Groenewegen, S. de Vries, and P. Spreeuwenberg, "Green space, urbanity, and health: how strong is the relation?" *Journal of epidemiology and community health*, vol. 60, no. 7, p. 587–92, Jul 2006. [Online]. Available: http://www.ncbi.nlm.nih.gov/pubmed/16790830

30. A. L. Bedimo-Rung, A. J. Mowen, and D. A. Cohen, "The significance of parks to physical activity and public health," *American Journal of Preventive Medicine*, vol. 28, no. 2, pp. 159–168, feb 2005. [Online]. Available: https://linkinghub.elsevier.com/retrieve/pii/S0749379704003046

31. E. Coombes, A. P. Jones, and M. Hillsdon, "The relationship of physical activity and overweight to objectively measured green space accessibility and use," *Social Science & Medicine*, vol. 70, no. 6, pp. 816–822, mar 2010. [Online]. Available: http://www.ncbi.nlm.nih.gov/pubmed/20060635http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC3759315https://linkinghub.elsevier.com/retrieve/pii/S0277953609008156

32. S. M. E. van Dillen, S. de Vries, P. P. Groenewegen, and P. Spreeuwenberg, "Greenspace in urban neighbourhoods and residents' health: adding quality to

quantity." *Journal of epidemiology and community health*, vol. 66, no. 6, p. e8, jun 2012. [Online]. Available: http://www.ncbi.nlm.nih.gov/pubmed/21715445

33. E. P. Flowers, P. Freeman, and V. F. Gladwell, "A cross-sectional study examining predictors of visit frequency to local green space and the impact this has on physical activity levels," *BMC Public Health*, vol. 16, no. 1, may 2016.

34. R. Maheswaran, "The health benefits of urban green spaces: a review of the evidence," *Journal of Public Health*, vol. 33, no. 2, p. 212–222, Jun 2011, quality: References, 54, 56 and 26. [Online]. Available: https://academic.oup.com/jpubhealth/article-lookup/doi/10.1093/pubmed/fdq068

35. U. K. Stigsdotter, O. Ekholm, J. Schipperijn, M. Toftager, F. Kamper-Jørgensen, and T. B. Randrup, "Health promoting outdoor environments - Associations between green space, and health, health-related quality of life and stress based on a Danish national representative survey," *Scandinavian Journal of Public Health*, vol. 38, no. 4, pp. 411–417, jun 2010. [Online]. Available: http://journals.sagepub.com/doi/10.1177/1403494810367468

36. B. Giles-Corti, M. H. Broomhall, M. Knuiman, C. Collins, K. Douglas, K. Ng, A. Lange, and R. J. Donovan, "Increasing walking," *American Journal of Preventive Medicine*, vol. 28, no. 2, pp. 169–176, feb 2005. [Online]. Available: http://www.ncbi.nlm.nih.gov/pubmed/15694525https://linkinghub.elsevier.com/retrieve/pii/S0749379704002983

37. T. Takano and K. Nakamura, "Urban residential environments and senior citizens' longevity in megacity areas: the importance of walkable green spaces," *J Epidemiol Community Health*, 2002. [Online]. Available: http://jech.bmj.com/

38. I. Janssen and A. Rosu, "Undeveloped green space and free-time physical activity

in 11 to 13-year-old children," *International Journal of Behavioral Nutrition and Physical Activity*, vol. 12, no. 1, feb 2015.

39. T. Sanders, X. Feng, P. P. Fahey, C. Lonsdale, and T. Astell-Burt, "The influence of neighbourhood green space on children's physical activity and screen time: Findings from the longitudinal study of Australian children," *International Journal of Behavioral Nutrition and Physical Activity*, vol. 12, no. 1, sep 2015.

40. K.-J. Toftager, M. Toftager, O. Ekholm, J. Schipperijn, U. Stigsdotter, P. Bentsen, M. Grønbaek, T. B. Randrup, and F. Kamper-Jørgensen, "Distance to Green Space and Physical Activity: A Danish National Representative Survey," *Journal of Physical Activity and Health*, vol. 8, pp. 741–749, 2011. [Online]. Available: https://pdfs.semanticscholar.org/eb76/26c2d6e4dc17edb0316b86fb4e6fe787e924.pdf

41. E. Cerin, C. Vandelanotte, E. Leslie, and D. Merom, "Recreational facilities and leisure-time physical activity: An analysis of moderators and self-efficacy as a mediator." *Health Psychology*, vol. 27, no. 2, Suppl, pp. S126–S135, 2008. [Online]. Available: http://doi.apa.org/getdoi.cfm?doi=10.1037/0278-6133.27.2(Suppl.).S126

42. R. Tiyarattanachai and N. M. Hollmann, "Green Campus initiative and its impacts on quality of life of stakeholders in Green and Non-Green Campus universities," *SpringerPlus*, vol. 5, no. 1, pp. 1–17, dec 2016.

43. H. Christian, M. Knuiman, M. Divitini, S. Foster, P. Hooper, B. Boruff, F. Bull, and B. Giles-Corti, "A Longitudinal Analysis of the Influence of the Neighborhood Environment on Recreational Walking within the Neighborhood: Results from RESIDE," *Environmental Health Perspectives*, vol. 125, no. 7, jul 2017. [Online]. Available: https://doi.org/10.1289/EHP823

44. A. Russo and G. T. Cirella, “Modern compact cities: How much greenery do we need?” *International Journal of Environmental Research and Public Health*, vol. 15, no. 10, oct 2018.

45. D. of Defense, “UNIFIED FACILITIES CRITERIA (UFC) APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED LANDSCAPE ARCHITECTURE,” Tech. Rep., 2009. [Online]. Available: http://www.dod.wbdg.org/.

46. C. P. Wen, J. P. M. Wai, M. K. Tsai, Y. C. Yang, T. Y. D. Cheng, M.-C. Lee, H. T. Chan, C. K. Tsao, S. P. Tsai, and X. Wu, “Minimum amount of physical activity for reduced mortality and extended life expectancy: a prospective cohort study,” *The Lancet*, vol. 378, no. 9798, pp. 1244–1253, oct 2011. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0140673611607496

47. L. D. Frank and P. O. Engelke, “The Built Environment and Human Activity Patterns: Exploring the Impacts of Urban Form on Public Health,” *Journal of Planning Literature*, vol. 16, no. 2, pp. 202–218, nov 2001. [Online]. Available: http://journals.sagepub.com/doi/10.1177/08854120122093339

48. P. Maghelal, “’Walkability: A Review of Existing Pedestrian Indices’ Spatial Analysis of Sex offenders in Brazos County View project,” Tech. Rep., 2011. [Online]. Available: https://www.researchgate.net/publication/279588344

49. L. D. Frank, J. F. Sallis, B. E. Saelens, L. Leary, K. Cain, T. L. Conway, and P. M. Hess, “The development of a walkability index: application to the Neighborhood Quality of Life Study.” *British journal of sports medicine*, vol. 44, no. 13, pp. 924–33, oct 2010. [Online]. Available: http://www.ncbi.nlm.nih.gov/pubmed/19406732

50. T. E. Mäki-Opas, K. Borodulin, H. Valkeinen, S. Stenholm, A. E. Kunst, T. Abel, T. Härkänen, L. Kopperoinen, P. Itkonen, R. Prättälä, S. Karvonen, and S. Koskinen, "The contribution of travel-related urban zones, cycling and pedestrian networks and green space to commuting physical activity among adults - A cross-sectional population-based study using geographical information systems," *BMC Public Health*, vol. 16, no. 1, aug 2016.

51. M. Weng, N. Ding, J. Li, X. Jin, Z. He, and S. Su, "The 15-minute walkable neighborhoods: Measurement, social inequalities and implications for building healthy communities in urban China," 2019. [Online]. Available: https://doi.org/10.1016/j.jth.2019.05.005

52. M. E. Northridge and E. Sclar, "A Joint Urban Planning and Public Health Framework: Contributions to Health Impact Assessment," *American Journal of Public Health*, vol. 93, no. 1, 2003. [Online]. Available: https://ajph.aphapublications.org/doi/pdf/10.2105/AJPH.93.1.118

53. V. H. Loh, J. N. Rachele, W. J. Brown, F. Ghani, S. Washington, and G. Turrell, "The potential for walkability to narrow neighbourhood socioeconomic inequalities in physical function: A case study of middle-aged to older adults in Brisbane, Australia," 2019. [Online]. Available: www.elsevier.com/locate/healthplace

54. K. R. Smith, H. Hanson, J. X. Fan, L. Kowaleski-Jones, and C. D. Zick, "Neighborhood design for walking and biking: Physical activity and body mass index," *American Journal of Preventive Medicine*, vol. 44, no. 3, p. 231–238, Mar 2013. [Online]. Available: https://www.sciencedirect.com/science/article/abs/pii/S074937971200880X

55. J. Parkin, "Comparisons of cycle use for the journey to work from the '81, '91

and 2001 censuses," *Traffic Engineering and Control*, vol. 44, no. 8, pp. 299–302, 2003.

56. J. Pucher and R. Buehler, "Making Cycling Irresistible: Lessons from The Netherlands, Denmark and Germany," *Transport Reviews*, vol. 28, no. 4, pp. 495–528, jul 2008. [Online]. Available: http://www.tandfonline.com/doi/abs/10.1080/01441640701806612

57. J. Pucher, R. Buehler, and M. Seinen, "Bicycling renaissance in North America? An update and re-appraisal of cycling trends and policies," *Transportation Research Part A: Policy and Practice*, vol. 45, no. 6, pp. 451–475, jul 2011. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0965856411000474

58. M. A. Harris, C. C. O. Reynolds, M. Winters, S. Babul, M. Chipman, M. D. Cusimano, J. R. Brubacher, G. Hunte, S. M. Friedman, M. Monro, and et al., "Route infrastructure and the risk of injuries to bicyclists: a case-crossover study." *American journal of public health*, vol. 102, no. 12, p. 2336–43, Dec 2012. [Online]. Available: http://ajph.aphapublications.org/doi/10.2105/AJPH.2012.300762

59. I. o. T. Engineers, "Traffic Calming: State of the Practice ITE/FHWA, August 1999," p. 206, 1999.

60. F. Creutzig, R. Mühlhoff, and J. Römer, "Decarbonizing urban transport in European cities: four cases show possibly high co-benefits," *Environmental Research Letters*, vol. 7, no. 4, p. 044042, dec 2012. [Online]. Available: http://stacks.iop.org/1748-9326/7/i=4/a=044042?key=crossref.f9b392df118c03d24e902ff914b851e1

61. C. E. Rissel, "Active travel: a climate change mitigation strategy with co-benefits

for health," *New South Wales Public Health Bulletin*, vol. 20, no. 2, p. 10, mar 2009. [Online]. Available: http://phrp.com.au/issues/volume-20-issue-1-2/active-travel-a-climate-change-mitigation-strategy-with-co-benefits-for-health/

62. E. Fishman, S. Washington, and N. Haworth, "Bikeshare's impact on active travel: Evidence from the United States, Great Britain, and Australia," *Journal of Transport and Health*, vol. 2, no. 2, pp. 135–142, sep 2014.

63. S. Kretman Stewart, D. C. Johnson, and W. P. Smith, "Bringing bike share to a low-income community: lessons learned through community engagement, Minneapolis, Minnesota, 2011." *Preventing chronic disease*, vol. 10, 2013.

64. R. B. Noland, M. J. Smart, and Z. Guo, "Bikeshare trip generation in New York City," *Transportation Research Part A: Policy and Practice*, vol. 94, pp. 164–181, dec 2016.

65. E. Fishman, P. Schepers, and C. B. M. Kamphuis, "Dutch Cycling: Quantifying the Health and Related Economic Benefits." *American journal of public health*, vol. 105, no. 8, pp. e13–5, aug 2015. [Online]. Available: http://ajph.aphapublications.org/doi/10.2105/AJPH.2015.302724http://www.ncbi.nlm.nih.gov/pubmed/26066942http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC4504332

66. D. of Defense, "UNIFIED FACILITIES CRITERIA (UFC) APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED INSTALLATION MASTER PLANNING," Tech. Rep., 2012. [Online]. Available: http://www.dod.wbdg.org/.

67. S. L. Handy, M. G. Boarnet, R. Ewing, and R. E. Killingsworth, "How the Built Environment Affects Physical Activity Views from Urban Planning," Tech. Rep.,

2002. [Online]. Available: https://www.ajpmonline.org/article/S0749-3797(02)00475-0/pdf

68. G. E. A. Eldayem, “Influence of mixed land-use on realizing the social capital,” *HBRC Journal*, vol. 11, no. 2, p. 285–298, Aug 2015. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S1687404814000303

69. M. J. Duncan, E. Winkler, T. Sugiyama, E. Cerin, L. DuToit, E. Leslie, and N. Owen, “Relationships of Land Use Mix with Walking for Transport: Do Land Uses and Geographical Scale Matter?” *Journal of Urban Health*, vol. 87, no. 5, pp. 782–795, sep 2010. [Online]. Available: http://link.springer.com/10.1007/s11524-010-9488-7

70. F. C. Bull, N. J. Middleton, M. W. Knuiman, M. L. Divitini, P. Hooper, A. Amarasinghe, and B. Giles-Corti, “How important is the land use mix measure in understanding walking behaviour? results from the reside study,” 2011. [Online]. Available: http://www.ijbnpa.org/content/8/1/55

71. R. Ewing, O. Clemente, S. Handy, R. C. Brownson, and E. Winston, “Identifying and Measuring Urban Design Qualities Related to Walkability Measuring Urban Design Qualities Related to Walkability,” 2005. [Online]. Available: http://smartgrowth.umd.edu/assets/documents/research/ewingclementehandyetal{_}walkableurbandesign{_}2005.pdf

72. L. R. Mobley, E. D. Root, E. A. Finkelstein, O. Khavjou, R. P. Farris, and J. C. Will, “Environment, Obesity, and Cardiovascular Disease Risk in Low-Income Women,” *American Journal of Preventive Medicine*, vol. 30, no. 4, pp. 327–332.e1, apr 2006. [Online]. Available: https://linkinghub.elsevier.com/retrieve/pii/S0749379705005040

73. M. A. Andresen and T. L. Schmid, “Obesity relationships with community design, physical activity, and time spent in cars,” *American Journal of Preventive Medicine*, vol. 27, no. 2, p. 87–96, Aug 2004. [Online]. Available: https://linkinghub.elsevier.com/retrieve/pii/S074937970400087X

74. B. B. Brown, I. Yamada, K. R. Smith, C. D. Zick, L. Kowaleski-Jones, and J. X. Fan, “Mixed land use and walkability: Variations in land use measures and relationships with BMI, overweight, and obesity.” *Health & place*, vol. 15, no. 4, pp. 1130–41, dec 2009. [Online]. Available: http://www.ncbi.nlm.nih.gov/pubmed/19632875http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC2778756

75. B. Z. Yang and B. P. Y. Loo, “Land use and traffic collisions: A link-attribute analysis using Empirical Bayes method,” *Accident Analysis and Prevention*, vol. 95, pp. 236–249, 2016. [Online]. Available: http://dx.doi.org/10.1016/j.aap.2016.07.002

76. J. C. Wo, “Mixed land use and neighborhood crime,” 2018. [Online]. Available: https://doi.org/10.1016/j.ssresearch.2018.12.010

77. Y. Song and G.-J. Knaap, “Measuring the effects of mixed land uses on housing values,” 2004. [Online]. Available: www.elsevier.com/locate/econbase

78. D. of Defense, “UNIFIED FACILITIES CRITERIA (UFC) APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED HIGH PERFORMANCE AND SUSTAINABLE BUILDING REQUIREMENTS,” Tech. Rep., 2016. [Online]. Available: http://www.dod.wbdg.org/.

79. ——, “UNIFIED FACILITIES CRITERIA (UFC) APPROVED FOR PUBLIC

RELEASE; DISTRIBUTION UNLIMITED ARCHITECTURE," Tech. Rep., 2011. [Online]. Available: http://www.dod.wbdg.org/.

80. S. N. Banerjee, A. L. Dannenberg, and A. M. Wendel, "Walking associated with public transit: moving toward increased physical activity in the united states." *American journal of public health*, vol. 103, no. 3, p. 536–42, Mar 2013. [Online]. Available: http://ajph.aphapublications.org/doi/10.2105/AJPH.2012.300912

81. M. Lindström, "Means of transportation to work and overweight and obesity: A population-based study in southern Sweden," *Preventive Medicine*, vol. 46, no. 1, pp. 22–28, jan 2008. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0091743507003052

82. L. Ming Wen and C. Rissel, "Inverse associations between cycling to work, public transport, and overweight and obesity: Findings from a population based study in Australia," *Preventive Medicine*, vol. 46, no. 1, pp. 29–32, jan 2008. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0091743507003714

83. G. Netuveli and C. Millett, "Free bus passes, use of public transport and obesity among older people in england." *Journal of epidemiology and community health*, vol. 66, no. 2, p. 176–80, Feb 2012. [Online]. Available: http://www.ncbi.nlm.nih.gov/pubmed/21911850

84. J. A. Hipp, M. W. Corseuil, and E. A. Dodson, "Correlates of walking for transportation and use of public transportation among adults in st louis, missouri, 2012." *Preventing chronic disease*, vol. 11, p. E112, Jul 2014. [Online]. Available: http://www.ncbi.nlm.nih.gov/pubmed/24995654

85. K. B. Watson, S. A. Carlson, T. Humbert-Rico, D. D. Carroll, and J. E. Fulton,

"Walking for Transportation: What do U.S. Adults Think is a Reasonable Distance and Time?" *Journal of physical activity & health*, vol. 12, no. Suppl 1, pp. S53–S61, 2015.

86. *PEDESTRIAN-AND TRANSIT-FRIENDLY DESIGN: A Primer for Smart Growth Based on a manual prepared for the Florida Department of Transportation and published by the American Planning Association*, 1999. [Online]. Available: www.smartgrowth.org

87. P. Seneviratne, "Acceptable Walking Distances in Central Areas," *Journal of Transportation Engineering-asce - J TRANSP ENG-ASCE*, vol. 111, 1985.

88. R. J. Shapiro, K. A. Hassett, and F. S. Arnold, "Conserving Energy and Preserving the Environment: The Role of Public Transportation," 2002.

89. T. Litman, B. Todd Alexander Litman, and W. Eric Doherty, "Transportation Cost and Benefit Analysis Techniques, Estimates and Implications Second Edition," 2009. [Online]. Available: www.measuringworth.org

90. B. Lachman, S. Resetar, and F. Camm, *Military Installation Public-to-Public Partnerships: Lessons from Past and Current Experiences*, 2017.

91. L. C. Falls and S. Tighe, "Coordinating Pavement and Maintenance Management with Asset Management Session Of the 2004 Annual Conference of the Transportation Association of Canada," 2004. [Online]. Available: http://conf.tac-atc.ca/english/resourcecentre/readingroom/conference/conf2004/docs/s7/cowefalls.pdf

92. L. D. Frank, T. L. Schmid, J. F. Sallis, J. Chapman, and B. E. Saelens, "Linking Objectively Measured Physical Activity with Objectively

Measured Urban Form Findings from SMARTRAQ," 2005. [Online]. Available: https://www.ajpmonline.org/article/S0749-3797(04)00325-3/pdf

III. Examining the Reliability and Validity of the Air Force Healthy Base Initiative Survey

Abstract

In 2018, the Air Force Civil Engineer Center developed a Healthy Base Initiative survey to explore the design and construction mission for healthy community layouts across all bases. The survey data was provided as a resource for studying the outcome of the planning and execution of active designs. This paper analyzes the survey questions based on four strategies of a healthy community layout: mix land use, public transportation access, green space access, and pedestrian and bicycle infrastructure access. The overall validity and reliability of the survey was assessed along with a pairwise correlation analysis on the responses from the survey. Additionally, descriptive statistics was utilized to examine the level to which the bases plans for healthy community designs and the execution of those plans. The results of the analysis indicated that the survey data did not achieve its desired effect to focus policy and guidance for healthy planning strategies implementable across Air Force bases. However, the survey provides a good foundation and offers potential for future community layout assessments. Overall, more research must be conducted to understand the causes behind the disparity between planning for healthy bases and the environments impact on physical health.

Introduction

Research in the field of physical health supports that the urban environment has an impact on physical activity [1; 2]. There is a rising trend of individuals living more in urban environments compared to rural areas. For the future, it is projected in the next 30 years individuals dwelling in an urban environment is expected to increase

by 18% [3]. As the number of individuals living in an urban environment increases, the effects of urbanization will likely impact the physical health of more people.

Four characteristics of the community layout have been proposed as key contributors to an individual's physical health (Yip et al. 2020). These contributing factors, or strategies for a healthy community, include mix land use, public transportation access, green space, and pedestrian and bicycle infrastructure access [4–8]. First, mix land use refers to two or more different types of functionalities that are placed within close proximity of each other; this enables individuals to increase walking between connected infrastructure and decrease the dependence of driving [9–11]. Second, public transportation connects different communities together and users of the transit network can likely achieve the daily recommended physical activity time by walking to and from transit stops [12–17]. Third, centralizing green space within communities has shown benefits to individual's physical health [18–22]. Community green spaces have influential qualities that encourage occupants to achieve a higher level of physical activity. Fourth and last, pedestrian and bicycle infrastructure links all the strategies together [23; 24]. The walkability/bike-ability of the community layout has the ability to motivate or discourage physical activity [25]. The combination of strategies work together synergistically to improve physical health in the community layout. After examining the body of knowledge, a baseline and model is developed to evaluate healthy community design.

In 2018, the Air Force Civil Engineer Center (AFCEC) developed its Healthy Base Initiative (HBI) survey to examine the design and construction mission for healthy community layouts across all infrastructure assets at 75+ locations worldwide. Their survey was a follow up to the 2014 Healthy Base Initiative project linked to Operation Live Well. The operation's goal was to make "healthy living the easy choice and the norm for service members, retirees, DoD civilians, and their families."

AFCEC's HBI survey was intended to gather input from base community planners on healthy planning strategies most applicable to the confines of Air Force bases. Due to this, their survey questions were purely investigative and generalized, which yielded inconclusive results.

In order to explore the reasons behind the inconclusive results, the responses were documented and provided as a resource for studying which healthy community designs are most applicable to bases. Reliability and validity analysis will be utilized to achieve an understanding of the HBI survey. Reliability refers to the degree to which research methods produces consistent results and validity describes the extent to which a tool is accurately measuring the construct it is intended to measure [26; 27]. The two concepts indicate the quality of research, for example, if the survey results can be reproduced or measured the same topic, it is both reliable and valid. The present work seeks to build upon the HBI survey and investigate the healthy design constructs within the survey. The research methodology begins with the categorization of the survey questions into the four strategies, from there, assess the validity and reliability of the questions, then, perform pairwise correlation analysis on the responses from the Air Force Healthy Base Initiative Survey, and finally, examine the overall descriptive statistics.

Methodology

Demographics

The HBI survey was distributed to Air Force base community planners globally as an assessment method for exploring the level to which and when a base community planner executes its proposals . The survey asked twenty-four questions on Air Force bases community planning in relationship to the current status and healthy opportunities (see Supplementary Material for survey questions). In total, there were 62

survey responses collected, 51 from base planners and 11 from non-planners. Of the 60 responses, three bases had multiple individuals submit responses due to different positions in the Civil Engineer Squadron. Between the 58 bases that responded, 45 bases were from the continental of the United States (CONUS) and 13 were from oversea bases (OCONUS). A subset of six of the CONUS responses was from Air Force Reserve bases while the remaining responses were from active duty locations.

Categorization

Four strategies were investigated in terms of community planning and the impact on physical health (Yip et al. 2020). The four strategies of a healthy community layout include: 1) mix land use, 2) public transportation, 3) green space, and 4) walkability/bike-ability. It is important to note that the strategies were developed post hoc by AFIT researchers. In this paper, prior to any statistical analysis, questions were placed into one of the four strategies. Namely, questions 5 and 13 were categorized into mix land use; questions 6, 7, 8, 15, 16, and 17 pertained to public transportation access and availability on base; and walkability and bike-ability related questions were 3, 4, 9, 10, 11, 18, 19, 20, and 21. There was no questions in the HBI survey on green space. Finally, survey questions 1, 2, 12, 14, 22 and 23 did not fit into the four strategies.

Data Cleaning and Numeric Coding

Prior to performing statistical analysis on the HBI survey, the dataset was subject to quality control. Two survey response were removed from the total responses as the answers were unresponsive to the survey. When applicable, survey responses were transformed from a qualitative answer to a numeric code on a nominal scale. Binomial questions were coded 1 for a positive outcome or 0 for a negative outcome. Categorical

questions were summarized as the total checked choices, i.e. 1 for one variable or 5 for five variables. Likert questions were scored from 1 to 5 for least likely (lowest) to most likely (highest). In total, there were: 1) two Likert questions for mix land use, 2) three binomial and three Likert for public transportation access, and 3) two categorical and seven Likert questions for walkability/bike-ability . The remaining six questions did not conform to any of the four investigated healthy community strategies (See Table 2).

Table 2. Healthy Base Initiative Survey Question Categorization

Category	Question Number	Numeric Scale
Mix Land Use	5, 13	Likert
Public Trans Access	6, 7, 17 8, 15, 16	Binomial Likert
Walkability/Bike-ability	3, 4 9, 10, 11, 18, 19, 20, 21	Categorical Likert
Other	1, 2, 12 14, 22, 23	Likert Categorical
Participant Demographics	24	N/A

Statistical analysis was performed in the Statistical Package for Social Sciences (SPSS Version 27, IBM Corp 2006). The construct reliability and validity of the four healthy community strategies was assessed using the Cronbach's Alpha test and factor analysis test. Furthermore, the bivariate correlation was computed for specific questions. Lastly, the overall descriptive statistics of the survey was analyzed.

Results

Construct Reliability Analysis

The internal consistency reliability analysis method measures whether items that propose to measure the same general construct produces similar scores [28]. Other empirical methods such as inter-rater, test-retest, and parallel forms were not applicable for reliability analysis given the available dataset [29; 30]. Analysis of the HBI

survey included only Likert scaled questions for three reasons: 1) it is inconsistent to use three different numeric scales to measure reliability, 2) categorical questions are qualitative and non-continuous, therefore, is impossible to infer the means or variance, and 3) dichotomous questions have the ability to measure internal consistency, however, Cronbach's Alpha offers more versatility to handle three or more answers per variable.

The statistical reliability analysis was calculated based on the categorization of survey questions into the four outlined strategies of a healthy community. Similar category questions were grouped together to measure the internal consistency of the construct. Namely, questions 5 and 13 were grouped to form the mix land use (MLU) construct, questions 8, 15, and 16 for public transportation access (PTA), and questions 9, 10, 11, 18, 19, 20, and 21 for walkability/bike-ability (WB). The groups were confirmed by AFCEC community planning experts. The reliability analysis determines the level to which the Likert scaled questions measure the MLU, PTA, and WB constructs (Table 3). The Cronbach's Alpha value for MLU, PTA, and WB were 0.602, 0.647, and 0.773, respectively. It is important to note that Cronbach's Alpha value is dependent on the number of questions per construct. And while acceptable values vary based on the situation, a higher value is generally preferred over lower ones and all Cronbach's Alpha values were less than 0.8; therefore, internal consistency reliability is not acceptable [28; 31].

Table 3. Reliability Statistics of Survey Question Categorization

Reliability Constructs	Cronbach's Alpha	# of items
Mix Land Use	0.602	2
Public Trans Access	0.647	3
Walkability/Bike-ability	0.773	7

Factor Analysis

Reliability is not the only method to assess the quality of data, therefore, exploratory factor analysis was conducted to measure validity [32]. Two different factor analysis were calculated using the same coded questions from the reliability analysis. Exploratory factor analysis is first utilized to identify the set of unobserved factors that form the construct [33]. Essentially, it works twofold to verify validity and helps researchers who have little idea how variables interact with one another account for variations and interrelationships of the variables [34]. Based on the initial Eigenvalues calculated from SPSS, five components with load factor values above 0.4 were determined as shown in Supplemental Information Table S1 . A follow-up data fit test based on the exploratory factor analysis using a method developed by Gignac et al. (2009) was completed to compare the existing model with three predetermined components: mix land use, public transportation access, and walkability/bike-ability access [35]. The data fit indices have the ability to support whether survey questions grouped together as hypothesized. Results from the data fit analysis are shown in Table 4 and equations used to calculate the absolute fit indices can be found in the supplemental information.

Table 4. Exploratory factor analysis data fit indices

Absolute Fit Indices	Index Value	Target Values
Normed Fit Index (NFI)	0.798	≥0.95
Comparative Fit Index (CFI)	0.936	≥0.95
Tucker-Lewis Index (TLI)	0.893	≥0.95
Root Mean Square Error of Approx. (RMSEA)	0.073	≤0.08
Standardised Root Mean Square Residual (SRMR)	0.064	≤0.06

Exploratory factor analysis is also known as theory testing because it is void of any preconceived grouping. Therefore, the exploratory factor analysis helped explain the multi-dimensionality of the reliability analysis by showing the five different principle

components with multiple cross-loading between the Likert survey questions. Although 73.67% of the data variance is explained with five components, the multiple cross-loading reflect a survey issue such as improper measurement of multiple independent variables per question. The subsequent exploratory factor analysis with three forced components (encompassing 51.2% of the total variance) tested the grouping of survey questions. The normed fit index, comparative fit index, and Tucker-Lewis index shown in Table 4were all below 0.95 (values above 0.95 is acceptable of good model fit) [36]. And, the root mean square error of approximation was not less than 0.06 and although standardized root mean square residual was below 0.08, it is also rejected as four of five did not meet acceptable values [36]. The NFI, CFI, TLI, RMSEA, and SRMR all indicate that the HBI questions did not group together to measure specific constructs which is unsurprising as the constructs were developed post hoc to the survey questions.

Correlation Analysis

Correlations were conducted for each Likert question in the survey as a means to investigate the overall consistency of the survey (Table S4). The premise for the check was to verify if participants answered the questions reasonably and if the questions were written logically. Prior to the analysis, a hypothesis on survey questions that should correlate was noted (Table 5). The correlation relationships were able to provide successful results. Actual Pearson-R values shows varying levels of association between paired questions. The agreement between expected and actual outcomes is a good indication that the respondents answered the survey consistently. One of the most correlated relationships is between “Does base network link to public trans effectively?” and “Does base network link to public trans systems?” The Pearson-R value 0.842 with 0.01 p-value significance confirms that respondents answered simi-

larly on both Likert scaled questions. Another paired question with favorable results is "Are traffic calming strategies considered in planning?" and "Are pedestrian crossings marked or otherwise protected?" There was a 0.530 Pearson-R value with significance at the 0.01 level between questions 9 and 20, another implication that the HBI survey offers some useful information. One of the weaker correlated questions is between questions 9 and 10. Respondents may answer that traffic calming strategy are considered during the planning processes, but, their answer for existing safety measures for walkability and bike-ability reflected a small association of 0.268 correlation. Overall, the ten paired questions in Table 8 all showed an analogous relationship between the expected outcome and actual Pearson-R value.

Table 5. Correlation Test Expected and Actual Outcomes

Correlation Questions	Expected Outcome	Actual Pearson-R Value	Sig. Level
Questions 8 and 15 Does base network link to public trans effectively? Does base network link to public trans systems?	Correlated	0.842	**
Questions 9 and 10 Are traffic calming strategies considered in planning? Is there a plan for safe walkability and bike-ability?	Correlated	0.268	*
Questions 11 and 19 How well are existing sidewalks connected? Are existing sidewalks connected?	Correlated	0.802	**
Questions 9 and 20 Are traffic calming strategies considered in planning? Are pedestrian crossings marked or otherwise protected?	Correlated	0.530	**
Questions 5 and 13 Is mixed land uses incorporated into planning? Is proximity of personnel considered when planning?	Correlated	0.432	**
Questions 5 and 9 Is mixed land uses incorporated into planning? Are traffic calming strategies considered in planning?	Correlated	0.432	**
Questions 12 and 13 Are active living features considered in planning? Is proximity of personnel considered when planning?	Correlated	0.551	**
Questions 9 and 11 Are traffic calming strategies considered in planning? How well are existing sidewalks connected?	Correlated	0.535	**
Questions 11 and 20 How well are existing sidewalks connected? Are pedestrian crossings marked or otherwise protected?	Correlated	0.598	**
Questions 19 and 20 Are existing sidewalks connected? Are pedestrian crossings marked or otherwise protected?	Correlated	0.541	**

*Note *p<.05, **p<.01

Prior to discussing the outcome of the planning and execution of active designs, the causal relationships drawn from the reliability and factor analysis must be supplemented with descriptive statistics to properly evaluate the survey and attain a summary which describes the existence of active designs. The following results will step through the HBI survey and detail the descriptive statistics for each healthy planning strategy and offer areas of improvement for future Air Force community planning.

Looking at mix land use questions first, 63.8% of the respondents always or usually incorporate compact and walkable designs into their base planning (question 5). Respondents also always or usually locate new facilities (81.4%) within proximity of civilians (question 13). Question 14 can be used as a cross reference to check consistency of questions 5 and 13; 74.6% of respondents report compact development, 56% report mixed use districts, and 44.1% report mixed use buildings during planning. The cross reference shows that while the community planners rate their base high for consideration of mixed land use, it is not reflected in the difference between their answers for questions 5, 13, and 14. The low percentage of mixed use presents an area for improvement for community planners. Placing residential land use areas next to commercial land use areas or recreational near residential increases the amount of time spent walking per week, leading to improved physical health [37–39].

Next, there is some conflicting thoughts on the public transportation availability on base. The majority of respondents (67.2%) report that there is no public transportation network on base (question 6) yet, 58% of answers also report that there is some form of public transportation (question 7). Furthermore, slightly more than 50% of the respondents also report that ride-share options are available on base (question 17). These survey answers are opposing as the results can be interpreted as either A) there is public transportation but it does not connect or B) there are mixed

thoughts on what is considered public transportation. Question 8 might have offered some explanation for interpretation A if it were specified for on-base transportation instead of neighboring transit systems. However, the question only focuses on how effectively on-base transit network connects to off-base transit networks, to which 68% of respondents reported not very well or not at all. In congruence with question 8, 72.9% of respondents report that on-base transportation does not or only connects to off-base networks a little (question 15). Difference in respondent answers exist between questions 6 and 16 further eluding to interpretation A; 16 of the 41 responses indicated some level of connectivity with off-base transit when there should have been none at all. Interpretation B can be expressed through the disagreement between the 14 respondents who positively indicated ride share options on-base (question 17); but did not select that choice for question 7. Lastly, individual positive responses for transportation on-base were examined against base demographics and there is no indication that CONUS or OCONUS base geography has any impact on availability of transit options.

Unsurprisingly at Air Force bases, the sidewalk network is more developed than the bicycle infrastructure. In terms of what community planners plan for, 39% of respondents report there is incorporation of both pedestrian and bicycle infrastructure in the design guidelines, 29% of respondents report pedestrian only, 15.3% report their guidelines are in development, and 17% of respondents report no guidelines for either (question 4). In terms existing infrastructure according to the participants, nearly 80% of respondents think that their bases' sidewalk network connects moderately, a lot, and a great deal (question 19). Their answers show existence of safety features in pedestrians crosswalks according to 85% of the responses (question 20). However, the bicycle infrastructure is lacking as 86.4% of respondents report that designated bicycle lanes are marked a little or not at all (question 18). Furthermore, 42.4% of

respondents disagree or strongly disagree with a network plan for safe walkability and bike-ability (question 10), also reflecting the contrast in pedestrian and bicycle infrastructure. An interesting question posed by the survey is whether pedestrian-only zones are incorporated or considered in planning (question 21). The question is clearly trying to measure pedestrian-only zones but offers two different variables (incorporated or considered) which blurs the response [40]. Although 83% of respondents report that there is no pedestrian-only zone planning, a little, or a moderate amount; a determination cannot be drawn between whether the answer is associated with incorporation or consideration.

Discussion

Although AFCEC intended to explore healthy planning designs applicable to Air Force bases, results indicate that more research needs to occur on healthy base planning. As evident by the reliability analysis results, the investigative nature of the 23 questions led to poor question grouping. In other words, there were not enough questions per healthy planning strategy to reliably determine whether it is applicable to Air Force bases. The exploratory factor analysis results confirmed there are too many factors of healthy community design. The four strategies identified by Yip et al. (2020) accomplishes AFCEC's intent by providing healthy designs for which Air Force community planners can focus their efforts to encourage more physical activity.

Moving forward, it is important to establish a baseline for how the strategies are being implemented. The Department of Defense requires service members to be fit for the fight, therefore, the Air Force would be wise to utilize all options available to ensure its personnel are physically fit. With that being said, further research must be conducted to examine how to improve incorporation of healthy planning strategies in community designs. The results from paper's HBI survey analysis implicates two

areas of focus for further exploration. First, shown previously by AFIT researchers, healthy designs can encourage or discourage physical activity, however, the monetary costs associated with implementing healthy designs have not been investigated. And second, the simplest strategy to execute has not been determined.

The benefits of implementing healthy community planning compared to benefits of lower obesity related costs have not been analyzed. Academic research indicates that physically fit individuals will decrease the cost of healthcare but more research is required to explore the costs associated with creating areas of green space, highly connected sidewalk and bicycle networks, integrated mixed land use, and access to public transportation. If future researchers can justify the cost savings of healthy planning versus healthcare, Air Force community planners may be able to better communicate the need for healthy bases. From another point of view, the most expeditious or straightforward healthy strategy to construct in order to produce physical health benefits requires more attention. Certain healthy design strategies will have longer time frames to materialize than others, therefore, determining the simplest strategy to implement such as connecting sidewalks may provide momentum to continue healthy community planning.

As far as causes for the discrepancy between plan and execution of healthy community layouts, this paper can theorize two different reasons: Air Force policy and regulation associated with monetary funds. While the Air Force is governed by guidelines for High Performance and Sustainable Building design, Architecture and Landscape Architecture [41–43], the disconnect between existing land uses and new constructed land use guidance may be attributed to the different fund sources in the federal government and timeline for requirements. For example, if community planners aim to collocate dormitories with the base exchange or commissary, it would require collaboration between appropriated funds and non-appropriated funds. This may deter

vertical mixed land use. Another theoretical example is the timing of requirements; if organization A and B are in need of new workspace, organization A may have a current requirement whereas organization B's window of opportunity may not be for another year. Therefore, it may not be possible to locate the two together into the same facility to encourage vertical mixed land use. These are but two examples of the difficulties associated with enforcing mixed land use on bases. Even then, more communication between stakeholders is required to promote opportunities for mixed land use which reinforces physical activity.

Next, occupants of Air Force bases at present cannot achieve the health benefits associated with public transit because there is no transit network and any bus service offered is not connected. Individuals who utilize public transportation can accomplish the daily recommended physical activity time by walking to and from transit stops and are less likely to be overweight. Therefore, if the Air Force wants to shift towards healthy planning, changes in design must occur to incorporate more transit infrastructure both on-base and connecting off-base as well as changes in policy to organize a public transportation network. It is important to note a trend within the HBI survey; if the neighborhood surrounding the base has a transportation network, public transportation on base is more likely to exist. The process to connect to from bases in or around a nearby city may be more straightforward. Needless to say, this may not be an option for all bases but a follow-up survey should investigate whether addition of a public transportation network on-base would be utilized by its occupants.

Finally, construction costs and anti-terrorism and force protection standards may theoretically be the cause for disconnected sidewalks and poorly marked bicycle paths. The health and economic benefits associated with active transportation is an important reason for community planners to focus on the difference in infrastructure

features between pedestrian and bicycle networks. Street design heavily influences physical activity and due to present bases lacking this healthy community characteristic, the benefits of physical activity are not available [25]. While pedestrian infrastructure is more prevalent on bases, emphasis must be placed on connecting all sidewalks to further promote a walkable community. Based on opinions voiced by community planning experts on the HBI survey, sidewalks are an afterthought during project construction. Subsequently, the project will be considered complete foregoing the placement of sidewalks, leading to disconnected sidewalks. Unique to the military, anti-terrorism and force protection (AT/FP) policies have consequently created unwalkable environments. AFIT researchers have cross-examined the contrast between walkability and AT/FP and concluded that overlaps exist in terms of vehicle defense and visual interest and more communication between community planners and anti-terrorism officers must occur to implement the two concepts together [44]. Incorporating an interconnected pedestrian and bicycle network on base is vital and it is the healthy planning strategy that encourages active transportation instead of auto dependency.

Limitations and Suggestions for Future Research

Following the analysis of the HBI survey, the results frames the requirement for a new survey to further explore healthy design strategies and whether it has the desired effect on physical health. It is clear that the original HBI survey was purely intended to explore healthy design options hence the reason for poor construct reliability and the investigative nature of the questions caused poor construct validity shown by the inability to form singular components.

One key aspect of the strategies not questioned on the survey is green space access or availability. Out of the 24 questions, the most comparable question linked to green

space is whether active living features (designs which encourage healthy lifestyle) are considered in the site design process to which respondents answered always or usually 49.1%. Utilizing a single question to investigate existence of green space on a base severely limits potential to gather useful information. Therefore, there is essentially no mention of green space in the survey. The research from Yip et al. (2020) shows the positive impacts of incorporating green space in the community layout and without questioning this category, the HBI survey did not explore a strategic factor in a base's healthy community layout.

The survey analysis as a whole was able to narrow the discussion of factors associated with a healthy base, however, each question measured multiple independent variables within the same questions leading to limited quantitative analysis. Additionally, due to the multiple numeric scales used, the methodology was reduced to nearly half the survey questions and the results were in-determinant. To address these concerns, a follow-on survey must be conducted to rectify the issues with the HBI survey. The new survey must first focus on covering the research gap of green space and its impact on base occupant's physical health. Then the questions must be written objectively to explore whether healthy design strategies have the desired effect on physical health. The future survey development may be improved upon by following a standardized research process.

It is possible to emulate the efforts in exploring the dimensionality of community planning and provide evidence of construct validity for a new healthy community layout measure based on well founded research methods [45–47]. The process generally begins by formulating questions that adhere to the domains of the topic. Second, multiple a priori factors are compared within that topic. Third, the method examines the outcomes associated with the constructs to group them in a larger analogous network to demonstrate predictive validity. Applying the same methodology, four to

five questions would be generated based on the healthy community planning domains with 1 representing a low response and 7 presenting a high response. Then, verify the a priori factors of a healthy community layout through: (1) sending the survey to experts in the field of research to narrow down the questions and (2) confirmatory factor analysis of results (checking for model fit). Lastly, compare the correlation to substantiate significance between the variables of a healthy community layout. The product of this procedure would correspond to a standardized survey able to measure healthy community layouts.

It is worth noting that while Air Force community planners are subject matter experts in their field and a trustworthy survey source, their survey opinions are limited and do not represent the Air Force as a whole, only a specific sample of the general population. Therefore, another follow-on method of measuring the effectiveness of a healthy community layout on Air Force bases is through a longitudinal study. Drawing from research conducted by Christian et al. (2011, 2017), the four strategies can be studied by surveying participant's perceived health and physical fitness assessment scores periodically throughout five years to document any changes associated with changes in their community layout [37; 48]. The four strategies can be treated as independent variables to help determine which community layout can provide the greatest impact on individual physical health.

Conclusion

In summation the data provided a priori to this paper was analyzed to verify the HBI survey's reliability, validity, and consistency. The reasons that caused the non-conclusive results can be determined. Since AFCEC intended to explore healthy base designs applicable to Air Force bases, their questions were investigative and broad in order to cover a wide breadth of community characteristics. This pro-

duces an unintended consequence where reliability becomes unacceptable because there were 23 questions examining multiple constructs. Furthermore, the five factors found in the exploratory factor analysis results reflects that the survey tried to cover too many factors in community design. Moving forward it is recommended that the Air Force focus on the four strategies of mixed land use, public transportation access, walkability/bike-ability, and green space to positively influence base occupant's physical health.

Active design in communities and neighborhoods is still a largely unknown field, and the contribution of this paper seeks to add to the body of knowledge through the analysis of the HBI survey. The survey holds value as a good starting point to understand the current state of healthy community planning and offers potential for future layout assessments. Follow-on studies should focus on research methods that look at research design, specifically how to formulate a objective, gather data through a survey tool, and target audience for the questionnaire. Understanding how to properly collect information will yield usable data for further statistical analysis.

Supplementary Material

Table S1. Exploratory Factor Analysis Variance Explained

Component	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	Var. %	Cumm. %	Total	Var. %	Cumm. %
1	5.313	35.42	35.42	3.557	23.713	23.713
2	2.01	13.402	48.822	2.889	19.257	42.97
3	1.424	9.494	58.316	2.021	13.473	56.443
4	1.303	8.688	67.004	1.298	8.654	65.097
5	1.001	6.673	73.677	1.287	8.58	73.677
6	0.772	5.145	78.822			
7	0.591	3.937	82.759			
8	0.549	3.661	86.42			
9	0.52	3.466	89.886			
10	0.447	2.981	92.867			
11	0.341	2.276	95.143			
12	0.32	2.131	97.274			
13	0.204	1.357	98.631			
14	0.129	0.859	99.49			
15	0.076	0.51	100			

*Note: Rotation Sums of Squared Loadings shown for Eigenvalues above 1.

Table S2. Three-Component Exploratory Factor Analysis Variance Explained

Component	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	Var. %	Cumm. %	Total	Var. %	Cumm. %
1	5.313	35.420	35.420	3.141	20.942	20.942
2	2.010	13.402	48.822	2.218	14.788	35.730
3	1.424	9.494	58.316	2.332	15.546	51.277
4	1.303	8.688	67.004			
5	1.001	6.673	73.677			
6	0.772	5.145	78.821			
7	0.591	3.937	82.759			
8	0.549	3.661	86.420			
9	0.520	3.466	89.886			
10	0.447	2.981	92.866			
11	0.341	2.276	95.143			
12	0.320	2.131	97.273			
13	0.204	1.357	98.631			
14	0.129	0.859	99.490			
15	0.076	0.510	100.000			

*Note: Rotation Sums of Squared Loadings shown for Eigenvalues above 1.

Table S3. Exploratory Factor Analysis Component Matrix

Var. %	23.713	19.257	13.473	8.654	8.58
Component #	1	2	3	4	5
MLU Q	0.772				
MLU Q	0.646			-0.405	
Public Trans Access Q			0.932		
Public Trans Access Q			0.942		
Public Trans Access Q				0.853	
Walk/Bike Q		0.568			
Walk/Bike Q	0.561				
Walk/Bike Q		0.92			
Walk/Bike Q					0.953
Walk/Bike Q		0.854			
Walk/Bike Q		0.746			
Walk/Bike Q	0.676				
Healthy Planning Q	0.672	0.404			
Planning Reps Q	0.674				
Healthy Design Q	0.728				

$$NFI = \frac{(x^2_{Null} - x^2_{Implied})}{(x^2_{Null})} \tag{E1}$$

$$CFI = 1 - \frac{(x^2_{Implied} - df_{Implied})}{(x^2_{Null} - df_{Null})} \tag{E2}$$

$$NFI = \frac{(x^2_{Null})/(df_{Null}) - (x^2_{Implied})/(df_{Implied})}{[(x^2_{Null})/(df_{Null}) - 1]} \tag{E3}$$

$$RMSEA = \sqrt{\frac{x^2_{Implied} - df_{Implied}}{(N-1) * df_{Implied}}} \tag{E4}$$

$$SRMR = \sqrt{\frac{S}{p(p+1)/(2+p)}} \tag{E5}$$

$$S = \sum_{j=1}^{p} \sum_{k=1}^{j-1} \left(\frac{s_{jk}}{\sqrt{s_{jj} s_{kk}}} - \frac{\sigma_{jk}}{\sqrt{\sigma_{jj}\sigma_{jk}}} \right)^2 + \sum_{j=1}^{p} \left(\frac{m_j}{\sqrt{s_{jj}}} - \frac{\mu_j}{\sqrt{\sigma_{jj}}} \right)^2 + \sum_{j=1}^{p} \left(\frac{s_{jj} - \sigma_{jj}}{s_{jj}} \right)^2$$

Table S4. HBI Survey Response Correlation Matrix

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Mix Land Use Likert Q5	1														
2. Mix Land Use Likert Q13	0.432**	1													
3. Public Trans Likert Q8	0.108	−0.053	1												
4. Public Trans Likert Q15	0.097	−0.042	0.842**	1											
5. Public Trans Likert Q16	0.098	−0.077	0.278*	0.187	1										
6. Walk Bike Likert Q9	0.432**	0.340**	.302*	0.269*	0.172	1									
7. Walk Bike Likert Q10	0.380**	0.299*	0.030	0.050	0.199	0.268*	1								
8. Walk Bike Likert Q11	0.305*	0.299*	0.064	0.068	0.212	0.535**	0.315*	1							
9. Walk Bike Likert Q18	0.004	0.028	0.107	0.105	0.102	0.247	0.061	0.014	1						
10. Walk Bike Likert Q19	0.270*	0.397**	0.122	0.199	0.181	0.439**	0.336**	0.802**	−0.057	1					
11. Walk Bike Likert Q20	0.243	0.350**	0.100	0.034	0.144	0.530**	0.384**	0.598**	0.181	0.541**	1				
12. Walk Bike Likert Q21	0.377**	0.432**	0.230	0.259*	0.000	0.324*	0.361**	0.197	0.150	0.346**	0.352**	1			
13. Healthy Planning Likert Q1	0.476**	0.367**	0.153	0.237	0.119	0.457**	0.358**	0.462**	−0.131	0.521**	0.472**	0.410**	1		
14. Planning Reps Likert Q2	0.483**	0.368**	0.239	0.242	0.342**	0.373**	0.460**	0.263*	−0.152	0.471**	0.314*	0.413**	0.619**	1	
15. Healthy Design Likert Q12	0.482**	0.551**	0.207	0.166	0.063	0.416**	0.314*	0.317*	0.169	0.427**	0.308*	0.453**	0.580**	0.464**	1

*Note *p<.05, **p<.01

Healthy Base Initiative Survey (Initial Survey sent by AFCEC)

1. Are community health and opportunities for facilitating physical activity considered in the installation planning process?

- ○ Always
- ○ Usually
- ○ Sometimes
- ○ Rarely
- ○ Never

Other (please specify)

[ ]

2. Are installation health professionals and MWR representatives included in visioning sessions, planning charrettes, and other planning opportunities?

- ○ Always
- ○ Usually
- ○ Sometimes
- ○ Other (please specify)
- ○ Rarely
- ○ Never

[ ]

3. Which modes of transportation does installation street design standards account for? (Select all that apply)

- ☐ Automobiles
- ☐ Public transportation modes and nodes
- ☐ Sidewalks
- ☐ Bicycle pathways
- ☐ Ride share
- ☐ Other (please specify)

[ ]

4. Are pedestrian and bicycle infrastructure features incorporated into installation design guidelines?

- ○ Design guidelines exist for both pedestrian and bicycle features.
- ○ Design guidelines exist for pedestrian features only.
- ○ Design guidelines exist for bicycle features only.
- ○ Design guidelines are being developed or revised.
- ○ Design guidelines do not exist.

5. Are high connectivity, mixed land uses, and compact, walkable design incorporated into district and site planning?

- ◯ Always
- ◯ Usually
- ◯ Sometimes
- ◯ Rarely
- ◯ Never

6. Is there a public transportation (e.g. public bus or shuttle) network on the installation?

- ◯ Yes
- ◯ No

7. What types of public transportation are available on the installation?

- ☐ Public bus
- ☐ Light or commuter rail
- ☐ Base shuttle service
- ☐ Ride Share
- ☐ Other (please specify)

8. How effectively do base networks link to public transportation systems in neighboring communities?

- ◯ Excellent
- ◯ Very well
- ◯ Moderately well
- ◯ Not very well
- ◯ Not at all

9. Are traffic calming strategies considered in the district, network or installation planning process?

- ☐ Strongly agree
- ☐ Agree
- ☐ Neither agree nor disagree
- ☐ Disagree
- ☐ Strongly disagree

10. Is there network plan for safe walkability and bikeability?

- ◯ Strongly agree
- ◯ Agree
- ◯ Disagree
- ◯ Strongly disagree

11. How well are existing sidewalks interconnected along all primary and secondary streets?

- ◯ A great deal
- ◯ A lot
- ◯ A moderate amount
- ◯ A little
- ◯ None at all

12. Are active living features (design which encourages healthy lifestyles) considered in the site design process?

- ◯ Always
- ◯ Usually
- ◯ Sometimes
- ◯ Rarely
- ◯ Never

13. Is proximity of personnel and civilians considered when siting new community support facilities?

- ◯ Always
- ◯ Usually
- ◯ Sometimes
- ◯ Rarely
- ◯ Never

14. Check all strategies used in the planning and visioning process? (select all that apply)

- ☐ Compact Development
- ☐ Transit-Oriented Development
- ☐ Mixed-Use Districts
- ☐ Mixed-Use Buildings
- ☐ Other (please specify)
- ☐ Connected Bicycle Networks
- ☐ Complete Streets
- ☐ Safe Sidewalks
- ☐ Accessible Public Spaces

15. Do on-base transportation networks link to public transportation systems in neighboring communities?

- ◯ A great deal
- ◯ A lot
- ◯ A moderate amount
- ◯ A little
- ◯ None at all

16. Are bus shelters provided at all primary bus stop locations?

- ◯ Always
- ◯ Usually
- ◯ Sometimes
- ◯ Rarely
- ◯ Never

17. Are ride-share (car or van pool) options available for base personnel?

- ◯ Yes
- ◯ No

18. Does the installation have designated bike lanes that are clearly marked?

- ◯ A great deal
- ◯ A lot
- ◯ A moderate amount
- ◯ A little
- ◯ None at all

19. Are existing sidewalks interconnected along all primary and secondary streets?

- ◯ A great deal
- ◯ A lot
- ◯ A moderate amount
- ◯ A little
- ◯ None at all

20. Are pedestrian crossings (crosswalks) at all primary (arterial) and secondary (collector) street intersections where sidewalks intesect appropriately designated, marked or otherwise protected?

- ◯ A great deal
- ◯ A lot
- ◯ A moderate amount
- ◯ A little
- ◯ None at all

21. Have pedestrian-only zones been incorporated or considered in planning?

- ◯ A great deal
- ◯ A lot
- ◯ A moderate amount
- ◯ A little
- ◯ None at all

22. Which types of pedestrian / bike safety features CURRENTLY EXIST on your installation?

- ☐ Primary sidewalks 5-feet wide
- ☐ ADA/ABA standard sidewalks and crossings
- ☐ Landscape medians / buffered sidewalks
- ☐ Lighting for primary sidewalks
- ☐ Sun protection (tree shade) along primary sidewalks?
- ☐ Traffic islands
- ☐ Traffic medians
- ☐ Separated / protected bike lanes
- ☐ Bus shelters
- ☐ Crosswalks marked with pavement marktings & MUTCD standard signs
- ☐ Bicycle racks
- ☐ Bike share program
- ☐ Curb bump outs
- ☐ Other (please specify)

23. Which types of pedestrian / bike safety features are PLANNED for the installation? (select all that apply)

- ☐ Primary sidewalks 5-feet wide
- ☐ ADA/ABA standard sidewalks and crossings
- ☐ Landscape medians / buffered sidewalks
- ☐ Lighting for primary sidewalks
- ☐ Sun protection (tree shade) along primary sidewalks
- ☐ Traffic islands
- ☐ Traffic medians
- ☐ Separated / protected bike lanes
- ☐ Bus shelters
- ☐ Crosswalks marked with pavement markings & MUTCD standard signs
- ☐ Bicycle racks
- ☐ Bike share program
- ☐ Curb bump outs
- ☐ Other (please specify)

24. Please provide.

Name

Position / Office

Base/Installation

State/Province

Country

Email Address

Phone Number

Bibliography

1. "Urban sprawl and risk for being overweight or obese." *American journal of public health*, vol. 94, no. 9, p. 1574–9, Sep 2004. [Online]. Available: http://www.ncbi.nlm.nih.gov/pubmed/15333317

2. H. P. Hynes, "Obesity, physical activity, and the urban environment: public health research needs," *Environmental Health*, vol. 5, no. 1, p. 25, Dec 2006. [Online]. Available: http://ehjournal.biomedcentral.com/articles/10.1186/1476-069X-5-25

3. D. of Economic, S. Affairs, and P. Division, *2018 Revision of World Urbanization Prospects*, 2018. [Online]. Available: https://www.un.org/development/desa/publications/2018-revision-of-world-urbanization-prospects.html

4. "Active community environments (aces) resource kit to prevent obesity," 2009. [Online]. Available: http://dhfs.wisconsin.gov/health/physicalactivity/index.htm

5. T. Community Preventive Services Task Force, "Task Force Finding and Rationale Statement - Physical Activity: Built Environment Approaches Combining Transportation System Interventions with Land Use and Environmental Design," 2016. [Online]. Available: https://www.thecommunityguide.org/sites/default/files/assets/PA-Built-Environments.pdf

6. E. T. McMahon and T. C. Thoerig, "Ten principles for building healthy places building healthy places initiative," *Urban Land Institute*, 2013. [Online]. Available: http://uli.org/wp-content/uploads/ULI-Documents/10-Principles-for-Building-Healthy-Places.pdf

7. "Intersections: Health and the built environment," *Urban Land Institute*, 2013. [Online]. Available: www.uli.org

8. *Active design*, 2018, transit and Parking: Ref 11, 24, 19-22, 23Grocery stores and fresh produce access: 53, 54, 55, 56Create vendiagram of 4 domains, UFC, and universal design.

9. M. J. Duncan, E. Winkler, T. Sugiyama, E. Cerin, L. DuToit, E. Leslie, and N. Owen, "Relationships of Land Use Mix with Walking for Transport: Do Land Uses and Geographical Scale Matter?" *Journal of Urban Health*, vol. 87, no. 5, pp. 782–795, sep 2010. [Online]. Available: http://link.springer.com/10.1007/s11524-010-9488-7

10. S. L. Handy, M. G. Boarnet, R. Ewing, and R. E. Killingsworth, "How the Built Environment Affects Physical Activity Views from Urban Planning," Tech. Rep., 2002. [Online]. Available: https://www.ajpmonline.org/article/S0749-3797(02)00475-0/pdf

11. G. E. A. Eldayem, "Influence of mixed land-use on realizing the social capital," *HBRC Journal*, vol. 11, no. 2, p. 285–298, Aug 2015. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S1687404814000303

12. A. L. Dannenberg, "Walking to public transit: Steps to help meet physical activity recommendations," *American Journal of Preventive Medicine*, vol. 29, no. 4, p. 273–280, Nov 2005. [Online]. Available: https://www.cdc.gov/healthyplaces/articles/besser_dannenberg.pdf

13. S. N. Banerjee, A. L. Dannenberg, and A. M. Wendel, "Walking associated with public transit: moving toward increased physical activity in the united states."

American journal of public health, vol. 103, no. 3, p. 536–42, Mar 2013. [Online]. Available: http://ajph.aphapublications.org/doi/10.2105/AJPH.2012.300912

14. M. Lindström, "Means of transportation to work and overweight and obesity: A population-based study in southern Sweden," *Preventive Medicine*, vol. 46, no. 1, pp. 22–28, jan 2008. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0091743507003052

15. L. Ming Wen and C. Rissel, "Inverse associations between cycling to work, public transport, and overweight and obesity: Findings from a population based study in Australia," *Preventive Medicine*, vol. 46, no. 1, pp. 29–32, jan 2008. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0091743507003714

16. G. Netuveli and C. Millett, "Free bus passes, use of public transport and obesity among older people in england." *Journal of epidemiology and community health*, vol. 66, no. 2, p. 176–80, Feb 2012. [Online]. Available: http://www.ncbi.nlm.nih.gov/pubmed/21911850

17. J. A. Hipp, M. W. Corseuil, and E. A. Dodson, "Correlates of walking for transportation and use of public transportation among adults in st louis, missouri, 2012." *Preventing chronic disease*, vol. 11, p. E112, Jul 2014. [Online]. Available: http://www.ncbi.nlm.nih.gov/pubmed/24995654

18. A. L. Bedimo-Rung, A. J. Mowen, and D. A. Cohen, "The significance of parks to physical activity and public health," *American Journal of Preventive Medicine*, vol. 28, no. 2, pp. 159–168, feb 2005. [Online]. Available: https://linkinghub.elsevier.com/retrieve/pii/S0749379704003046

19. E. Coombes, A. P. Jones, and M. Hillsdon, "The relationship of physical

activity and overweight to objectively measured green space accessibility and use," *Social Science & Medicine*, vol. 70, no. 6, pp. 816–822, mar 2010. [Online]. Available: http://www.ncbi.nlm.nih.gov/pubmed/20060635http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC3759315https://linkinghub.elsevier.com/retrieve/pii/S0277953609008156

20. S. M. E. van Dillen, S. de Vries, P. P. Groenewegen, and P. Spreeuwenberg, "Greenspace in urban neighbourhoods and residents' health: adding quality to quantity." *Journal of epidemiology and community health*, vol. 66, no. 6, p. e8, jun 2012. [Online]. Available: http://www.ncbi.nlm.nih.gov/pubmed/21715445

21. R. A. Verheij, P. P. Groenewegen, S. de Vries, and P. Spreeuwenberg, "Green space, urbanity, and health: how strong is the relation?" *Journal of epidemiology and community health*, vol. 60, no. 7, p. 587–92, Jul 2006. [Online]. Available: http://www.ncbi.nlm.nih.gov/pubmed/16790830

22. "Advancing obesity solutions through investments in the built environment: Proceedings of a workshop in brief (2017)," *National Academy of Sciences*, p. 10, 2017. [Online]. Available: https://doi.org/10.17226/24963.

23. B. Giles-Corti, M. H. Broomhall, M. Knuiman, C. Collins, K. Douglas, K. Ng, A. Lange, and R. J. Donovan, "Increasing walking," *American Journal of Preventive Medicine*, vol. 28, no. 2, pp. 169–176, feb 2005. [Online]. Available: http://www.ncbi.nlm.nih.gov/pubmed/15694525https://linkinghub.elsevier.com/retrieve/pii/S0749379704002983

24. T. E. Mäki-Opas, K. Borodulin, H. Valkeinen, S. Stenholm, A. E. Kunst, T. Abel, T. Härkänen, L. Kopperoinen, P. Itkonen, R. Prättälä, S. Karvonen, and S. Koskinen, "The contribution of travel-related urban zones, cycling and pedestrian networks and green space to commuting physical activity among adults - A cross-

sectional population-based study using geographical information systems," *BMC Public Health*, vol. 16, no. 1, aug 2016.

25. L. D. Frank and P. O. Engelke, "The Built Environment and Human Activity Patterns: Exploring the Impacts of Urban Form on Public Health," *Journal of Planning Literature*, vol. 16, no. 2, pp. 202–218, nov 2001. [Online]. Available: http://journals.sagepub.com/doi/10.1177/08854120122093339

26. R. A. Zeller, *Reliability and validity assessment*. Sage publications, 1979, vol. 17.

27. F. Middleton, "Reliability vs Validity in Research — Differences, Types and Examples," 2019. [Online]. Available: https://www.scribbr.com/methodology/reliability-vs-validity/

28. D. L. Streiner, "Starting at the Beginning: An Introduction to Coefficient Alpha and Internal Consistency," *Journal of personality assessment*, vol. 80, pp. 99–103, 2003.

29. J. Sauro, "Measuring: How to Measure the Reliability of Your Methods and Metrics," 2015. [Online]. Available: https://measuringu.com/measure-reliability/

30. K. S. Taber, "The Use of Cronbach's Alpha When Developing and Reporting Research Instruments in Science Education," *Research in Science Education*, vol. 48, no. 6, pp. 1273–1296, dec 2018.

31. L. J. Cronbach and P. E. Meehl, "Construct validity in psychological tests," *Psychological Bulletin*, vol. 52, no. 4, pp. 281–302, jul 1955.

32. C. D. Stapleton, "Basic Concepts in Exploratory Factor Analysis (EFA) as a Tool To Evaluate Score Validity: A Right-Brained Approach." p. 19p., 1997.

33. M. Matsunaga, "How to Factor-Analyze Your Data Right: Do's, Don'ts, and How-To's." *International Journal of Psychological Research*, vol. 3, no. 1, pp. 97–110, 2010.

34. R. K. Henson and J. K. Roberts, "Use of exploratory factor analysis in published research: Common errors and some comment on improved practice," *Educational and Psychological Measurement*, vol. 66, no. 3, pp. 393–416, 2006.

35. G. E. Gignac, "Partial confirmatory factor analysis: Described and illustrated on the NEO-PI-R," *Journal of Personality Assessment*, vol. 91, no. 1, pp. 40–47, 2009.

36. L. T. Hu and P. M. Bentler, "Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives," *Structural Equation Modeling*, vol. 6, no. 1, pp. 1–55, 1999.

37. F. C. Bull, N. J. Middleton, M. W. Knuiman, M. L. Divitini, P. Hooper, A. Amarasinghe, and B. Giles-Corti, "How important is the land use mix measure in understanding walking behaviour? results from the reside study," 2011. [Online]. Available: http://www.ijbnpa.org/content/8/1/55

38. R. Ewing, O. Clemente, S. Handy, R. C. Brownson, and E. Winston, "Identifying and Measuring Urban Design Qualities Related to Walkability Measuring Urban Design Qualities Related to Walkability," 2005. [Online]. Available: http://smartgrowth.umd.edu/assets/documents/research/ewingclementehandyetal{_}walkableurbandesign{_}2005.pdf

39. M. A. Andresen and T. L. Schmid, "Obesity relationships with community design, physical activity, and time spent in cars," *American Journal of*

Preventive Medicine, vol. 27, no. 2, p. 87–96, Aug 2004. [Online]. Available: https://linkinghub.elsevier.com/retrieve/pii/S074937970400087X

40. "The meanings of methodology," *Social research methods*, vol. 60, p. 87, 2000.

41. D. of Defense, "UNIFIED FACILITIES CRITERIA (UFC) APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED HIGH PERFORMANCE AND SUSTAINABLE BUILDING REQUIREMENTS," Tech. Rep., 2016. [Online]. Available: http://www.dod.wbdg.org/.

42. ——, "UNIFIED FACILITIES CRITERIA (UFC) APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED LANDSCAPE ARCHITECTURE," Tech. Rep., 2009. [Online]. Available: http://www.dod.wbdg.org/.

43. ——, "UNIFIED FACILITIES CRITERIA (UFC) APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED ARCHITECTURE," Tech. Rep., 2011. [Online]. Available: http://www.dod.wbdg.org/.

44. A. S. Fenner, "Walkability and Anti-Terrorism/Force Protection: Understanding the relationship and how it can work on the United States Air Force's Main Operating Bases," Ph.D. dissertation, 2019.

45. J. A. Colquitt, "On the Dimensionality of Organizational Justice: A Construct Validation of a Measure," *Journal of Applied Psychology*, vol. 86, no. 3, pp. 386–400, 2001.

46. N. Golafshani, "Understanding reliability and validity in qualitative research," *The qualitative report*, vol. 8, no. 4, pp. 597–606, 2003.

47. *How to measure survey reliability and validity.* Sage, 1995, vol. 7.

48. H. Christian, M. Knuiman, M. Divitini, S. Foster, P. Hooper, B. Boruff, F. Bull, and B. Giles-Corti, “A Longitudinal Analysis of the Influence of the Neighborhood Environment on Recreational Walking within the Neighborhood: Results from RESIDE,” *Environmental Health Perspectives*, vol. 125, no. 7, jul 2017. [Online]. Available: https://doi.org/10.1289/EHP823

IV. Development of the future Department of Defense Community Layout Survey

Abstract

Healthy communities are a cause for concern stemming from the increase in global urbanization. It is estimated that more than 66% of the world will live in urban areas by 2050. The transformation from rural land into urban environments has caused a detrimental effect on physical activity and public health due to vehicular dependency, reduced rates of exercise, and decreased walking due to poor street connectivity. To explore these effects, the Air Force Civil Engineer Center sought to explore the healthy community designs most applicable to military bases, through the utilization of their own survey, however, the study performed achieved non-conclusive results. This paper builds upon the Healthy Base Initiative survey and provides a novel survey to assess Air Force bases. Using research method procedures, an examination of issues with the HBI survey is followed with practices to counteract the problems. The new DoD Healthy Activity Public Planning Investigative (HAPPI) Survey quantifies existing healthy designs and seeks to ultimately enhance base occupant's physical health. With knowledge of how the current design impacts the physical health of the occupants, optimal improvements can be made which maximize the dollars spent, and the well-being of the base occupants.

Introduction

Healthy communities are a cause for concern stemming from the increase in global urbanization. Urbanization is the process that transforms the formerly rural land into urban environments and based on the latest World Urbanization Prospects, more than 66% of the world will live in urban areas by 2050 [1; 2]. Urban sprawl has a

detrimental effect on physical activity and public health due to vehicular dependency, reduced rates of exercise, and decreased walking due to poor street connectivity [3–5]. Community planning researchers have sought to alter the negative effects of urbanization into a positive aspect by studying different factors of community layouts that promote physical activity.

There are multiple healthy design characteristics recognized by the body of knowledge on community planning associated with physical health. For a community design to be considered healthy, it embodies these four domains: integrated access to green space, highly connected pedestrian and bicycle network with traffic calming features, developed and mixed land use, and access to public transit and transit facilities [6–10]. The four healthy design criterions work in conjunction to strategically improve physical health by encouraging physical activity in the public. Overlaps between each domain exist but each one covers an aspect within a community environment. The first domain involves incorporation of green space into the community layout for recreational activities and environmental appeal [11; 12]. Past research has shown an increase in amount of physical activity when green space is within proximity of centralized community areas [13; 14]. The second domain is design of interconnected sidewalks and bicycle paths. Studies have shown that the connectivity of pedestrian and bicycle infrastructure coupled with safety elements influence both leisure-time and travel-related physical activities of individuals [15–18]. The third domain of collocating different land uses reduces dependency on vehicles and increases the amount of time spent walking. By shifting from an automobile focused method of travel to an active transportation of walking or bicycling, individuals can improve their physical health [19–22]. Lastly, the fourth domain of a healthy community environment is access to public transit and transit facilities. Physical health research has shown that individuals can achieve the daily recommended fifteen-minutes physical activity time

by walking to and from transit stops [23–28].

Many community planners have developed their own processes such as following a checklist or using data from a public survey to gather input to ensure healthy community factors are considered when planning. The Healthy Community Design checklist [29] developed by the National Center for Environmental Health is one example where participants are encouraged to voice their opinion on how to reverse obesity, reduce traffic injuries, and make the community stronger. New York City's Active Design Guidelines [10] publication is another of many examples of a checklist followed by community planners to reinforce healthy community design. Similarly, the Washington State Active Community Environments Checklist [30] is a self-assessment tool for communities to identify gaps in community practices in support of physically active lifestyles.

Like the public, the Air Force Civil Engineer Center (AFCEC) sought to examine the healthy community designs most applicable to military bases, through the utilization of their own survey tool, however, the study performed achieved inconclusive results. Due to the exploratory nature of the survey questions, unintended consequences compounded due to research techniques utilized in the Healthy Base Initiative (HBI) survey. This paper builds upon the HBI survey and provides a novel survey to assess Air Force bases. Using research method procedures, an examination of issues with the HBI survey is followed with practices to counteract the problems. The new survey assessment tool is developed seeking to add to the Department of Defense's body of knowledge by investigating the causal relationship between healthy base infrastructure and the perception of people's well-being. The intended sample population will be occupants such as ones employed on base or living in base quarters. Research generally follows the path shown in Figure 1 [31] and the purpose of this paper is focused on operationalization of variables, research design, and data

collection.

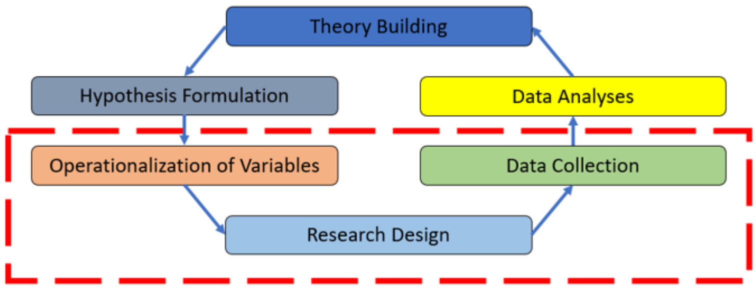

Figure 4. Research Method Process. Adopted from [31]

Results from Initial Survey

Previous analysis from Yip et al. (2020) showed the reliability and validity issues which explained the inconclusive results of the HBI survey. Both the reliability and exploratory factor analysis yielded undesirable results and there was essentially no mention of green space in the survey, which was one of the key strategies of a healthy community layout. The survey was generally able to confirm the hypothesis: to measure how well the base plans for healthy community layouts and the execution of those plans however, the research methodology was limited to the survey data provided. This outcome can be improved upon if a new survey is developed following the recommendations in this paper.

Important Considerations for a Survey

1. Provide Questions with Clear Objectives

In research, it is essential to ask questions focused on investigating relationships between variables of interest. To begin the process, standard quantitative research can be categorized by one of three methods: group comparison where a group of independent variables are compared to a dependent variable, a survey that correlates

variables where one or more independent variables are related to one or more dependent variables, and a descriptive study where the independent or dependent data is described [32]. After determining the method of quantitative research, descriptive or hypotheses survey questions are created. According to Neuman et al. (2000), the format of survey questions should avoid: (1) questions that cannot be empirically tested or non-scientific questions, (2) statements that include general topics instead of research questions, (3) statements that include a set of variables without questions, (4) questions too vague or ambiguous, and (5) questions that need to be more specific [33]. Focusing on these concepts will aid the research in staying on topic.

Not only do questions need to centralize on the subject, the reliability and validity of the questions must be considered when testing a hypothesis. Reliability refers to the degree to which a research tool yields stable and consistent results. Simply put, a yard stick should measure three feet each time or else it is unreliable. Deeper levels of reliability such as internal consistency, inter-rater reliability, and stability must be examined as these sub-components will help the survey responses limit random error. For example, a survey with high stability, internal consistency, and inter-rater reliability will give the same score each time and if two base occupants take the survey, they will give similar scores for each question. Another method of verifying reliability is through the test-retest method [31]. By checking the correlation between pretest and post-test, the researcher can determine precision of the survey, an ideal outcome would be identical results.

A common measurement of tool reliability is the Cronbach's Alpha value. The more homogeneous the survey construct objectives, the higher the reliability. Even though reliability is vital to an assessment tool, a high reliability does not guarantee high validity. A high Cronbach's Alpha does not necessarily mean the survey is measuring what is intended. Unreliability can result in two consequences: issues

associated with unreliable dependent variables will result in net results having zero effect on the regression coefficient, and unreliability in the independent variable will result in the opposite [34].

Research supports construct validity being more important than construct reliability. Validity refers to how accurately a tool is measuring the intended phenomenon [35]. In other words, if a tool was designed to measure intelligence but measured something else, the data collected is not valid. Therefore, even if an instrument measures consistently, if it cannot accurately measure what it is supposed to, there is no reason to use it. There are four different types of validity: construct, content, face, and criterion related [31; 34]. Due to the difficulty measuring the impact of the community layout on physical health directly, the four types of validity must be used. Construct validity is the extent to which an operational variable accurately represents the construct it is intended to measure [31; 34]. Content validity is aimed at capturing and measuring all the research issues of the construct [31; 34]. For instance, the new survey will have to cover all four strategies of a healthy community layout to ensure content validity. Face validity is the extent to which the test appears to measure the construct [34]. The new survey will question what characteristics of a healthy base exists and how occupants feel about their health; on the surface the survey seems like a good representation of what to test, leading to high face validity. Criterion validity is how closely the results of the test corresponds to the results of another test [31; 34]. If the results from the new survey correlates highly with results of a verified survey, it gives good indication that the survey met its mark.

There are also two additional factors associated with validity: internal and external validity [36; 37]. Internal validity describes the confidence that the factors contributing to the results being measured is dependable and not influenced by other reasons. In other words, the new survey questions must link how occupants feel about

their physical health with the community layout and not outside factors. External validity refers to the ability to apply the same test to a generalized group such as using the new survey for communities outside the DoD.

Questions were not written with any independent or dependent variables, therefore limiting the correlation between questions to qualitative analysis. At face value, initial assessment of the questions and survey results did not lead the analyzer to definitive conclusions that can be acted upon in the future. Stated previously, the survey constructs were both unreliable and not validated. It did not fit into the four-factor model of mix land use, public transportation access, walkability/bike-ability, or green space.

To address these concerns, the new survey begins with generating and testing a theory established by a literature review in the field of healthy community design [31; 34; 38; 39]. Supported by previous research of Yip et al. (2020), characteristics of the base community layout such as mix land use, public transportation access, walkability/bike-ability, and green space can influence physical health [6–10]. There are a multitude of independent variables that affect health such as diet, exercise and genetics [40–43] but, the focus of this paper is the development of survey questions which measure the constructs of the factors in the community layout. Every question will have an independent variable that helps to measure the dependent variable.

As a whole, without goal oriented questions adhering to proper construct reliability and validity standards, the new survey used to measure the relationship between a healthy community layout and physical health will result in inaccurate results not representative of reality [44]. It is vital to apply standard research techniques in the development of the new healthy base survey.

2. Properly Format Questions

Well founded in the field of questionnaires, a good survey question asks for only one answer on only one dimension [31; 39]. Research questions should avoid multi-variable answers or several sub-questions [31], for example, "does your base construct safety curbs for pedestrians and bicyclers?" This example question poses a problem for both respondent and researcher because the base may consider pedestrians and not bicyclers, causing the respondent's answer to be inaccurate, and the researcher's data result to be uncertain. Therefore, each question should be about one topic. In addition, while it is good practice to ask multiple questions to reinforce reliability of the individual's response [39], it is beneficial to map the questions such that it flows logically from one construct to the next. Returning to previous topics can confuse the respondent because they think they have dealt with this already; referring back to information already given can lead to errors [44].

Similar to creating questions with clear objectives, some HBI survey questions offered multiple answer choices for inclusion (i.e. select all that apply). Each survey question should measure individual objectives instead of mixing multiple independent variables. The consequence of multi-variable objective questions is the inability to determine whether any one specific independent variable influences the dependent variable. Shown by Table S3 from previous AFIT research (Yip 2020), the exploratory factor analysis found five different constructs with multiple cross-loading. This issue can be avoided through proper de-lineation of the four healthy community constructs.

The new survey will properly format questions by pairing a single independent and dependent variable per question. Using the same example from above, pedestrian and bicycle safety factors will be measured separately through two separate questions. Doing so will resolve any cross-loading of components when performing confirmatory factor analysis to validate constructs. Furthermore, the flow of survey questions is

organized to transition seamlessly from one construct to the next.

3. Increase Sample Size

In order to produce supported results, the level of significance desired or degree of precision will drive the smallest sample size needed to detect the effect of healthy community layout strategies [45]. To explain this simply, a researcher wants to avoid a type I error which is rejecting the null hypothesis when it is true, or a type II error which is failing to reject the null hypothesis when it is false. The power analysis adopted from Cohen et al. (Cohen 1962) which depends on three things: effect size, sample size, and decision criteria is recommended to drive the sample selection requirement [46]. A high statistical power would indicate trustable test results but also increases the chance of a type II error whereas a low statistical power would elude to debatable results.

There was a total of 59 usable responses to the HBI survey after outlier removal. This is a small sample size of the population. Furthermore, the survey was only offered to community planners within the Civil Engineering Squadron. Due to the small sample, any relevant or significant results would have been unsupported because it is not representative of the general population. The HBI survey sampling was also subject to convenient and volunteer sampling. As the term convenient sampling suggests, it was convenient to distribute the survey to all community planners [34]. Additional problems can exist with volunteer sampling where there is no evidence that the sample is representative nor generalizable to the wider population.

The follow-on researcher will need to determine a target power where the effect results will avoid incorrect rejection of the null hypothesis. Generally speaking, the larger the effect size, the higher percentage of variance explained and better the ability to detect the effect of each construct. To provide an example using the power table

[47], the number of samples required to detect a medium effect size and significance level of 0.05 for a correlation test is 85 participants. Effect size in research is a way of quantifying the size of the difference between two groups [48]. Simply put, it offers researchers an explanation for 'how well does the tool work', more so than 'does it work' [49]. Common practice is to use a value of 0.5 as a starting point before conducting research.

After the target sample size is determined by the power analysis, the next stage is the level of sampling: psychological, organizational, and strategic, low to high. This survey will be at the psychological/individual level. It is unrealistic to do a census level survey of the whole population in the Air Force, therefore, only a sample of the population will be surveyed. Although sampling can save both time and money, the researcher needs to consider sampling bias as it can lead to error. Ways to reduce sampling bias and error are simple random sample where each member in the population has an equal probability of being selected to participate [34; 38]. While it is difficult to implement this practice, it is the recommended method for the follow-on survey pending IRB approval. If simple random sampling is unachievable, other ways include accessibility bias, cluster bias, non-response bias, order bias, self-selection bias, termination bias, and visibility bias.

4. Standardize Question Responses

There are four levels of measurement and scaling that encompasses comparative and non-comparative evaluation [50–52]. The basic level begins with the nominal or categorical scale where individual items are described with no order, for example, companies, products, or brands. The nominal scale counts the frequency of the items with no ability to establish any causal relationships [50–52]. The next level is ordinal scales where ranking is involved between items. It is commonly used by researchers

to determine the order of preference between items but not the degree of how much between each item [52]. The third level is the interval scale which builds upon the ordinal scale by creating equal distance between each ranked item. One example of interval or cardinal scale is the Likert scale. Lastly, the ratio scale is the highest level of measurement with one key difference between interval scale: a fixed origin or zero point [50–52]. The ratio scale provides researchers the ability to conduct any statistical analysis. Typical studies follow at least one of four scales while performing research.

In the HBI survey had an non-standardized question scale. Answers not only switched between radio buttons and check boxes, Likert scales varied between 1-4 (1 representing strongly disagree and 4 representing strongly agree) and 1-5 (1 for never, 5 for always), (1 for not at all, 5 for excellent), (1 for strongly disagree, 5 for strongly disagree), or (1 for none at all and 5 for a great deal). Although it is common practice to reverse code questions to ensure participants are not thoughtlessly answering the survey, the HBI survey did not utilize this strategy. Two questions were binary (yes or no) and four questions were categorical with multiple answer choices. The different numerical scales consequently led to limited statistical survey analysis. It is ineffective to conduct causal analysis on both discrete and continuous variables because the data is not normally distributed and doing so violates statistical practice. For better illustration, question 22 on the HBI survey offered 14 categorical choices to select (continuous variables) for pedestrian/bicycle safety features and question 9 had a discrete answer between 1 and 5. Mentioned above, causal relationships cannot be calculated with nominal items removing categorical questions on the HBI survey from usage. As a side note, researchers occasionally reverse code questions to verify that participants are thoroughly reading the questions, however, the numeric scale must still follow the same standardization. The survey questions will conform to an ordinal

Likert scale. Likert scale questions are flexible which offers the ability to transform qualitative questions into quantitative aggregated values [34]. A seven-point scale is beneficial to both researcher and participant. The scale offers participants more variance because answer options include satisfied and dissatisfied with a neutral option at the midpoint [39]. Furthermore, this offers precise responses without any hindrances for the researcher to perform quantitative data analysis. Slight variations in the Likert questions can measure agreement, frequency, importance, or quality for the four healthy community strategies.

Discussion

Due to the time constraint of this research program, the questions cannot be validated through experts in the community planning field. Therefore, the new survey draws from examples of validated community questionnaires [53–58]. The six source-questionnaires all gathered inputs from their communities to produce a plan that is technically sound and grounded in the needs of the community. There were areas of overlap in each questionnaire concerning walkability, bike-ability, green space, mix land use, and public transportation and the topics pertinent to this research was extrapolated from the source-questionnaires and utilized as the baseline for development of the new survey.

The DoD Healthy Activity Public Planning Investigative (HAPPI) survey (Appendix B) is comprised of 13 questions which examines the four strategies of a healthy community layout combined with a validated Global Physical Activity Questionnaire from the World Health Organization to determine the impact of community designs on physical health. Question 1 looks at whether the infrastructure supports walking and biking for participants around the base as a whole. Questions 2 and 3 are focuses on the safety of the sidewalk and bicycle network, respectively. Question 4

aims at participant's perception of the base public transportation network. Question 5 is written to explore whether participants would utilize a base public transportation network if it was offered. Question 6 examines the mix land use characteristics of the base and whether it encourages or discourages physical activity. Green space characteristics are examined similarly with question 7 in relation to its ability to motivate participants to physically exercise. Question 8 investigates if participants value green space for their physical health. Question 9 asks participants what generally impacts their physical activity, whether it is due to the community layout or their own fitness routine. Question 10 asks participants to rate their priority of the healthy community layout strategies and how each factor is personally important. Question 11 is a generalized inquiry of the participant's feeling of their base's existing infrastructure. Overall, the eleven main questions with sub-parts are focused on measuring participant's feeling on healthy community strategies and existing infrastructure on their base. Finally, the remaining two questions are for demographic purposes.

The Global Physical Activity Questionnaire (GPAQ) was developed by the World Health Organization to survey physical activity in countries. It collects information on physical activity in three different settings: activity at work, travel to and from places, and recreational activities [59]. The GPAQ utilizes Metabolic Equivalents (METs) to determine the intensity of physical activities, it is a ratio of a person's working relative to the resting metabolic rate. There are 16 questions specifically targeting time spent doing different types of physical activity in a typical week between: work, travel to and from places, and recreational activities.

The HAPPI survey can be analyzed through the usage of Statistical Package for the Social Sciences (SPSS). Questions 1 - 3 can be grouped together to form the walkability/bike-ability construct. Questions 4 and 5 can be combined for public transportation access. The mixed land use construct is created from question 6.

Lastly, the green space construct is comprised of questions 7 and 8. Questions 9 - 11 form a self-perceived construct for community influence on physical activity. Categorization of questions can be seen in Table 6 The four main constructs can be verified for reliability and validity using SPSS through its reliability analysis and dimension reduction factor analysis functions. The World Health Organization provides their own guidance for analyzing the GPAQ [59]. Their guide recommends two ways to calculate physical activity: estimate the sample's mean physical activities through MET-minutes per week and classify a certain population as 'inactive' or 'insufficiently active' and set a cut-point for a specific amount of activity (Appendix C). Post verification of the four healthy design constructs, participant responses can be correlated to MET-minutes per week. A high correlation between the value of MET-minutes and Likert rating of healthy infrastructure would indicate a healthy base that positively influences occupant's physical activity; the opposite would be high MET-minutes and low Likert rating of infrastructure suggesting poor influence on physical activity.

Table 6. HAPPI Survey Question Categorization

Category	Question Number	Numeric Scale
Walkability/Bike-ability	1, 2, 3	Likert
Public Trans Access	4, 5	Likert
Mixed Land Use	6	Likert
Green Space	7, 8	Likert
Other	9, 10 11	Likert Binomial
Participant Demographics	12, 13	N/A

Administering this new survey can lead to a few positive impacts for the DoD. First, a Q-sort systematic review of the survey can validate the four constructs that form healthy community design. The Q-sort method in a research setting examines how experts think about a topic [60]. For example, each evaluator receives individual HAPPI survey questions written on note cards. From there, each question/card is then sorted into the appropriate bin based on how well the bin is representative of

the topic on the card. Following the placement of cards, a discussion will occur to determine reasons for whether the distribution confirms the grouping of healthy design characteristics or if the question/card should be removed from the survey. Second, the survey can be used as a trustworthy assessment tool of healthy community design. Third, community planners can devise future projects targeted at the four characteristics of healthy community design. Future researchers can utilize the theory of planned behavior to their advantage when trying to encourage more physical activity. It is important to recognize that base occupants will forego physical activity even though their environment have shifted to a healthier layout. To maximize the results, the theory of planned behavior examines intention toward attitude, subjective norms, and perceived behavioural control to shape an individual's behavioural intentions and behaviours [61]. Therefore, studying various fields such as advertising, public relations, and advertising campaigns can help to change base occupant's behavior to utilize sidewalks for active transportation. Fourth and last, Air Force community planners and public health officers can measure the level of physical health impacted by the base community layout. The new survey in the Appendix should not be limited to single use as it can be utilized multiple times to continually measure a base's healthy design progress.

Conclusion

Although the initial HBI survey had its issues, it provided a starting point from which to assess healthy communities. Based on support from standard research methods, the four main issues of the HBI survey were identified and addressed, leading to the development of the DoD HAPPI Survey. The new survey is written with a specific and measurable construct, resolving issue #1 of poor reliability and validity. It is also able to measure one dependent and independent variable per question, resolving issue

#2 of multiple cross-loading. This paper provides a recommended sample selection method addressing issue #3. Lastly, the survey questions are on a standardized scale of 1-7 with 1 anchored at the low end and 7 at the high end for flexible statistical analysis, fixing issue #4. While this novel idea of measuring the relationship of healthy community design on physical health through a survey is produced for the Air Force Civil Engineer Center, it has potential to be applicable to agencies outside of the DoD and utilized by general community planners. Quantifying healthy community design is key to ultimately making improvements to communities. With knowledge of how the current design impacts the physical health of the occupants, optimal improvements can be made which maximize the dollars spent, and the well-being of the base occupants.

Bibliography

1. D. of Economic, S. Affairs, and P. Division, *2018 Revision of World Urbanization Prospects*, 2018. [Online]. Available: https://www.un.org/development/desa/publications/2018-revision-of-world-urbanization-prospects.html

2. U. Nations, "The Speed of Urbanization Around the World," 2018. [Online]. Available: https://esa.un.org/unpd/wup/

3. F. B. Laube, "Automobile dependence in cities: An international comparison of urban transport and land use patterns with implications for sustainability," *Environmental Impact Assessment Review*, vol. 16, no. 4–6, p. 279–308, 1996.

4. "Urban sprawl and risk for being overweight or obese." *American journal of public health*, vol. 94, no. 9, p. 1574–9, Sep 2004. [Online]. Available: http://www.ncbi.nlm.nih.gov/pubmed/15333317

5. H. P. Hynes, "Obesity, physical activity, and the urban environment: public health research needs," *Environmental Health*, vol. 5, no. 1, p. 25, Dec 2006. [Online]. Available: http://ehjournal.biomedcentral.com/articles/10.1186/1476-069X-5-25

6. "Active community environments (aces) resource kit to prevent obesity," 2009. [Online]. Available: http://dhfs.wisconsin.gov/health/physicalactivity/index.htm

7. T. Community Preventive Services Task Force, "Task Force Finding and Rationale Statement - Physical Activity: Built Environment Approaches Combining Transportation System Interventions with Land Use and Environmental Design," 2016. [Online]. Available: https://www.thecommunityguide.org/sites/default/files/assets/PA-Built-Environments.pdf

8. E. T. McMahon and T. C. Thoerig, "Ten principles for building healthy places building healthy places initiative," *Urban Land Institute*, 2013. [Online]. Available: http://uli.org/wp-content/uploads/ULI-Documents/10-Principles-for-Building-Healthy-Places.pdf

9. "Intersections: Health and the built environment," *Urban Land Institute*, 2013. [Online]. Available: www.uli.org

10. *Active design*, 2018, transit and Parking: Ref 11, 24, 19-22, 23Grocery stores and fresh produce access: 53, 54, 55, 56Create vendiagram of 4 domains, UFC, and universal design.

11. R. A. Verheij, P. P. Groenewegen, S. de Vries, and P. Spreeuwenberg, "Green space, urbanity, and health: how strong is the relation?" *Journal of epidemiology and community health*, vol. 60, no. 7, p. 587–92, Jul 2006. [Online]. Available: http://www.ncbi.nlm.nih.gov/pubmed/16790830

12. "Advancing obesity solutions through investments in the built environment: Proceedings of a workshop in brief (2017)," *National Academy of Sciences*, p. 10, 2017. [Online]. Available: https://doi.org/10.17226/24963.

13. R. Maheswaran, "The health benefits of urban green spaces: a review of the evidence," *Journal of Public Health*, vol. 33, no. 2, p. 212–222, Jun 2011, quality: References, 54, 56 and 26. [Online]. Available: https://academic.oup.com/jpubhealth/article-lookup/doi/10.1093/pubmed/fdq068

14. L. R. O and A. Dearry, "Creating healthy communities, healthy homes, healthy people: Initiating a research agenda on the built environment and public health," *American Journal of Public Health*, vol. 93, no. 9, 2003. [Online]. Available: https://ajph.aphapublications.org/doi/pdf/10.2105/AJPH.93.9.1446

15. K. R. Smith, H. Hanson, J. X. Fan, L. Kowaleski-Jones, and C. D. Zick, "Neighborhood design for walking and biking: Physical activity and body mass index," *American Journal of Preventive Medicine*, vol. 44, no. 3, p. 231–238, Mar 2013. [Online]. Available: https://www.sciencedirect.com/science/article/abs/pii/S074937971200880X

16. H. Christian, M. Knuiman, M. Divitini, S. Foster, P. Hooper, B. Boruff, F. Bull, and B. Giles-Corti, "A Longitudinal Analysis of the Influence of the Neighborhood Environment on Recreational Walking within the Neighborhood: Results from RESIDE," *Environmental Health Perspectives*, vol. 125, no. 7, jul 2017. [Online]. Available: https://doi.org/10.1289/EHP823

17. B. Giles-Corti, F. Bull, M. Knuiman, G. McCormack, K. Van Niel, A. Timperio, H. Christian, S. Foster, M. Divitini, N. Middleton, and B. Boruff, "The influence of urban design on neighbourhood walking following residential relocation: Longitudinal results from the RESIDE study," *Social Science & Medicine*, vol. 77, pp. 20–30, jan 2013. [Online]. Available: https://www.sciencedirect.com/science/article/abs/pii/S0277953612007381

18. M. A. Harris, C. C. O. Reynolds, M. Winters, S. Babul, M. Chipman, M. D. Cusimano, J. R. Brubacher, G. Hunte, S. M. Friedman, M. Monro, and et al., "Route infrastructure and the risk of injuries to bicyclists: a case-crossover study." *American journal of public health*, vol. 102, no. 12, p. 2336–43, Dec 2012. [Online]. Available: http://ajph.aphapublications.org/doi/10.2105/AJPH.2012.300762

19. F. C. Bull, N. J. Middleton, M. W. Knuiman, M. L. Divitini, P. Hooper, A. Amarasinghe, and B. Giles-Corti, "How important is the land use mix measure in understanding walking behaviour? results from the reside study," 2011. [Online]. Available: http://www.ijbnpa.org/content/8/1/55

20. *PEDESTRIAN-AND TRANSIT-FRIENDLY DESIGN: A Primer for Smart Growth Based on a manual prepared for the Florida Department of Transportation and published by the American Planning Association*, 1999. [Online]. Available: www.smartgrowth.org

21. M. A. Andresen and T. L. Schmid, "Obesity relationships with community design, physical activity, and time spent in cars," *American Journal of Preventive Medicine*, vol. 27, no. 2, p. 87–96, Aug 2004. [Online]. Available: https://linkinghub.elsevier.com/retrieve/pii/S074937970400087X

22. G. E. A. Eldayem, "Influence of mixed land-use on realizing the social capital," *HBRC Journal*, vol. 11, no. 2, p. 285–298, Aug 2015. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S1687404814000303

23. A. L. Dannenberg, "Walking to public transit: Steps to help meet physical activity recommendations," *American Journal of Preventive Medicine*, vol. 29, no. 4, p. 273–280, Nov 2005. [Online]. Available: https://www.cdc.gov/healthyplaces/articles/besser_dannenberg.pdf

24. S. N. Banerjee, A. L. Dannenberg, and A. M. Wendel, "Walking associated with public transit: moving toward increased physical activity in the united states." *American journal of public health*, vol. 103, no. 3, p. 536–42, Mar 2013. [Online]. Available: http://ajph.aphapublications.org/doi/10.2105/AJPH.2012.300912

25. M. Lindström, "Means of transportation to work and overweight and obesity: A population-based study in southern Sweden," *Preventive Medicine*, vol. 46, no. 1, pp. 22–28, jan 2008. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0091743507003052

26. L. Ming Wen and C. Rissel, "Inverse associations between cycling to work,

public transport, and overweight and obesity: Findings from a population based study in Australia," *Preventive Medicine*, vol. 46, no. 1, pp. 29–32, jan 2008. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0091743507003714

27. G. Netuveli and C. Millett, "Free bus passes, use of public transport and obesity among older people in england." *Journal of epidemiology and community health*, vol. 66, no. 2, p. 176–80, Feb 2012. [Online]. Available: http://www.ncbi.nlm.nih.gov/pubmed/21911850

28. J. A. Hipp, M. W. Corseuil, and E. A. Dodson, "Correlates of walking for transportation and use of public transportation among adults in st louis, missouri, 2012." *Preventing chronic disease*, vol. 11, p. E112, Jul 2014. [Online]. Available: http://www.ncbi.nlm.nih.gov/pubmed/24995654

29. N. Center for Environmental Health, "Healthy Community Design Checklist Community Guide to Preventive Services. Environmental and Policy Approaches to Increase Physical Activity: Community-Scale Urban Design Land Use Policies www.thecommunityguide.org/pa/environmental-policy/communitypolicie." [Online]. Available: www.cdc.gov/physicalactivity/everyone/health/index.htmlwww.epa.gov/smartgrowthwww.nyc.gov/html/ddc/html/design/active{_}design.shtmlwww.planning.org/research/healthy/pdf/electedofficialsfactsheet.pdf

30. "Active community environment toolkit creating environments that encourage walking, biking, and public transit in washington state," 2015.

31. *Introducing research methodology: A beginner's guide to doing a research project.* Sage, 2015.

32. *Qualitative, Quantitative, and Mixed Methods Approaches*, 2014.

33. "The meanings of methodology," *Social research methods*, vol. 60, p. 87, 2000.

34. J. D. Schvaneveldt, *Understanding research methods.* Longman, 1991.

35. L. J. Cronbach and P. E. Meehl, "Construct validity in psychological tests," *Psychological Bulletin*, vol. 52, no. 4, pp. 281–302, jul 1955.

36. R. A. Zeller, *Reliability and validity assessment.* Sage publications, 1979, vol. 17.

37. *How to measure survey reliability and validity.* Sage, 1995, vol. 7.

38. "Research design: Successful designs for social and economic research / c. hakim." 2000.

39. N. M. Bradburn, "Asking questions: a practical guide to questionnaire design." 1983.

40. M. C. Neale and L. J. Eaves, "Genetic and environmental factors in relative body weight and human adiposity," *Behavior Genetics*, vol. 27, no. 4, p. 325–351, 1997.

41. C. Abraham, C. Whittington, J. McAteer, and S. Gupta, "Effective techniques in healthy eating and physical activity interventions: A meta-regression." *Health Psychology*, vol. 28, no. 6, p. 690–701, 2009. [Online]. Available: http://doi.apa.org/getdoi.cfm?doi=10.1037/a0016136

42. F. Sacks, A. Trichopoulou, G. Drescher, A. Ferro-Luzzi, E. Helsing, and D. Trichopoulos, "Mediterranean diet pyramid: a cultural model for healthy eating," *The American Journal of Clinical Nutrition*, vol. 61, no. 6, pp. 1402S–1406S, Jun 1995. [Online]. Available: https://academic.oup.com/ajcn/article/61/6/1402S-1406S/4651234

43. M. L. Stefanick, P. T. Williams, and W. L. Haskell, "The effects on plasma lipoproteins of a prudent weight-reducing diet, with or without exercise, in overweight men and women," *New England Journal of Medicine*, vol. 325, no. 7, p. 461–466, Aug 1991. [Online]. Available: http://www.nejm.org/doi/abs/10.1056/NEJM199108153250703

44. *Questionnaire design: How to plan, structure and write survey material for effective market research.* Kogan Page Publishers, 2018.

45. "Sampling in a nutshell," *New York*, 1960.

46. "The statistical power of abnormal-social psychological research: A review," *Journal of Abnormal and Social Psychology*, vol. 65, no. 3, p. 145–153, Sep 1962.

47. "A power primer." *Psychological bulletin*, vol. 112, no. 1, p. 155, 1992.

48. *Statistical power analysis for the behavioral sciences*, 2013. [Online]. Available: https://content.taylorfrancis.com/books/download?dac=C2010-0-30830-5&isbn=9781134742707&format=googlePreviewPdf

49. "It's the effect size, stupid: what effect size is and why it is important," Sep 2002.

50. K. W. Spence, "The logic of psychological measurement," *Psychological Review*, vol. 51, no. 1, p. 1–24, Jan 1944.

51. *Scales of Measurement*, 1983, p. 1–73.

52. M. W. Wartofsky, *Language, Logic and Method*, ser. Boston Studies in the Philosophy of Science, R. S. Cohen and M. W. Wartofsky, Eds. Springer Netherlands, 1983, vol. 31. [Online]. Available: http://link.springer.com/10.1007/978-94-009-7702-0

53. *Parks and Recreation Questionnaire Results Summary*, 2015. [Online]. Available: http://www.ci.ellensburg.wa.us/

54. J. Tafforeau, L. Gisle, L. Oja, T. Ziese, J. Thelen, G. B. M. Mensink, and C. Lange, "Development of the european health interview survey - physical activity questionnaire (ehis-paq) to monitor physical activity in the european union," *Archives of Public Health*, vol. 73, no. 1, p. 59, Dec 2015. [Online]. Available: http://archpublichealth.biomedcentral.com/articles/10.1186/s13690-015-0110-z

55. *Active Transportation Summer Outreach Project*, 2016, no. September 2016.

56. *Pembroke MP Community Survey All Results - 09-17 Q1 HOW DID YOU HEAR ABOUT THIS SURVEY? CHECK ALL THAT*, 2017.

57. *East Portland Active Transportation Survey*, 2011, no. May.

58. *The 2018 City of Takoma Park Resident Survey Report of Results The 2018 City of Takoma Park Resident Survey*, 2019. [Online]. Available: www.n-r-c.com

59. W. H. Organization, "Global Physical Activity Questionnaire," Tech. Rep.

60. J. Block and M. Harrower, "The Q-Sort Method in Personality Assessment and Psychiatric Research," Tech. Rep., 1978.

61. I. Ajzen, "The Theory of Planned Behavior," Tech. Rep., 1991.

V. Conclusions and Recommendations

Conclusions of Research

In seeking to provide and understand the impact the community layout has on public health, the purpose of this research sought to address the following three research objectives:

1. Determining the proven common community layout factors in current literature that influence physical activity.
2. Analyze the Healthy Base Initiative Survey for reliability, validity, and consistency.
3. Develop a survey tool for the Air Force Civil Engineer Center to assess healthy community design and examine public perception of physical health impacted by the base community layout.

In order to answer the first objective, an in-depth literature review of past and present academic research is needed. Chapter 2 of this paper, "Factors of Healthy Community Design" accomplishes this task by narrowing the body of knowledge in community planning to four strategies that influence physical health: (1) improving access to plazas, parks, green spaces, and recreational facilities, (2) designing accessible, pedestrian-friendly streets and bicycle infrastructure with high connectivity, and traffic calming features for recreation and transportation, (3) developing and maintaining mixed land use in neighborhoods incorporating availability of fresh produce, and (4) improving access to public transit and transit facilities. Not only are community layout characteristics reviewed, they are compared to current DoD design guidelines and as a whole, the Unified Facilities Criteria (UFC) documents cover many of the design strategies that influence physical health. Although the community planning discipline is well researched, the wide variety of research techniques used poses limitations. Constraints exist with longitudinal and cross sectional studies such as at-

trition of participants, long length of study time, and gathering data that is not 100% reliable with the former and timing of snapshot may not be representative, cannot analyze behavior over time, and may not help determine cause and effect with the latter. However, different methods such as a controlled experiments or interventional studies can lead to improved and useful results.

Objective two is achieved through chapter 3, "Examining the Reliability and Validity of the Air Force Healthy Base Initiative Survey". The survey tool collected data from 59 participants and investigated the difference between what community planners designed and how well the designs are executed. From the data, it is found that while the four strategies of healthy community design model developed in chapter 2 does not fit the Healthy Base Initiative survey through the reliability and exploratory factor analysis, participant answers were still consistent through paired-question correlation analysis. Additionally, the data produced profound results through descriptive statistics where the participant answers helped identify gaps in community planning. Data trends indicated that the bicycle infrastructure is under-developed in comparison to pedestrian infrastructure and public transportation networks are nearly unavailable and not well connected across Air Force bases. Most significant is the baseline set by the HBI survey. While it is has issues in terms of reliability and validity, the problems can be overcome through understanding and following standard research procedures. The initial survey combined with the literature review from chapter 1 provides focus on healthy community designs most applicable to Air Force bases as well as create a future survey to be able to measure the association between healthy community design and physical health.

The third objective is accomplished through chapter 4, "Development of the future Department of Defense Community Layout Survey" where the results gathered from the previous chapters are assembled into a follow-on survey from the HBI survey.

The major corrections (which stemmed from the HBI survey) established by the novel survey are (1) questions with clear objectives, (2) properly formatted questions, (3) increased sample size, and (4) standardized question responses. The first and second correction utilizes standard research method techniques to operationalize each question to target specific independent variables in pursue of determining its causal relation to the dependent variable. In other words, each question will measure one strategy of healthy community design and its impact to physical health. The third correction provides guidance to the Air Force Civil Engineer Center recommending the target of a larger audience of base occupants vice only community planners. The fourth correction works doubly to standardize questions on a 1-7 Likert scale with lowest anchored at 1 and highest anchored at 7, as well as create more questions with which to compute statistical analysis. This chapter seeks to ultimately gain further knowledge on how the current base designs impact the physical health of its occupants so that optimal improvements can be made to future community layouts.

Significance of Research

With the growing urban sprawl and physical health problems associated with obesity, it is important to continue striving to understand the interaction between the two disciplines. As this problem also affects active duty military and base occupants, a unique opportunity is presented by this research. While the first survey produced by the Air Force Civil Engineer Center explored the most applicable healthy designs within the microcosm of bases, the factors of healthy planning found in the academic literature of chapter 2 focuses attention on four strategies. Additionally, the significance and novelty presented by the DoD HAPPI survey enables the ability to directly compare an individual's perceived physical health and their community environment. Furthermore, not only can the Air Force explore the causal relationship between the

base community layout and occupant's perceived physical health in the future, participants are able to voice their opinions on how their base can change to improve their well-being.

The results achieved in this study can also be immediately actionable for community planners through projects geared towards building a bicycle network and supporting infrastructure as well as organizing a base public transportation system. Furthermore, a panel of subject matter experts can verify the DoD HAPPI survey by validating the four constructs of a healthy community design through the Q-sort method. Lastly, this novel idea can be generalized and applied to other government agencies as well as city community planners.

Recommendations for Future Research

The foundation set by this research can be built upon through future interventional studies and monitoring of the sample population. Surveys are limited by the observational nature of the tool, however, by creating an environment where physical health can be measured before and after the intervention of at least one of the factors of a healthy community design, the outcomes of the intervention and no-intervention groups can then be compared. The advantage of conducting interventional studies is the ability to suggest that the outcome is impacted by the intervention. In addition, as there were only 59 respondents for the HBI survey, striving for a larger sample population would yield more meaningful and significant results for the DoD HAPPI survey.

Two aspects not covered in this research was the cost benefit of healthy community planning versus health care savings, as well as the simplest and most straightforward strategy to implement which would yield the highest results. More research must be conducted to determine the most cost effective strategy to implement as trade-offs

will occur between which strategy will require the least amount of time to execute and which will utilize the least amount of funds. If future researchers can determine that the cost for constructing connected sidewalks or integrated public transportation network can out-weigh the cost of obesity related healthcare, justification for healthy related projects can be realized.

Alternatively, follow on research can focus on development of theoretical model which produces a healthiness index rating for each base. The four strategies of a healthy community layout can be evaluated individually and summarised in a composite score. The use of geospatial information systems (GIS) technology can help standardize how to identify the healthy designs within the base. GIS technology can virtually measure the square footage and density of green space, linear feet of sidewalk and bicycle paths, locations of public transit stops, as well as different mixed land use types in an area. Using that spatial information, a map can be generate to visualize the areas on a base where attention can be focused to try and improve the community layout. As a whole, this research fills a small gap in the body of knowledge but continual focus on healthy community designs and its impact on public health will generate a better understanding.

V. Appendix

A. Healthy Base Initiative Survey (Initial Survey sent by AFCEC)

1. Are community health and opportunities for facilitating physical activity considered in the installation planning process?

- ○ Always
- ○ Usually
- ○ Sometimes
- ○ Rarely
- ○ Never

Other (please specify)

2. Are installation health professionals and MWR representatives included in visioning sessions, planning charrettes, and other planning opportunities?

- ○ Always
- ○ Usually
- ○ Sometimes
- ○ Other (please specify)
- ○ Rarely
- ○ Never

3. Which modes of transportation does installation street design standards account for? (Select all that apply)

- ☐ Automobiles
- ☐ Public transportation modes and nodes
- ☐ Sidewalks
- ☐ Bicycle pathways
- ☐ Ride share
- ☐ Other (please specify)

4. Are pedestrian and bicycle infrastructure features incorporated into installation design guidelines?

- ○ Design guidelines exist for both pedestrian and bicycle features.
- ○ Design guidelines exist for pedestrian features only.
- ○ Design guidelines exist for bicycle features only.
- ○ Design guidelines are being developed or revised.
- ○ Design guidelines do not exist.

5. Are high connectivity, mixed land uses, and compact, walkable design incorporated into district and site planning?

- ◯ Always
- ◯ Usually
- ◯ Sometimes
- ◯ Rarely
- ◯ Never

6. Is there a public transportation (e.g. public bus or shuttle) network on the installation?

- ◯ Yes
- ◯ No

7. What types of public transportation are available on the installation?

- ☐ Public bus
- ☐ Light or commuter rail
- ☐ Base shuttle service
- ☐ Ride Share
- ☐ Other (please specify)

8. How effectively do base networks link to public transportation systems in neighboring communities?

- ◯ Excellent
- ◯ Very well
- ◯ Moderately well
- ◯ Not very well
- ◯ Not at all

9. Are traffic calming strategies considered in the district, network or installation planning process?

- ☐ Strongly agree
- ☐ Agree
- ☐ Neither agree nor disagree
- ☐ Disagree
- ☐ Strongly disagree

10. Is there network plan for safe walkability and bikeability?

- Strongly agree
- Agree
- Disagree
- Strongly disagree

11. How well are existing sidewalks interconnected along all primary and secondary streets?

- A great deal
- A lot
- A moderate amount
- A little
- None at all

12. Are active living features (design which encourages healthy lifestyles) considered in the site design process?

- Always
- Usually
- Sometimes
- Rarely
- Never

13. Is proximity of personnel and civilians considered when siting new community support facilities?

- Always
- Usually
- Sometimes
- Rarely
- Never

14. Check all strategies used in the planning and visioning process? (select all that apply)

- Compact Development
- Transit-Oriented Development
- Mixed-Use Districts
- Mixed-Use Buildings
- Other (please specify)
- Connected Bicycle Networks
- Complete Streets
- Safe Sidewalks
- Accessible Public Spaces

15. Do on-base transportation networks link to public transportation systems in neighboring communities?

- ◯ A great deal
- ◯ A lot
- ◯ A moderate amount
- ◯ A little
- ◯ None at all

16. Are bus shelters provided at all primary bus stop locations?

- ◯ Always
- ◯ Usually
- ◯ Sometimes
- ◯ Rarely
- ◯ Never

17. Are ride-share (car or van pool) options available for base personnel?

- ◯ Yes
- ◯ No

18. Does the installation have designated bike lanes that are clearly marked?

- ◯ A great deal
- ◯ A lot
- ◯ A moderate amount
- ◯ A little
- ◯ None at all

19. Are existing sidewalks interconnected along all primary and secondary streets?

- ◯ A great deal
- ◯ A lot
- ◯ A moderate amount
- ◯ A little
- ◯ None at all

20. Are pedestrian crossings (crosswalks) at all primary (arterial) and secondary (collector) street intersections where sidewalks intesect appropriately designated, marked or otherwise protected?

- ◯ A great deal
- ◯ A lot
- ◯ A moderate amount
- ◯ A little
- ◯ None at all

21. Have pedestrian-only zones been incorporated or considered in planning?

- ◯ A great deal
- ◯ A little
- ◯ A lot
- ◯ None at all
- ◯ A moderate amount

22. Which types of pedestrian / bike safety features CURRENTLY EXIST on your installation?

- ☐ Primary sidewalks 5-feet wide
- ☐ ADA/ABA standard sidewalks and crossings
- ☐ Landscape medians / buffered sidewalks
- ☐ Lighting for primary sidewalks
- ☐ Sun protection (tree shade) along primary sidewalks?
- ☐ Traffic islands
- ☐ Traffic medians
- ☐ Separated / protected bike lanes
- ☐ Bus shelters
- ☐ Crosswalks marked with pavement marktings & MUTCD standard signs
- ☐ Bicycle racks
- ☐ Bike share program
- ☐ Curb bump outs
- ☐ Other (please specify)

23. Which types of pedestrian / bike safety features are PLANNED for the installation? (select all that apply)

- ☐ Primary sidewalks 5-feet wide
- ☐ ADA/ABA standard sidewalks and crossings
- ☐ Landscape medians / buffered sidewalks
- ☐ Lighting for primary sidewalks
- ☐ Sun protection (tree shade) along primary sidewalks
- ☐ Traffic islands
- ☐ Traffic medians
- ☐ Separated / protected bike lanes
- ☐ Bus shelters
- ☐ Crosswalks marked with pavement markings & MUTCD standard signs
- ☐ Bicycle racks
- ☐ Bike share program
- ☐ Curb bump outs
- ☐ Other (please specify)

24. Please provide.

Name

Position / Office

Base/Installation

State/Province

Country

Email Address

Phone Number

B. DoD HAPPI Survey (New Survey for AFCEC)

DoD Healthy Activity Public Planning Investigative Survey

Thank you for taking the time to help us out by answering the following questions.

1. Below are statements about your base community with which you may or may not agree. Please number the answer that best applies to you and your community. (1 - 7, 1 is lowest and 7 is highest)

a. Stores are within 15-minute walking distance of my work. ______

b. Other facilities are within 15-minute walking distance of my work. ______

c. Parks and open green space are within 15-minute walking distance of my work. ______

d. Bus stops are within 15-minute walking distance of my work. ______

e. My community is a good place for riding a bicycle. ______

f. My community is a good place for walking. ______

g. I feel safe from traffic while walking along busy streets. ______

h. I feel safe from traffic while biking along busy streets. ______

2. To what extent would any of the following make it more likely that you would choose to walk to get around in your base community? (1 - 7, 1 is lowest and 7 is highest)

a. Sidewalks along busy streets. ______

b. Connected sidewalks in the community. ______

c. Destinations within walking distance. ______

d. Marked crosswalks across busy streets. ______

e. Separated sidewalks with buffers along busy streets. ______

f. A map from the base showing safe routes for walking to popular destinations. ______

3. To what extent would any of the following make it more likely that you would choose to bike to get around in your base community? (1 - 7, 1 is lowest and 7 is highest)

a. Bike paths along busy streets. ______

b. Connected bike paths in the community. ______

c. Destinations within biking distance. ______

d. Marked bike paths across busy streets. ______

e. Separated bike paths with buffers along busy streets. ______

f. A map from the base showing safe routes for biking to popular destinations. ______

4. To what extent would any of the following make it more likely that you would choose buses to get around in your community? (1 - 7, 1 is lowest and 7 is highest)

a. Bus routes along busy streets. ______

b. Connected bus stops in the community. ______

c. Bus stops within walking distance. ______

d. Bus shelters at bus stops. ______

e. Seats at bus stops. ______

f. A map from the base showing the bus routes available. ______

5. Would you use the bus network to commute around base? (1 - 7, 1 is lowest and 7 is highest) ______

6. To what extent would any of the following mix land use characteristics encourage physical activity in your base community? (1 - 7, 1 is lowest and 7 is highest)

a. There are open green spaces within 15-minute walking distance of my work. ______

b. There are open green spaces within 15-minute biking distance of my work. ______

c. There are commercial facilities within 15-minute walking distance of my work. ______

d. There are commercial facilities within 15-minute biking distance of my work. ______

e. There are recreational facilities within 15-minute walking distance of my work. ______

f. There are recreational facilities within 15-minute biking distance of my work. ______

7. To what extent would any of the following green space (public recreational areas) characteristics encourage physical activity in your base community? (1 - 7, 1 is lowest and 7 is highest)

a. There are open green spaces within 15-minute walking distance of my work. ______

b. There are open green spaces within 15-minute biking distance of my work. ______

c. The green space is well maintained near my work. ______

d. The green space is large enough for activities near my work. ______

e. The green space is aesthetically pleasing. ______

f. The green space is well maintained. ______

g. There needs to be more green space. ______

8. How important are parks and recreational green areas to your overall physical health? (1 - 7) ______

9. To what extent would any of the following impact your physical activity? (1 - 7)

a. The sidewalks are well connected. ______

b. The bike paths are well connected. ______

c. There is a lot of mixed land use in the community. ______

d. There is a lot of open green space in the community. ______

e. The bus stops are connected to sidewalks. ______

f. The sidewalks are safe to walk and run on. ______

g. The bike paths are safe to ride on. ______

h. There is a lot of recreational facilities. ______

i. Mandated unit fitness training. (optional) ______

j. Workplace supported fitness programs. ______

k. Individual fitness training. ______

10. On a scale of 1 – 7, how important do you think each of the following priorities should be for your base community? (1 - 7, 1 is lowest and 7 is highest)

a. Building sidewalks on busy streets. ______

b. Building sidewalks that improve access to bus stops. ______

c. Installing signals or other improvements to make crossing busy streets safer. ______

d. Making wider bike lanes on busy streets. ______

e. Building new trails/multi-use paths separated from traffic. ______

f. Building more open green space areas around the base. ______

11. Overall do you feel that the base community layout encourages physical activity? (Y/N) ______

12. Do you live on base housing? (Y/N) ______

13. Personal Information

a. With which gender do you identify? (M/F/Other) ______

b. What is your current age? (Under 18/18-29/30-44/45-64/65 or over) ______

c. What is your height and weight? (inches and pounds) ______

d. Where are you stationed? (optional) ______

e. What is your AFSC or job description? (optional) ______

f. If you have taken the physical fitness assessment, what did you score? (0 - 100) (optional) ______

2 The questionnaire

Physical Activity		
Next I am going to ask you about the time you spend doing different types of physical activity in a typical week. Please answer these questions even if you do not consider yourself to be a physically active person. Think first about the time you spend doing work. Think of work as the things that you have to do such as paid or unpaid work, study/training, household chores, harvesting food/crops, fishing or hunting for food, seeking employment. *[Insert other examples if needed].* In answering the following questions 'vigorous-intensity activities' are activities that require hard physical effort and cause large increases in breathing or heart rate, 'moderate-intensity activities' are activities that require moderate physical effort and cause small increases in breathing or heart rate.		
Question	**Response**	**Code**
Work		
Does your work involve vigorous-intensity activity that causes large increases in breathing or heart rate like *[carrying or lifting heavy loads, digging or construction work]* for at least 10 minutes continuously? *[INSERT EXAMPLES] (USE SHOWCARD)*	Yes 1 No 2 *If No, go to P 4*	P1
In a typical week, on how many days do you do vigorous-intensity activities as part of your work?	Number of days └─┘	P2
How much time do you spend doing vigorous-intensity activities at work on a typical day?	Hours : minutes └─┴─┘ : └─┴─┘ hrs mins	P3 (a-b)
Does your work involve moderate-intensity activity, that causes small increases in breathing or heart rate such as brisk walking *[or carrying light loads]* for at least 10 minutes continuously? *[INSERT EXAMPLES] (USE SHOWCARD)*	Yes 1 No 2 *If No, go to P 7*	P4
In a typical week, on how many days do you do moderate-intensity activities as part of your work?	Number of days └─┘	P5
How much time do you spend doing moderate-intensity activities at work on a typical day?	Hours : minutes └─┴─┘ : └─┴─┘ hrs mins	P6 (a-b)
Travel to and from places		
The next questions exclude the physical activities at work that you have already mentioned. Now I would like to ask you about the usual way you travel to and from places. For example to work, for shopping, to market, to place of worship. *[Insert other examples if needed]*		
Do you walk or use a bicycle *(pedal cycle)* for at least 10 minutes continuously to get to and from places?	Yes 1 No 2 *If No, go to P 10*	P7
In a typical week, on how many days do you walk or bicycle for at least 10 minutes continuously to get to and from places?	Number of days └─┘	P8
How much time do you spend walking or bicycling for travel on a typical day?	Hours : minutes └─┴─┘ : └─┴─┘ hrs mins	P9 (a-b)

Continued on next page

Physical Activity, Continued		
Question	**Response**	**Code**
Recreational activities		
The next questions exclude the work and transport activities that you have already mentioned. Now I would like to ask you about sports, fitness and recreational activities (leisure), *[Insert relevant terms]*.		
Do you do any vigorous-intensity sports, fitness or recreational *(leisure)* activities that cause large increases in breathing or heart rate like *[running or football]* for at least 10 minutes continuously? *[INSERT EXAMPLES] (USE SHOWCARD)*	Yes 1 No 2 *If No, go to P 13*	P10
In a typical week, on how many days do you do vigorous-intensity sports, fitness or recreational *(leisure)* activities?	Number of days └─┘	P11
How much time do you spend doing vigorous-intensity sports, fitness or recreational activities on a typical day?	Hours : minutes └─┴─┘ : └─┴─┘ hrs mins	P12 (a-b)
Do you do any moderate-intensity sports, fitness or recreational *(leisure)* activities that cause a small increase in breathing or heart rate such as brisk walking, *[cycling, swimming, volleyball]* for at least 10 minutes continuously? *[INSERT EXAMPLES] (USE SHOWCARD)*	Yes 1 No 2 *If No, go to P16*	P13
In a typical week, on how many days do you do moderate-intensity sports, fitness or recreational *(leisure)* activities?	Number of days └─┘	P14
How much time do you spend doing moderate-intensity sports, fitness or recreational *(leisure)* activities on a typical day?	Hours : minutes └─┴─┘ : └─┴─┘ hrs mins	P15 (a-b)
Sedentary behaviour		
The following question is about sitting or reclining at work, at home, getting to and from places, or with friends including time spent sitting at a desk, sitting with friends, traveling in car, bus, train, reading, playing cards or watching television, but do not include time spent sleeping. *[INSERT EXAMPLES] (USE SHOWCARD)*		
How much time do you usually spend sitting or reclining on a typical day?	Hours : minutes └─┴─┘ : └─┴─┘ hrs mins	P16 (a-b)

6 Analysis Guidelines and Calculations

Introduction

A population's physical activity (or inactivity) can be described in different ways. The two most common ways are

(1) to estimate a population's mean or median physical activity using a continuous indicator such as MET-minutes per week or time spent in physical activity, and
(2) to classify a certain percentage of a population as 'inactive' or 'insufficiently active' by setting up a cut-point for a specific amount of physical activity.

The following guidelines describe both how to derive at continuous as well as categorical indicators when analysing GPAQ data.

Continuous indicator

As described in the overview (p. 3), MET values are applied to the time variables according to the intensity (moderate or vigorous) of the activity. Applying MET values to activity levels allows us to calculate total physical activity.

For the calculation of a person's overall energy expenditure using GPAQ data, the following MET values are used:

Domain	MET value
Work	• Moderate MET value = 4.0 • Vigorous MET value = 8.0
Transport	Cycling and walking MET value = 4.0
Recreation	• Moderate MET value = 4.0 • Vigorous MET value = 8.0

WHO recommend-dations on physical activity for health

For the calculation of a categorical indicator, the total time spent in physical activity during a typical week and the intensity of the physical activity are taken into account.

Throughout a week, including activity for work, during transport and leisure time, adults should do at least

- 150 minutes of moderate-intensity physical activity OR
- 75 minutes of vigorous-intensity physical activity OR
- An equivalent combination of moderate- and vigorous-intensity physical activity achieving at least 600 MET-minutes.

Not meeting WHO recommen-dations on physical activity for health

Description: Percentage of respondents not meeting WHO recommendations on physical activity for health (respondents doing less than 150 minutes of moderate-intensity physical activity per week, or equivalent).

Instrument questions:
- **P1-P6a&b:** activity at work
- **P7-P9a&b:** travel to and from places
- **P10-P15a&b:** recreational activities

Not meeting WHO recommendations on physical activity for health											
Age Group (years)	**Men**				**Women**				**Both Sexes**		
	n	% not meeting recs	95% CI		n	% not meeting recs	95% CI		n	% not meeting recs	95% CI

Questions Used	P1-P15a&b
Program	**Pnotmeetingrecs** (unweighted), **PnotmeetingrecsWT** (weighted)
Equations	Total physical activity MET-minutes/week (= the sum of the total MET minutes of activity computed for each setting) Equation: Total Physical Activity MET-minutes/week = [(P2 * P3 * 8) + (P5 * P6 * 4) + (P8 * P9 * 4) + (P11 * P12 * 8) + (P14 * P15* 4)]

WHO recommen-dations	Physical activity cutoff value
Not meeting recommen-dations	• IF: Total Physical Activity MET minutes per week is < 600

Program Information	Reports percentage of respondents who do not meet WHO recommendations on physical activity for health. Before any of the below variables are created ALL CleanRecode programs are called. To be included in the output, the respondent must have either left blank or given a valid response to each subset of the physical activity questions AND have given a valid response to at least one subset of the physical activity questions (CLN=1).

Created Variables	Name	Purpose	Values	Condition
	P1t3	MET value of vigorous work activity per week	P2*P3*8	P1t3CLN=1
			(.)	ELSE
	P4t6	MET value of moderate work activity per week	P5*P6*4	P4t6CLN=1
			(.)	ELSE
	P7t9	MET value of transport activity per week	P8*P9*4	P7t9CLN=1
			(.)	ELSE
	P10t12	MET value of vigorous recreational activity per week	P11*P12*8	P10t12CLN=1
			(.)	ELSE
	P13t15	MET value of moderate recreational activity per week	P14*P15*4	P13t15CLN=1
			(.)	ELSE
	Ptotal	Sum of all activity per week	p1t3+p4t6+p7t9+p10t12+p13t15	
	CLN	Checks to see if all physical activity responses, as a combined set, are valid: all subsets of responses must be clean and at least one subset of responses must have a response (not missing)	1	Valid=1 AND P1t3CLN=1 AND P4t6CLN=1 AND P7t9CLN=1 AND P10t12CLN=1 AND P13t15CLN=1 **AND** P1≠(.) OR P4≠(.) OR P7≠(.) OR P10≠(.) OR P13≠(.)
			2	ELSE
	C	Output table values	"Does not meet recommendations"	Ptotal<600
			"Meets recommendations"	Ptotal≥600

Total physical activity

Description: Mean / median time of total physical activity on average per day.

Instrument questions

- **P1-P6a&b:** activity at work
- **P7-P9&b:** travel to and from places
- **P10-P15a&b:** recreational activities

Mean/Median minutes of total physical activity on average per day											
Age Group (years)	Men				Women				Both Sexes		
	n	# minutes	95% CI		n	# minutes	95% CI		n	# minutes	95% CI

Questions Used	P1-P15a&b				
Program	**Ptotal** (unweighted mean & median values), **PtotalWT** (weighted mean values), **PtotalmedianWT** (weighted median values)				
Program Information	Reports the mean or median amount of physical activity per day in minutes. Before any of the below variables are created ALL CleanRecode programs are called. To be included in the output, the respondent must have either left blank or given a valid response to each subset of the physical activity questions AND have given a valid response to <u>at least one subset</u> of the physical activity questions (CLN=1).				
Created Variables	**Name**	**Purpose**	**Values**	**Condition**	
	P1t3	Vigorous work activity in minutes per week	P2*P3	P1t3CLN=1	
			(.)	ELSE	
	P4t6	Moderate work activity in minutes per week	P5*P6	P4t6CLN=1	
			(.)	ELSE	
	P7t9	Transport activity in minutes per week	P8*P9	P7t9CLN=1	
			(.)	ELSE	
	P10t12	Vigorous recreational activity in minutes per week	P11*P12	P10t12CLN=1	
			(.)	ELSE	
	P13t15	Moderate recreational activity in minutes per week	P14*P15	P13t15CLN=1	
			(.)	ELSE	
	Ptotalday	Sum of all activity per week divided by 7 to get avg. per day	(p1t3+p4t6+ p7t9+p10t12 +p13t15)/7		
	CLN	Checks to see if all physical activity responses, as a combined set, are valid: all subsets of responses must be clean and at least one subset of responses must have a response (not missing)	1	Valid=1 AND P1t3CLN=1 AND P4t6CLN=1 AND P7t9CLN=1 AND P10t12CLN=1 AND P13t15CLN=1 **AND** P1≠(.) OR P4≠(.) OR P7≠(.) OR P10≠(.) OR P13≠(.)	
			2	ELSE	

Setting-specific physical activity- mean / median	Description: Mean / median number of minutes spent on average per day, in work-, transport- and recreation-related physical activity. Instrument questions • **P1-P6a&b:** activity at work • **P7-P9&b:** travel to and from places • **P10-P15a&b:** recreational activities

Mean/Median minutes of [*insert domain*]-related physical activity on average per day									
Age Group (years)	**Men**			**Women**			**Both Sexes**		
	n	# minutes	95% CI	n	# minutes	95% CI	n	# minutes	95% CI

Questions Used	P1-P15a&b			
Program	**Psetspecific** (unweighted mean & median values), **PsetspecificWT** (weighted mean values), **PsetspecificmedianWT** (weighted median values)			
Program Information	Reports the mean or median amount of physical activity in minutes. Before any of the below variables are created ALL CleanRecode programs are called. To be included in the output, the respondent must have either left blank or given a valid response to each subset of the physical activity questions AND have given a valid response to <u>at least one subset</u> of the physical activity questions (CLN=1).			
Created Variables	**Name**	**Purpose**	**Values**	**Condition**
	P1t3	Vigorous work activity in minutes per week	P2*P3	P1t3CLN=1
			(.)	ELSE
	P4t6	Moderate work activity in minutes per week	P5*P6	P4t6CLN=1
			(.)	ELSE
	P7t9	Transport activity in minutes per week	P8*P9	P7t9CLN=1
			(.)	ELSE
	P10t12	Vigorous recreational activity in minutes per week	P11*P12	P10t12CLN=1
			(.)	ELSE
	P13t15	Moderate recreational activity in minutes per week	P14*P15	P13t15CLN=1
			(.)	ELSE
	Pwork-day	Average work-related activity per day	(p1t3+p4t6)/7	
	Ptravel-day	Average transport-related activity per day	p7t9/7	
	Precday	Average recreation-related activity per day	(p10t12+p13t15)/7	
	CLN	Checks to see if all physical activity responses, as a combined set, are valid: all subsets of responses must be clean and at least one subset of responses must have a response (not missing)	1	Valid=1 AND P1t3CLN=1 AND P4t6CLN=1 AND P7t9CLN=1 AND P10t12CLN=1 AND P13t15CLN=1 **AND** P1≠(.) OR P4≠(.) OR P7≠(.) OR P10≠(.) OR P13≠(.)
			2	ELSE

No physical activity by setting	Description: Percentage of respondents classified as doing no work-, transport-, or recreation-related physical activity. Instrument questions • **P1-P6a&b:** activity at work • **P7-P9&b:** travel to and from places • **P10-P15a&b:** recreational activities

No [*insert domain*]-related physical activity									
Age Group (years)	**Men**			**Women**			**Both Sexes**		
	n	%	95% CI	n	%	95% CI	n	%	95% CI

Questions Used	P1-P15a&b			
Program	**Pnoactivitybyset** (unweighted), **PnoactivitybysetWT** (weighted)			
Program Information	Reports the percentage of respondents who reported no work-, transport-, or recreation-related physical activity. Before any of the below variables are created ALL CleanRecode programs are called. To be included in the output, the respondent must have either left blank or given a valid response to each subset of the physical activity questions AND have given a valid response to <u>at least one subset</u> of the physical activity questions (CLN=1).			
Created Variables	**Name**	**Purpose**	**Values**	**Condition**
	Work	Indicates whether or not respondent did any work-related activity	"did work activity"	P1=1 OR P4=1
			"did no work activity"	ELSE
	Trans	Indicates whether or not respondent did any transport-related activity	"did transport activity"	P7=1
			"did no transport activity"	ELSE
	Rec	Indicates whether or not respondent did any recreation-related activity	"did recreation activity"	P10=1 OR P13=1
			"did no recreation activity"	ELSE
	CLN	Checks to see if all physical activity responses, as a combined set, are valid: all subsets of responses must be clean and at least one subset of responses must have a response (not missing)	1	Valid=1 AND P1t3CLN=1 AND P4t6CLN=1 AND P7t9CLN=1 AND P10t12CLN=1 AND P13t15CLN=1 **AND** P1≠(.) OR P4≠(.) OR P7≠(.) OR P10≠(.) OR P13≠(.)
			2	ELSE

Composition of total physical activity

Description: Percentage of total physical activity on average per day that comes from each of the 3 types of activity: work-, transport-, or recreation-related.
Instrument questions

- **P1-P6a&b:** activity at work
- **P7-P9&b:** travel to and from places
- **P10-P15a&b:** recreational activities

Composition of total physical activity							
Age Group (years)	Gender						
	n	% Work	95% CI	% Transport	95% CI	% Recreation	95% CI

Qu. Used	P1-P15a&b			
Program	**Pcomposition** (unweighted), **PcompositionWT** (weighted)			
Program Infor-mation	Reports the percentage of activity that comes from each of the three types of activity (work, transport, or recreation). Before any of the below variables are created ALL CleanRecode programs are called. To be included in the output, the respondent must have either left blank or given a valid response to each subset of the physical activity questions AND have given a valid response to at least one subset of the physical activity questions (CLN=1).			
Created Variables	**Name**	**Purpose**	**Values**	**Condition**
	P1t3	Vigorous work activity in minutes per week	P2*P3	P1t3CLN=1
			(.)	ELSE
	P4t6	Moderate work activity in minutes per week	P5*P6	P4t6CLN=1
			(.)	ELSE
	P7t9	Transport activity in minutes per week	P8*P9	P7t9CLN=1
			(.)	ELSE
	P10t12	Vigorous recreational activity in minutes per week	P11*P12	P10t12CLN=1
			(.)	ELSE
	P13t15	Moderate recreational activity in minutes per week	P14*P15	P13t15CLN=1
			(.)	ELSE
	Ptotal	Sum of all activity per week	p1t3+p4t6+p7t9+ p10t12+p13t15	
	Percent-Work	Percent of all activity from work-related activities	(p1t3+p4t6)/Ptotal*100	
	Percent-Trans	Percent of all activity from transportation-related activities	p7t9/Ptotal*100	
	Percent-Rec	Percent of all activity from recreational activities	(p10t12+p13t15)/ Ptotal*100	
	CLN	Checks to see if all physical activity responses, as a combined set, are valid: all subsets of responses must be clean and at least one subset of responses must have a response (not missing)	1	Valid=1 AND P1t3CLN=1 AND P4t6CLN=1 AND P7t9CLN=1 AND P10t12CLN=1 AND P13t15CLN=1 **AND** P1≠(.) OR P4≠(.) OR P7≠(.) OR P10≠(.) OR P13≠(.)
			2	ELSE

No vigorous physical activity

Description: Percentage of respondents not engaging in vigorous physical activity.

Instrument questions
- **P1-P6a&b:** activity at work
- **P7-P9&b:** travel to and from places
- **P10-P15a&b:** recreational activities

No vigorous physical activity									
Age Group (years)	Men			Women			Both Sexes		
	n	%	95% CI	n	%	95% CI	n	%	95% CI

Qu. Used	P1-P15a&b			
Program	**Pnovigorous** (unweighted), **PnovigorousWT** (weighted values)			
Program Infor-mation	Reports percentage of respondents who did no vigorous physical activity. Before any of the below variables are created ALL CleanRecode programs are called. To be included in the output, the respondent must have either left blank or given a valid response to each subset of the physical activity questions AND have given a valid response to <u>at least one subset</u> of the physical activity questions (CLN=1).			
Created Variables	**Name**	**Purpose**	**Values**	**Condition**
	C	Output table values	"did vigorous physical activity"	P1=1 OR P10=1
			"did no vigorous physical activity"	ELSE
	CLN	Checks to see if all physical activity responses, as a combined set, are valid: all subsets of responses must be clean and at least one subset of responses must have a response (not missing)	1	Valid=1 AND P1t3CLN=1 AND P4t6CLN=1 AND P7t9CLN=1 AND P10t12CLN=1 AND P13t15CLN=1 AND P1≠(.) OR P4≠(.) OR P7≠(.) OR P10≠(.) OR P13≠(.)
			2	ELSE

Sedentary Description: Minutes spent in sedentary activities on average per day.

Instrument questions
- **P16:** sedentary behaviour

Mean/Median minutes spent in sedentary activities on average per day									
Age Group (years)	**Men**			**Women**			**Both Sexes**		
	n	# minutes	95% CI	n	# minutes	95% CI	n	# minutes	95% CI

Questions Used	P16a&b			
Program	**Psedentary** (unweighted mean & median values), **PsedentaryWT** (weighted mean values), **PsedentarymedianWT** (weighted median values)			
Program Information	Reports the mean or median amount of sedentary activity in minutes. Before any of the below variables are created ALL CleanRecode programs are called. To be included in the output, the respondent must have either left blank or given a valid response to each subset of the physical activity questions AND have given a valid response to at least one subset of the physical activity questions (CLN=1). Note: P16 was created in CleanRecodeP16 from P16a and P16b. It contains the total sedentary time in mins.			
Created Variables	**Name**	**Purpose**	**Values**	**Condition**
	CLN	Checks to see if all physical activity responses, as a combined set, are valid: all subsets of responses must be clean and at least one subset of responses must have a response (not missing)	1	Valid=1 AND P16CLN=1
			2	ELSE

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14. ABSTRACT
Current obesity rate trends associated with the community layout constitutes research towards understanding the interaction between the two in order to improve the public's physical health. Successes in healthy community planning studies for the public can be harnessed and implemented within the microcosm of military bases to yield similar results. Four factors were recognized through a literature review that showed positive influence on physical health. The four healthy planning strategies formed the necessary background to analyze the HBI survey. A priori data from Air Force Civil Engineer Center was examined for reliability, validity, and consistency. The results uncovered the fact that the exploratory nature of the Healthy Base Initiative survey was too wide-ranged leading to inconclusive effects. The development of a novel survey addresses the issues of the original survey by narrowing down applicable healthy planning factors to the four strategies highlighted from the literature review. The novel survey examines existing base infrastructure and physical health questionnaire to determine the relationship between physical health and environment. Altogether, the significance of this research presents four concise healthy planning strategies as well as a recommendation for a way forward on understanding how to improve base occupant's physical health through healthy community planning.

15. SUBJECT TERMS
healthy community planning, physical health, walkability

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