Lifestyle and environmental assessment tools in relation to adiposity for military populations

A dissertation submitted in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

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Defense Date: April 19, 2018

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To my husband Jeff, to my parents Hamid and Edy, and my twin sister Nicole
for your unconditional love, for always believing in me, and for supporting me in chasing my dreams. You gave me wings.

To my children, Spencer and Vivienne
for your boundless love and joy and for inspiring me to be the best parent and role model I can be. You gave me courage.

To Aviva, Nicola, Ken, Patty, and Fernando
for your wisdom, guidance, time, and support, and for sharing your passion for this field with me. You taught me to fly.

Abstract

In 2011, an estimated 63.6% of all US military were overweight or obese, which is comparable to the rate observed in the civilian population. Not only are major chronic diseases and healthcare costs associated with obesity, but in military personnel obesity is also linked to musculoskeletal injuries and heat-related illness in hot climate conditions. Furthermore, overweight and obesity jeopardize job security: military personnel may not be retained because of their inability to meet fitness standards, which include weight. Thus, obesity can endanger military careers, affect operational readiness and put the long-term welfare of the military and national security at risk. Accurate measurements of adiposity are thus a priority need for military personnel. Additionally, though optimal nutrition is known to serve an important role in the health and physical readiness of military personnel, how well the diets of military personnel adhere to the current nutritional recommendations set forth by the 2015-2020 Dietary Guidelines for Americans (DGA) remains unclear. The main objective of this dissertation research is to evaluate lifestyle and environmental assessment tools currently used by US military researchers and to propose evidence-based improvements to strengthen them.

First, at the individual level and in the context of the military's goals, we determined the level of agreement between several anthropometric measures of adiposity and explored whether a combination of measures would be more valid for screening overweight and obesity than body mass index (BMI) alone. We found that BMI combined with circumference-based equation (CBE) measures of body fat was the best combination to categorize overweight/obesity in our study sample. BMI+CBE had the relatively highest sensitivity and lowest false discovery rate, as well as a moderate level of agreement with bioelectrical impedance analysis, which we used as the criterion measure. This combination was notably stronger in females. Second, we aimed to strengthen the 5-item Healthy Eating Score (HES-5) that is currently part of the military's Global Assessment Tool to improve its correlation with the 2015 Healthy Eating Index (2015-HEI), a current measure of dietary adherence to the DGA. By doing so, our goal was to provide an improved nutrition assessment tool for future military studies when collecting detailed dietary data is impractical. We examined the addition of items to assess breakfast frequency, post-exercise recovery fueling snack frequency (RFsnack), and sugar-sweetened beverage (SSB) consumption. We found that the addition of SSBs (8oz/serv) and RFsnack significantly improved the correlation between the HES-5 and the HEI-2015. Their inclusion in the HES-5 could improve the validity of this field measure.

Lastly, at the environmental level, we examined perspectives on the implementation and utility of the Creating Active Communities and Healthy Environments Toolkit, a new Toolkit from the Army Public Health Center developed to assess the health-promoting attributes of the built environment on military installations. Participants identified the need for (1) detailed manuals to improve Toolkit and Action Plan Guide functionality; (2) leadership's enforcement of policies and their prioritization of health-promoting improvements to the built environment; and (3) consideration of finances in Action Plan Guide recommendations.

Our findings suggest the opportunity for substantial impact on military obesity research: they elucidate methods to more accurately measure and address obesity and dietary trends, which represents an important step in the further development of health promoting policies and messages related to food environments in military settings.

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Abbreviations

24HR: 24-hour recall

χ^2: chi square

AAFES: Army and Air Force Exchange Services

AFI: Air Force Instruction

APHC: U.S. Army Public Health Center

BF%: percent body fat

BIA: bioelectrical impedance analysis

BMI: body mass index

C_k: Cohen's kappa

CACHE: Creating Active Communities and Healthy Environments

CAIB: Community Action Information Board

Candidate HES-5+: updated healthy eating score with more than five items

CBE: circumference-based equation

CDC: Centers for Disease Control and Prevention

CHAMP: Consortium of Health and Military Performance

CHPC: Community Health Promotion Council

CSF2 Study: Comprehensive Soldier and Family Fitness Study

DEXA: Dual-energy x-ray absorptiometry

DFACs: Dining facilities

DGA: Dietary Guidelines for Americans

DoD: Department of Defense

FDR: false discovery rate

FFQ: food frequency questionnaire

FOR: false omission rate

G4G: Go for Green

GAT: Global Assessment Tool

HBI: Healthy Base Initiative

HEI-2005: 2005 Healthy Eating Index

HEI-2015: 2015 Healthy Eating Index

HES-5: Five-item healthy eating score

HES-5+: updated healthy eating score with more than five items

HES-6: six-item healthy eating score

HES-7: seven-item healthy eating score

HES-8: eight-item healthy eating score

HRBS: Survey of Health-Related Behaviors Among Military Personnel

KAB: Knowledge, attitudes, and beliefs

m-NEAT: Military Nutrition Environment Assessment Tool

N/A: Not Applicable

NHANES: National Health and Nutrition Examination Survey

NHBLI: National Heart Blood and Lung Institute

NPV, negative predictive value

OKF: Operation Kid Fit

PAC: Promoting Active Communities

POC: points of contact

PPV: positive predictive value

PRT: physical readiness test

QITS: Quantitative Indicators for Tobacco Systems

RFsnack: post-exercise recovery fuel snack

RFsnack-A post-exercise recovery fueling snack with the highest category receiving score option A (i.e., a score of four)

RFsnack-B: post-exercise recovery fueling snack with the highest category receiving score option B (i.e., a score of five)

SME: Subject Matter Expert

SSB: sugar-sweetened beverage

SSB-8: sugar-sweetened beverage servings/day with 8-oz/serving

SSB-12: sugar-sweetened beverage servings/day with 12-oz/serving

USU: Uniformed Services University

WC: waist circumference

WHO: World Health Organization

Chapter 1. Introduction and Review of the Literature

1.1 Specific Aims

The U.S. military has experienced similar trends in overweight and obesity as adults in the civilian population. An estimated 63.6% of all U.S. military personnel are overweight or obese, which is comparable to the prevalence observed in two-thirds of U.S. civilian adults (1). From 2002 to 2011, the prevalence of military obesity alone increased from 8.7% to 12.4% (1-3). The 1995-1998 Department of Defense (DoD) Survey of Health-Related Behaviors Among Military Personnel (HRBS) found a positive correlation between physical activity and weight gain, which suggests that these trends may be due to lifestyle behaviors other than physical inactivity, such as dietary intake (4). The role of dietary factors is supported by the 2011 DoD HRBS results, where only 11.2%, 9.5%, and 11.3% of military personnel met the Healthy People 2010 objectives for fruit, vegetable, and whole grain intake, respectively (5).

Few studies have been undertaken in military populations to evaluate the methods currently used to assess adiposity and the dietary, environmental, and lifestyle factors that affect weight control (3). Increasing numbers of military personnel are failing to meet their age- and sex-related body fat standards and thereby failing their biannual physical readiness tests (PRT) (6, 7). With military careers put at risk by PRT failures, it is important for the anthropometric methods used by the military to accurately assess adiposity to ensure military readiness as well as reduce misidentification (6, 7). Thus, establishing methods to both accurately identify overweight and obesity among military personnel and measure and address key factors associated with obesity in the military population is a priority for research.

The main objective of this dissertation research project is to evaluate lifestyle and environmental assessment tools currently in use by U.S. military researchers and propose evidence-based improvements to strengthen them. Our findings can serve as important steps to justify modifications to these tools and thus help provide more valid measures for use in future military research. The specific aims and hypotheses are:

Specific Aim 1: To determine 1) the level of agreement between body mass index (BMI), circumference-based equation (CBE) measures, waist circumference (WC) alone, and bioelectrical impedance analysis (BIA) estimates of adiposity, and 2) if BMI, CBE measures, or WC alone adequately reflect adiposity among a population of military personnel compared to BIA-based measures, or if a combination better meets the needs for screening for the military.
Hypothesis 1: WC and/or CBE measures alone or in conjunction with BMI measures will more accurately identify overweight and obesity than BMI alone.

Specific Aim 2: To determine whether modifications to the Global Assessment Tool's (GAT) five-item Healthy Eating Score (HES) could improve its correlation with the 2015 Healthy Eating Index (HEI-2015) score.
Hypothesis 2: Modifying the GAT's HES-5 by adding items to address frequency of 1) breakfast consumption, 2) recovery fueling post-exercise, and/or 3) SSB consumption strengthens its correlation with the HEI-2015.

Specific Aim 3: To investigate beliefs and attitudes about the implementation and utility of the Creating Active Communities and Healthy Environments (CACHE) Toolkit and leadership's ability to improve aspects of the installation that relate to nutrition and physical activity behaviors.
Goal: To improve the toolkit implementation process, identify ways to better assist installations with toolkit implementation, and to assess the utility of the U.S. Army Public Health Center's (APHC's) action plan guides in recommending improvements to the built environment.

1.2 Review of the literature

Obesity in the US The prevalence of obesity in US adults has doubled over the past twenty years and is recognized as a global epidemic (8). Currently in the U.S., approximately 38% of all adults 20 years and older are obese, with similar rates of obesity (i.e., more than 30%) in most adult sex and age groups (9, 10). In 2016, the

prevalence of obesity was over 30% in 30 US states and all states had an obesity prevalence over 20% (8, 9).

Obesity is predominantly the result of a dietary energy intake that exceeds energy expenditure, the latter reflecting the energy needed to support the body's metabolic processes and one's physical activity level (11). This positive energy balance leads to hyperplasia and hypertrophy of adipose cells, adipose tissue dysfunction and, thus, increased adiposity (11, 12). Obesity is currently considered the fifth most important risk factor contributing to the global disease burden (10). Obesity has a central role in the development of various chronic conditions, including cardiovascular diseases, stroke, type II diabetes, gallbladder disease, osteoarthritis, respiratory problems, and many types of cancer, all of which affect long-term health and contribute to increasing healthcare utilization and medical costs (3, 7, 8, 13-17). Its ramifications on health and its persistent prevalence rates contribute to its continued growth as a public health concern.

Obesity in the military The U.S. military is experiencing similar trends in obesity as observed among adults in the general U.S. population. Currently, an estimated 63.6% of all U.S. military personnel are overweight or obese (1). From 2002 to 2011, the prevalence of military obesity increased from 8.7% to 12.4%, with the highest obesity prevalence of 15.8% observed in the US Army (1-3, 7, 18).

In addition to the many chronic diseases and healthcare costs associated with obesity, other elements of military life are impacted by obesity and weight gain. Military personnel are required to meet weight standards to be retained, but also need to maintain good health for physical readiness, which will reduce their likelihood of combat injury or

mortality (3, 19, 20). Unfortunately, obesity has been associated with both acute and chronic musculoskeletal injuries as well as heat-related illness in hot climate conditions, all of which can jeopardize military personnel's operational readiness and the long-term welfare of the U.S. military (7, 13, 19-27).

The financial and productivity implications of obesity for the military are serious. Currently, the DoD Military Health System spends 1.1 billion dollars annually to treat obesity-related illnesses among the 70% of beneficiaries who are overweight or obese (20, 23, 28). Overweight and obesity are also responsible for approximately 658,000 missed workdays and 17,000-equivalent missed workdays due to lowered productivity, costing the DoD an estimated 105.6 million dollars each year (23). Thus, from both a healthcare utilization and financial perspective, it is essential to improve weight status and reduce overweight and obesity in the military, and most importantly to retain military personnel who are healthy and fit (29).

Increasing the number of new, healthy recruits is a challenge given that obesity prevalence continues to rise in the general population. Approximately 27% of adults 17-24 years of age in the US cannot qualify for military service due to overweight/obesity alone (30). Furthermore, being overweight and unfit for service are currently the leading medical reasons for military service disqualifications: the proportion of those disqualified increased by almost 70% from 1995 to 2008 (23, 31). Using data from the National Health and Nutrition Examination Survey (NHANES) and the Army's weight and body fat standards (which are the most lenient weight requirements of the military branches), the percentage of male and female civilians who exceed standards doubled from 5.6% to 11.5% and tripled from 11.7% to 34.7%, respectively, in the fifty years between 1959 and

2008 (23). Also concerning is the projection that 27% (> 9 million) young adults, aged 17-24 years are ineligible for recruitment due to their excess body weight, yet over 90% of applicants and recruits fall in this age range (31). Furthermore, it costs approximately $50,000 to recruit and train each new soldier to replace retired and discharged service members, which is estimated at 183 million dollars annually (3, 28, 31). Thus, retention of current military personnel and work to improve their nutritional and physical fitness is a priority.

Measuring obesity in the military Due to the physical demands that military personnel may endure, each military service branch is required by the DoD to enforce fitness and body fat standards through physical fitness tests for both enlistment and retention of military personnel. Body fat standards use weight-for-height tables and estimate percent body fat via circumference-based equations (CBEs). In the 1800's, the military used weight-for-height measurements to eliminate those who were underweight and suffered from chronic malnourishment (32). However, after the Vietnam War, obesity and poor fitness levels became the more dominant concerns in the military (32). To improve physical readiness, in 1981 the DoD released directive DODI 1308.1 which mandated each service develop their own minimum and maximum levels, upper limit circumferences, and body composition programs that accounted for physical strength, aerobic performance, professional military appearance, and general health and chronic health risks (23, 32, 33). The current standards by military branch are provided as **Appendix A**.

For each military branch (except the Air Force), measured weight and height are used to calculate BMI and, if military personnel are within a healthy range, screening is complete. Although BMI measures correlate with body fat and are useful to characterize obesity at the population level, they also have low sensitivity and specificity to distinguish between fat mass versus fat-free mass at the individual level (32). Thus, if an individual exceeds the maximum BMI measurements for their age and sex, percent body fat is then assessed via sex-specific CBEs (29, 32, 33). All branches use CBEs based on the Navy's Hodgdon equations (32, 34).

Percent body fat (BF%) calculated from CBEs was adopted as the criterion measure with the goal to retain recruits and military personnel with higher muscle mass who could be misclassified as overweight or obese by weight-for-height screening measurements (23, 32). CBEs are based on different site measurements in male and female military personnel to take into account varying body fat distribution and endocrine physiology by sex: neck and abdominal circumferences are measured in males and neck, waist, and hip circumferences are measured in females (32). The measurement sites selected, such as abdominal or waist circumference to measure intra-abdominal fat, are based on their association with chronic disease risk (26, 32, 34, 35). Because aging affects one's body composition and its relationship to fitness, age is accounted for in the BF% cut-offs for normal versus overfat (32). This modification allows for less strict standards for older military personnel while still keeping minimum requirements above the threshold associated with chronic disease risks (32).

BMI and circumference measurements are favored as quick, convenient, easy to administer, non-intrusive tools to screen for overweight and obese military personnel;

they also require little training (33, 36-38). Potential recruits who fail both measurements must lose weight before another assessment or, depending on the service, can apply for a waiver that allows them a set amount of time during which to lose weight (23, 29). At the same time, current military personnel who do not meet standards must complete short-term remedial weight management programs in their respective branches; failure to meet standards following the program may result in an early discharge (3, 7, 19). According to Hruby et al, from 1998-2010, personnel diagnosed as overweight or obese were discharged from the military a median of 15 months earlier than healthy weight personnel (7, 39).

The Air Force no longer applies BMI criteria and requires only waist circumference measurements to assess health status of military personnel during their scheduled fitness test visits (33, 40). In contrast to BMI, waist circumference measurements tend to be more accurate and are directly affected by dietary and physical activity habits (32). Studies have since shown that abdominal adiposity is a marker of metabolic risk and is more strongly correlated with mortality and chronic disease risk, including cardiovascular disease and diabetes mellitus, than BMI (40, 41).

Controversy remains regarding which measure(s) of adiposity most accurately account for variation in muscle and fat mass and fat distribution both for military fitness tests and for research purposes (3, 37, 42). A study by Heinrich et al. in Air Force military personnel (N=451) found that both BMI and WC measurements performed adequately in assessing obesity rates on a population level, but equally underestimated obesity on an individual level compared to percent body fat by bioelectrical impedance analysis (BIA) (37). A review by Friedl et al. (2012) in older military personnel noted

that certain prescription drugs and age-related decreases in testosterone levels may increase intra-abdominal fat distributions, which thereby affect both CBE and WC measures (32). Additionally, genetic and ethnic variations for body composition measures, including waist circumference has been reported (32, 41, 43). Thus, studies are needed in military populations comparing different approaches of assessing adiposity to examine the extent of agreement in classifying military personnel as overweight and obese.

Individual Level: Assessing the overall diet The field of nutrition epidemiology has gradually shifted its emphasis on how best to capture dietary exposures from single nutrients to whole foods and dietary patterns. Although a focus on single nutrients allows for simpler analyses than is required to understand the role of complex dietary patterns, obesity does not arise due to one specific nutrient. In addition, the study of single nutrients also does not allow for an examination of their synergistic interactions when consumed together in a food or meal. These are best accounted for by analysis of whole foods and by dietary pattern approaches (12, 44-47). Furthermore, from a public health perspective, recommendations about whole foods and dietary patterns associated with obesity may be more actionable than messages about individual nutrients (44).

Optimal nutrition plays an important role in the health and physical readiness of military personnel. Analysis of the 1995-1998 DoD HRBS found a positive correlation between greater physical activity and weight gain, suggesting that current obesity trends may not be due to physical inactivity, but may reflect other lifestyle behaviors such as dietary intake (4, 48). This idea is supported by a second more recent study based on

2005 DoD HRBS data, which found that 57.5% of the active duty military personnel, compared to 32% of the U.S. civilian population, met the Healthy People 2010 objectives for moderate or vigorous leisure-time physical activity (49). However, though slightly higher than the civilian population, only 29% of military personnel met the objectives for fruit intake (civilian: 28%), 9.5% for vegetable intake (civilian: 3%), 11.3% for whole grain intake (civilian: 7%) and 3% for all three (49, 50). Results from the 2011 HRBS survey differed slightly, but intakes remained low, with only 11.2%, 12.9% and 12.7% meeting the objectives for fruit, vegetable and whole grain intake, respectively (5). Thus, there is a gap between these nutrition recommendations and what military personnel report typically consuming for fruits, vegetables and whole-grains.

A common method to capture and summarize dietary components is by using an *a priori*, hypothesis-driven score or index (45). One example is the USDA 2015 Healthy Eating Index (HEI-2015), which assesses the extent to which one's diet follows key recommendations of the 2015-2020 Dietary Guidelines for Americans (DGA). In this approach, the diet is scored on a scale from 0-100, with a higher score representing higher adherence to DGA and better diet quality (51-54). The HEI-2015 relies on data from a dietary assessment instrument (e.g., a food frequency questionnaire (FFQ) or 24-hour recall (24HR)) and scores 12 components: nine focusing on diet adequacy (total fruit, whole fruit, total vegetables, greens and beans, whole grains, dairy, total protein, seafood and plant proteins, and fatty acids) and three focusing on foods that should be consumed in moderation (refined grains, sodium, and empty calories, the latter including energy from added sugars, alcohol and solid fats) (52, 53). Although often used in dietary pattern research, collecting data for the HEI-2015 via a FFQ or 24HR may be impractical

in the military for large studies or clinical screenings due to the cost and time burden on participants.

Alternatively, the five-item Healthy Eating Score (HES-5) uses a more abbreviated, but similar, approach to assessing the overall diet of military personnel. Military researchers developed the HES-5 as a modified version of the USDA HEI-2005; it looks only at five components via five questions as part of the updated Comprehensive Soldier and Family Fitness Global Assessment Tool's (GAT) physical dimension. The five intake components include fruit, vegetables, whole grains, dairy, and fish and these aspects of diet are used to calculate a dietary score ranging from 0-25 (5, 55). The HES-5 may be a practical tool for researchers and clinicians in situations in which the collection of more detailed dietary data (e.g., via ASA24, FFQ) is impractical. Although a Cronbach α analysis estimated the HES-5 to be a reliable instrument (α=0.81), the association of this alternate dietary screening method only been studied thus far with the HEI-2005 and not the HEI-2010 or HEI-2015 (5, 55). Additional studies are needed to examine the association between the HES-5 and HEI-2015 and evaluate if adding additional questions to the HES-5 can strengthen their association.

A 2013 study by Purvis et al. in military personnel (N= 13,858) examined the association between dietary behaviors and the HES-5 (mean score: 15.7±3.4) (5, 55). The authors found that participants who were in the highest HES-5 quartile were more likely to report eating breakfast regularly (vs ≤5 times per week, OR 4.2, 95% CI 3.8-4.7) and/or eating a post-exercise recovery fuel snack (RFsnack) ≥2 times per day (vs not regularly consumed, OR 3.1, 95% CI 2.8-3.4) (5). They were less likely to be in the highest quartile if they regularly drank diet sodas (vs. those who did not consume soda,

OR 0.56, 95% CI 0.51-0.61) (5). These dietary behaviors (i.e., breakfast frequency, RFsnack frequency, and soda consumption) may reflect aspects of dietary quality not currently addressed by the HES-5; adding one or more of these items may strengthen this research tool in relation to the 2015-HEI.

Environmental Level: The food environment on military installations and obesity

Like the civilian population, personnel on military installations are exposed daily to unhealthy, high-calorie foods (3, 56). Several factors affect whether military personnel purchase and consume meals on military installations, including marital status, age, rank, status of deployment, time constraints and enjoyment of cooking (24). For those personnel who eat on installations, the military dining facilities (DFACs) represent a main source of meals. It is estimated that approximately 74% of non-deployed military personnel eat at least one meal at DFACs daily (21). DFACs are thus a practical location to increase the availability of fruits, vegetables and whole grains for military personnel as a way to promote healthy changes in nutritional habits (21, 57). Past intervention studies in Army DFACs found that healthier food options placed at the beginning of food service lines resulted in soldiers purchasing foods that were lower in total caloric and total fat intakes compared to traditional food service lines in DFACs (21, 58). In 2009, the Go for Green (G4G) health initiative, was implemented by the Army to promote healthier eating. Briefly, this initiative promotes traffic-light colored labels to aid military personnel in differentiating foods of higher nutritional quality that should be eaten often (i.e., green label) from those that should be eaten in moderation or sparingly (i.e., yellow and red labels, respectively). For example, low, moderate, and high saltshaker symbols depict the

sodium content of foods as low, medium or high (56, 59). The G4G nutrition initiative is also used in the Navy and Air Force DFACs; the Marine Corps uses a version of G4G called Fueled to Fight (56, 59). The initial evaluation of this program was a study by Arsenault et al. (N=299) that found 47% of soldiers reported using the labels sometimes or always; however, there was no association between label use and BMI (56). Other studies are ongoing.

Depending on an installation's size and location, DFACs may only be open for a limited number of hours; they may be closed in the early morning, later evening and even all weekend hours (42). Limited hours of operation, as well as a general desire for accessible, convenient, low-cost foods can lead military personnel to consume foods at any of the many fast-food franchises located on installations (3, 24). The Army and Air Force Exchange, Navy Exchange and Marine Corps Exchange Services hold franchises with various fast-food chains, such as Dunkin' Donuts®, Burger King®, Popeye's®, and Subway® to meet the demands of military personnel and their families (3). The limitations of DFAC hours and presence of fast-food chains represent environmental-level factors that may influence obesity prevalence in the military. With limited obesity prevention research in military settings to date, new research to aid in understanding determinants of nutritional and health behaviors that may contribute to military personnel current weight problems is needed (3, 17, 42). The evaluation of current DoD initiatives can be an important step in helping to identify current program challenges on installations as well as characteristics of successful programs that should be disseminated as best practices and further expanded (17, 42).

1.3 Significance

Unlike most civilian occupations, the job security of military personnel is affected by their overweight and obesity status. The military imposes fitness retention standards and, if military personnel do not meet them for their respective military branches, they are at risk of failed promotions and, in some cases, early discharge (3, 19, 28, 38). Thus, military careers are jeopardized, operational readiness is affected and national security is put at risk (6, 7, 12, 42, 60). In 2008 alone, 4,500 military personnel were discharged for failing to meet age and sex-related weight and body fat standards (3). Nonetheless, to the best of our knowledge, a limited number of studies have been conducted to date to re-evaluate the tools currently used to assess the diet and adiposity of military personnel, as well as the built environment in which they work, and often live.

The significance of this dissertation is two-fold. At the individual level, the proposed project may significantly impact military obesity research by identifying key ways to improve upon assessment methods currently used to measure overweight/obesity and the overall diet in the military. On an environmental level, findings can also identify for local leaders opportunities for improvement and help prioritize community needs to allow for optimal use of limited taxpayer dollars (61). At both the individual and environmental level, findings from this dissertation research can serve as an important step in the development of health promoting action plans, policies, and messages related to food environments in the military setting. From a population health perspective, the military is a large, relatively healthy population with a rich array of high quality data available. Due to the array of similar lifestyle and environmental exposures and higher levels of physical activity compared to the civilian population, studying military

personnel may help “control for” many known and unknown confounders and thereby provide new insights on the association between dietary factors and obesity more generally.

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Chapter 2. A comparison of anthropometric measures with bioelectrical impedance analysis in the classification of overweight and obesity: a secondary analysis in U.S. military personnel

2.1 Abstract

Introduction: The prevalence of obesity in the military is a growing national security concern. Valid measures of adiposity are needed to ensure that recruitment and job security are not negatively impacted by inaccurate body fat standards.

Objective: The aims of this secondary analysis were to determine 1) the level of agreement between body mass index (BMI), circumference-based equation (CBE) measures, waist circumference (WC), and bioelectrical impedance analysis (BIA) measures, and 2) if BMI, CBE measures, or WC alone adequately reflect adiposity in military personnel compared to BIA-based measures, or if a combination is best.

Methods: Anthropometric measurements taken by trained personnel were used to estimate BMI (using overweight cut-offs in males from the military (BMI, ≥27.5 kg/m^2) and World Health Organization (WHO BMI, ≥25.0 kg/m^2)), BMI percent body fat (BF%), WC, CBE BF%, and BIA BF%. Respondents' were categorized as normal vs. overweight/obese or overfat. Anthropometric measures alone and in combination were compared to BIA to examine levels of agreement and standard screening performance measures.

Results: Among the 389 participants (78% male), WHO BMI and BIA BF% classified the most males (61.1% and 42.6%, respectively) and females (both 51.2%) as overweight/obese, whereas WC combined with BMI (BMI+WC) and WC alone were the least likely to classify males (10.9% and 11.6%, respectively) and females (both 9.3%) as overweight/obese. The levels of agreement were all statistically significant and highest for BMI (males Cohen's kappa (C_k)= 0.711, females C_k=0.814) and WHO BMI (males C_k=0.578, females C_k=0.814); moderate for BMI+CBE (males C_k=0.447, females

C_k=0.676); and lowest for WC (males C_k=0.270, females C_k=0.178) and WC+BMI (males C_k=0.268, females C_k=0.178). Sensitivity was highest overall for BMI (80.4%), CBE (54.9%), and BMI+CBE (50.9%) and lowest for BMI+WC, WHO BMI+WC, and WC (all <24.0%). However, the false discovery rate (FDR) was lowest for BMI+WC (2.4%), WHO BMI+WC (4.7%), and WC (4.7%). To maximize sensitivity and minimize FDR, BMI + CBE performed best overall (sensitivity=50.9%, FDR=5.4%).

Conclusion: Our findings support BMI+CBE as an easy-to-implement combination of anthropometric measures to assess normal versus overweight/obesity in the military. However, future studies need to consider overall goals before expanding on these findings- i.e., to identify the best measures of overweight/obesity to assess health risks, or both.

2.2 Introduction

Obesity prevalence is of growing concern in the military, with 63.6% of all U.S. military personnel currently categorized as overweight or obese (1). Not only is obesity associated with increased chronic disease risks and healthcare costs, but it can also threaten military personnel's careers, operational readiness and safety, and national security (2-4). Valid, precise measures of adiposity are needed to both ensure that current military obesity trends are accurate and that civilians' potential recruitment and military personnel's job security are not negatively impacted by inaccurate body fat standards (5). However, at present (2018), there are no universal adiposity standard requirements across the military. Each service sets its own minimum and maximum cut-offs for their chosen adiposity measures, taking into account physical strength, aerobic performance, professional military appearance, and general health and chronic health risks.

Body mass index (BMI) is often used as a quick, convenient, non-intrusive tool to screen for overweight and obese military personnel (6, 7). All military branches except the Air Force first screen for overweight and obesity by calculating BMI from weight and height. Whereas underweight (<18.5 kg/m^2) and obese (>30.0 kg/m^2) categories in the military are identical to those defined by the World Health Organization (WHO) and the Center for Disease Control and Prevention (CDC) (8, 9), the cut-off used to define overweight in males differs. The cut-off for overweight status is increased from >25.0 kg/m^2 to >27.5 kg/m^2 for males in the military to account for increases in muscle mass. This higher BMI cut-point results in more men meeting standards when using BMI measurements and lowers the number who must have body fat assessed at semi-annual physical fitness tests (10).

As a screening measure, however, BMI has low sensitivity and specificity to distinguish between fat versus fat-free mass at the individual level and may misclassify muscular military personnel as overweight or obese (4, 7, 10-15). BMI's limitations have led to the consideration of circumference-based measurements as alternative, potentially more accurate, measures of body fatness. First, waist circumference (WC) measurements in particular may be more directly affected by dietary and physical activity habits than BMI (10). Second, circumference-based measurements may be more valid assessment tools than BMI inasmuch as waist circumferences reflect abdominal adiposity, which appears to be a stronger predictor of associated health risks (e.g., cardiovascular disease, cancer, type 2 diabetes, dementia, depression) compared to overall adiposity (16-23). Because of this justification, in 2009 the Air Force began requiring only waist circumference measurements from all military personnel during fitness tests (24, 25). At the same time, if military personnel in the other service branches exceeded the maximum BMI measurements for their age and sex, percent body fat (BF%) was to be estimated via sex-specific circumference-based equations (CBEs) (10, 26).

In 2017, the Military Health System began reassessing the utility of using BMI as a measure of body fatness among military personnel (27, 28). Given this review, there is a pressing need to compare different approaches of adiposity assessments for examining their extent of agreement in classifying military personnel as overweight and obese, and assessing whether a composite approach using BMI along with a circumference-based measurement could better categorize military personal as overweight or obese. Although dual-energy x-ray absorptiometry (DEXA) is currently considered the gold standard for assessing body composition (29), bioelectrical impedance analysis (BIA) is often favored

clinically to assess adiposity, as it is less expensive, more portable, and less time-consuming than DEXA (29-32). Some studies have also reported BIA to have good reliability and predictive value compared to DEXA (29, 31, 32), supporting that it may be a more practical criterion measure than DEXA for research purposes. Therefore, the aims of this study were to examine data from the Consortium of Health and Military Performance (CHAMP)'s Comprehensive Soldier and Family Fitness (CSF2) Study to determine 1) the level of agreement between BMI, CBE measures, WC, and BIA estimates of adiposity, and 2) if BMI, CBE measures, or WC alone adequately reflect adiposity among a population of military personnel compared to BIA-based measures, or if a combination better meets the needs of screening for the military. We hypothesized that WC and CBE measures, alone or in conjunction with BMI measures, would more accurately identify overweight and obesity than BMI and should be considered for inclusion in military regulations and/or future military population studies.

2.3 Subjects and methods

Participants

This study is a secondary analysis of cross-sectional data from the CHAMP's CSF2 Study. The study was advertised as an assessment of physical fitness and nutritional status in active duty military personnel. Volunteers were recruited from June 2014 through November 2017 via fliers, word of mouth, social media (i.e., Facebook) advertisements, and snowball recruiting from installations with points of contact (POC) and commands supportive of recruitment. Study briefings were held by POC with interested personnel at five chosen installation recruitment sites until recruitment goals

were met: Fort Bliss (TX) (N=301), Fort Bragg (NC) (N=104), Fort Myer (VA) (N=78), Fort Detrick (MD) (N=32); and Naval Support Activity Bethesda (MD) (N=4). In total, 519 active duty military personnel were included in CHAMP's CSF2 Study. Twenty-five-dollar gift cards were given as an incentive for participation.

Participants were included in this secondary analysis if they were not pregnant, wounded warriors, or warriors in transition; provided data on sex and age; and had complete anthropometric data. These inclusion criteria reduced our final sample size from 519 to 389 (303 males, 86 females, **Figure 2.1**). The study was approved by the Uniformed Services University (USU) and Tufts University Institutional Review Boards.

Anthropometric measures

Trained laboratory personnel measured height and weight via calibrated balance-beam scales. Participants were measured in light clothing and no shoes, with height measured to the nearest 0.1 cm and weight measured to the nearest 0.1 kg. BMI was calculated as weight (kg)/ height (m^2). We used both military and WHO standards with cut-offs for overweight/obese in males at $\geq$27.5 kg/m^2 and $\geq$25.0 kg/m^2, respectively, in our analyses to facilitate comparisons with studies conducted in both military and civilian populations. The Deurenberg equation (i.e., BF%= 1.20*BMI + 0.23*age – 10.8*male-5.4) was used to estimate percent BF% from BMI, sex and age (33).

Neck, waist, and hip circumference measurements were taken in inches via a non-elastic tape measure by trained laboratory personnel using standard techniques and protocols as described elsewhere (10, 14). CBEs from the Army Body Composition

Program, (Army Regulation 600-9) were used to calculate each participant's BF% (34, 35):

Men: $BF\% = [86.010 * \log_{10}(\text{waist-neck})] - [70.041 * \log_{10}(\text{height})] + 36.76$

Women: $BF\% = [163.205 * \log_{10}(\text{waist + hip - neck})] - [97.684 * \log_{10}(\text{height})] - 78.387$

Army maximum allowable BF% standards were used to categorize normal from overfat by age group (**Table 2.1)**. WC measurements were also assessed alone using both the Air Force and National Heart Blood and Lung Institute's (NHBLI's) cut-offs linked to increased health risks: 40 inches or greater in men and 35 inches or greater in women were considered overfat (36, 37).

BIA was conducted by trained personnel. Surface electrodes from a portable body composition analyzer (RJL Systems; Clinton Township, MI) were placed on participants' hands and feet. While each participant lay supine with arms at a 30-degree angle from the body and legs not touching, a low current was used to determine fat mass via resistance in each participant's body surface area (i.e., with its high water content, muscle allows the current to pass through versus fat will provide resistance) (38, 39). Each participant's resistance measurement was then entered along with age and body weight into Segal's sex-specific generalized equations (Segal GEN) to estimate BF%:

Males: $FFM = 0.00132 * H^2 - 0.04394 * R + 0.30520 * BW - 0.16760 * A + 22.66827$

Females: $FFM = 0.00108 * H^2 - 0.02090 * R + 0.23199 * BW - 0.06777 * A + 14.59453$

Where FFM is fat-free mass, H is height (cm), R is resistance (ohm), BW is bodyweight (kg), and A is age (years) (32, 40). We considered this BIA-based estimate of BF% as the

"gold standard" and used the Army's maximum allowable BF% standard cut-offs to distinguish normal from overfat by age group (Table 2.1).

Statistical Analysis

De-identified data were obtained from researchers at USU. To determine the level of agreement between BMI, WC, CBE, and BIA measures, each respondents' body composition measurements were independently categorized (normal vs. overweight/obese or overfat by WHO/CDC and NHBLI/military classifications, respectively); the chi square (χ^2) test was used to compare these proportions by sex. Level of agreement was determined by examination of Cohen's kappa (C_k) coefficients and categorized qualitatively using Landis and Koch's guidelines: 0.0-0.2 slight agreement, 0.21-0.40 fair agreement, 0.41-0.60 moderate agreement, 0.61-0.80 substantial agreement, and 0.81-1.0 almost perfect or perfect agreement (41). In addition, Bland Altman plots of BF% derived from the aforementioned equations based on BMI, CBE, and BIA measures were examined to visualize the extent of agreement between them, the width of limits of agreement, and, if present, how error may differ across a range of values.

Next, the body composition categories were used to compare anthropometric measures with BIA using standard screening measures. The screening measures were defined as follows:

Sensitivity= [TP/(TP+FN)]*100

Specificity= [TN/(TN+FP)]*100

Positive predictive value (PPV)= [TP/(TP+FP)]*100

Negative predictive value (NPV)= [TN/(TN+FN)]*100

False Discovery Rate (FDR)= 1-PPV or [FP/(TP+FP)]*100

False Omission Rate (FOR)= 1-NPV or [FN/(TN+FN)]*100

For example, in the equations above, if one was screening overweight/obese vs. normal, TP is true positive, or the proportion of overweight/obese participants correctly classified as overweight/obese; TN is true negative, or the proportion of normal weight participants correctly classified as normal weight; FP is false-positive, or the proportion of normal weight participants incorrectly classified as overweight/obese; and FN is false negative, or the proportion of overweight/obese participants incorrectly classified as normal weight. These were calculated for BMI, WC, and CBE measures separately, then re-examined combining BMI with both WC (BMI+WC) and CBE (BMI+CBE) to determine whether any combination performed better than the measures individually (e.g., sensitivity and specificity of BMI alone vs. BMI+WC). Though WC, CBE, and BIA cut-offs categorize participants as normal vs. overfat, when combined with BMI or referred to in total with all anthropometric measures, the categories are referred to as normal vs. overweight/obese.

Given that our goals were to 1) identify the anthropometric measure(s) that can best positively identify military personnel as overweight/obese who are truly overweight/obese while 2) decreasing the probability of being normal weight but being diagnosed as overweight/obese, an emphasis was placed on sensitivity and FDR, respectively.

All analyses were conducted in total participants and stratified by sex using SAS (version 9.4; SAS Institute, Cary, NC). Statistical tests were two-sided with a significance level of 0.05.

2.4 Results

Participant characteristics of the 389 military personnel included in this study are listed in **Table 2.1.** Approximately 80% of participants were male and of median age 25y, ranging from 18-58y. Whereas mean BMI and WC measures were higher in males than females, BF% measures were higher in females (Table 2.1).

A breakdown of normal versus overweight/obese participants by various anthropometric measures is presented in **Table 2.2**. WHO BMI measures classified the most males as overweight/obese (61.1%), followed by BF% by BIA (42.6%) and BF% via the Deurenberg equation using BMI (40.9%). A combination of BMI with WC (BMI+WC) was the least likely to categorize male participants as overweight/obese (10.9%), followed by WC (11.6%), a combination of WHO BMI with WC (WHO BMI+WC, 11.6%), and BMI with CBEs (BMI+CBE, 18.8%). Similar to males, both BMI and BIA measures classified the most females as overweight/obese (all 51.2%), whereas BMI+WC as well as WC alone identified the fewest female participants as overweight/obese (9.3%). However, unlike males, females were significantly more likely to be categorized as overweight/obese by CBEs alone (48.8% vs. 21.8%, χ^2= 24.45, p<0.0001) BMI+CBE (41.9% vs. 18.8%, χ^2= 19.56, p<0.0001), WHO BMI+CBE (41.8% vs. 21.5%, χ^2= 14.51, p=0.0001), and BMI alone (51.2% vs. 36.6%, χ^2= 5.90, p=0.015) (Table 2.2).

When the level of agreement for anthropometric measures with BIA in categorizing participants as overweight/obese was examined, both BMI and WHO BMI measures had the highest agreement among total and sex-stratified participants (**Table**

2.3). BMI+CBE had an overall moderate level of agreement and performed particularly better in females. Of all the measures, WC had the lowest level of agreement with BIA, both alone and when combined with BMI (Table 2.3).

Bland Altman plots comparing BMI and CBE to BIA are included in **Figure 2.2**. Overall, the plots showed large limits of agreement. Neither comparison revealed a particular bias compared to BIA among total participants (**Fig 2.2a** and **d**). However, similar to the Cohen's kappa coefficient results, the agreement between CBE and BIA appeared slightly stronger in females than males. When CBE was stratified by sex, it underestimated body fatness in males, as depicted by the participants close to and below the lower limit of agreement (**Fig 2.2e**).

Table 2.4 further examines how each of the anthropometric measures performs as screening measures compared to BIA in categorizing participants as normal versus overweight/obese. Looking at total participants, similar to Ck findings, BMI had the highest sensitivity (80.4%), followed by CBE (54.9%) and BMI+CBE (50.9%); sensitivity for all three were particularly high in females (Table 2.4). Conversely, WC measures had the lowest sensitivity, especially in females. However, FDR findings had inverse results to sensitivity: the lowest FDR was in BMI+WC (2.4%), WHO BMI+WC (4.7%), and WC alone (4.7%); CBE had the highest FDR in females and WHO BMI and BMI had the highest FDR in males. When sensitivity and FDR are considered together, BMI + CBE performed best, with a sensitivity of 50.9% and FDR of 5.4%. BMI+CBE still performed the best when results were stratified by sex, with a particularly higher sensitivity in females than males (75.0% vs 42.6%) (Table 2.4).

2.5 Discussion

We sought to identify the best way to quickly and accurately measure adiposity in the military. In a military context where a large number of military personnel are routinely screened, it is particularly important for an anthropometric test to categorize military personnel who are truly overweight/obese, while limiting false identification of overweight/obesity in those who are normal weight. These considerations will allow for quicker and more accurate screenings that do not unfairly impact fit military personnel. Based on these considerations, we found that BMI+CBE was the best anthropometric combination to categorize overweight/obesity in our study sample. BMI+CBE had the relatively highest sensitivity and lowest FDR, as well as a moderate level of agreement with BIA; this combination was notably stronger in females. As CBEs are based on different site measurements in males (neck and abdominal circumferences) and females (neck, waist, and hip circumferences) to take into account varying body fat distribution and endocrine physiology by sex (10), it may be that the accuracy of body fat assessment was affected by the equations' site choices. However, given that FDR was higher in females than males and that there were much fewer females included in this study than males, one should be cautious in interpreting this study's stratified differences for CBE.

Notably, BMI+CBE out-performed WHO BMI+CBE in comparison to BIA in categorizing overweight/obesity in males. Though WHO BMI alone had a lower level of agreement in males with BIA than BMI alone, it had a slightly higher level of agreement once combined with CBE. However, this may have contributed to the fact that WHO BMI had the highest sensitivity overall. WHO BMI had a greater FDR than BMI; though it improved when combined with CBE, it was still higher than BMI+CBE's FDR. Thus,

BMI+CBE overall performed better than WHO BMI+CBE. These findings support the current use of the military BMI cut-off point for overweight in males (i.e., 27.5 kg/m^2) to account for muscle mass, but only when combined with CBE to help lower false diagnoses of overweight/obesity in military personnel.

A debate as to the best way to assess adiposity in the military is ongoing. Previous studies report WC to be more accurate at categorizing overweight/obesity (15) and a more accurate measure of body composition-related health outcomes compared to other anthropometric measures (10, 15). They proposed WC as a quick and easy to administer method, which makes it an ideal anthropometric method for both research and the field (42). Currently, the Air Force relies on WC exclusively to risk stratify for health risk rather specifically targeting body composition in their branch (24, 25). Though we found that WC had among the lowest FDRs whether alone or in combination with BMI measures, it also had the lowest sensitivity and levels of agreement with BF% categories by BIA in both male and females. A study by Heinrich et al. (7) conducted in 451 Air Force military personnel similarly found WC measurements to underestimate obesity on an individual level compared to BF% by BIA; however, unlike our study, they found BMI underestimated obesity compared to BIA as well. These findings are not surprising, as WC alone is not a measure of body fatness, but rather often used to assess health-related risks more than adiposity itself (10, 43).

Body composition and fat distribution changes take place as one ages. Friedl et al. (10) suggested age-related decreases in testosterone levels in older military personnel may affect intra-abdominal fat distribution. Importantly, the CBEs used in our study do account for age in assessing body fat.

Our study had a few notable limitations. First, BIA was used as the criterion measure to assess BF% in participants rather than DEXA. A recent study by Combest et al. (29) in active duty military personnel reported BF% by BIA had excellent agreement with DEXA in both males (N=31 ICC=0.89, 95% CI 0.78-0.94) and females (N=45, 0.93, 95% CI 0.87-0.96). However, unlike our study, the study protocol followed by Combest et al. did ensure the hydration status of participants. To the extent that some participants were not well hydrated, this could impact the accuracy of our "gold standard" BF% estimates by adding random error to the measurement (29). Second, various studies report older military personnel are at higher risk of overweight/obesity compared to those in younger categories (2, 4, 5, 11, 44-46). As previously mentioned, our sample sizes were not adequate to explore results stratified by age. Similarly, we could not stratify by race/ethnicity, though they may affect the accuracy of body composition cut-offs and the association between visceral fat and health risks (47, 48). Third, our sample included only 22.1% females. Although this is reflective of the proportion in the military, it limited our statistical power (29). Lastly, though BMI, CBEs, and WC were compared to BIA, it must be emphasized that WC is not a measure of body fatness; its low level of agreement and sensitivity compared to BIA should be interpreted with caution. Consideration must be given to the goal of the assessment by the military- body composition alone or in combination with a stronger assessment of health risk. If the latter, WC should be compared to these other measures in future studies in the military to examine not just the accuracy of overweight/obesity categorization, but to also identify which is more strongly associated with health risk.

Our study also had several noteworthy strengths. First, a key strength was that trained personnel conducted all of the anthropometric and BIA measures in triplicate, thereby removing the possibility of participants' self-reporting errors and reducing measurement error. Second, access to the extensive anthropometric and BIA data collected as part of the CHAMP's CSF2 study provided an opportunity to compare the accuracy of multiple, popular approaches to defining overweight/obesity in active duty military personnel. Additionally, all methods assessed in comparison to BIA are practical, cost-effective, and time-efficient anthropometric measures that require little training and can be used in a large population should they be implemented military-wide.

2.6 Conclusions

Quick, accurate methods to measure body composition are needed in the military. With an emphasis on an easy-to-implement screening measure for the military, our study supports BMI+CBE as a favorable combination to assess normal versus overweight/obesity in military personnel. WC, neither alone nor in combination with BMI, had a high sensitivity or level of agreement compared to BIA to assess overall adiposity, but our study was not intended to shed light on the best measures to assess risks for health-related outcomes of interest. Future studies should aim to recruit a larger sample of military personnel- with a greater emphasis on female participant recruitment- to ensure that the choice of measure performs well across age and sex-specific groups, as well as examine the relationship of these measurements with health-related outcomes.

2.7 Figures and tables

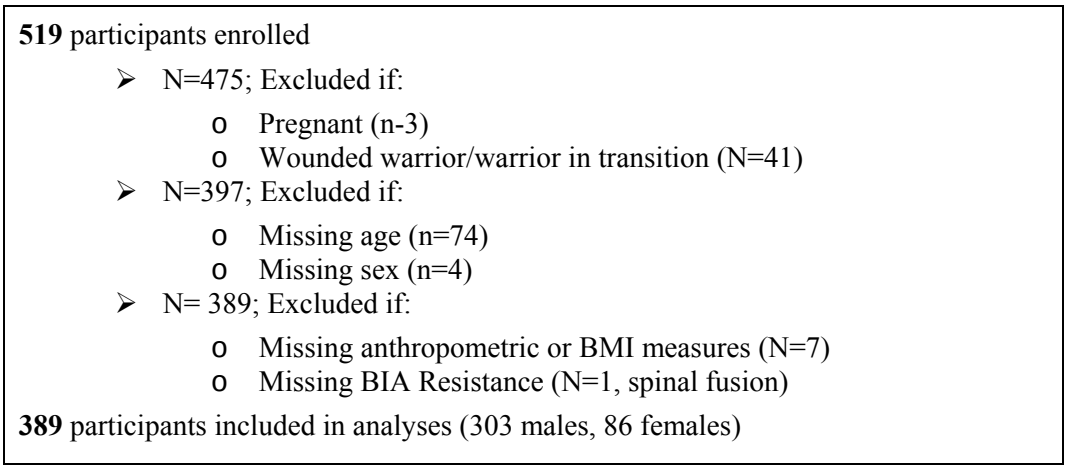
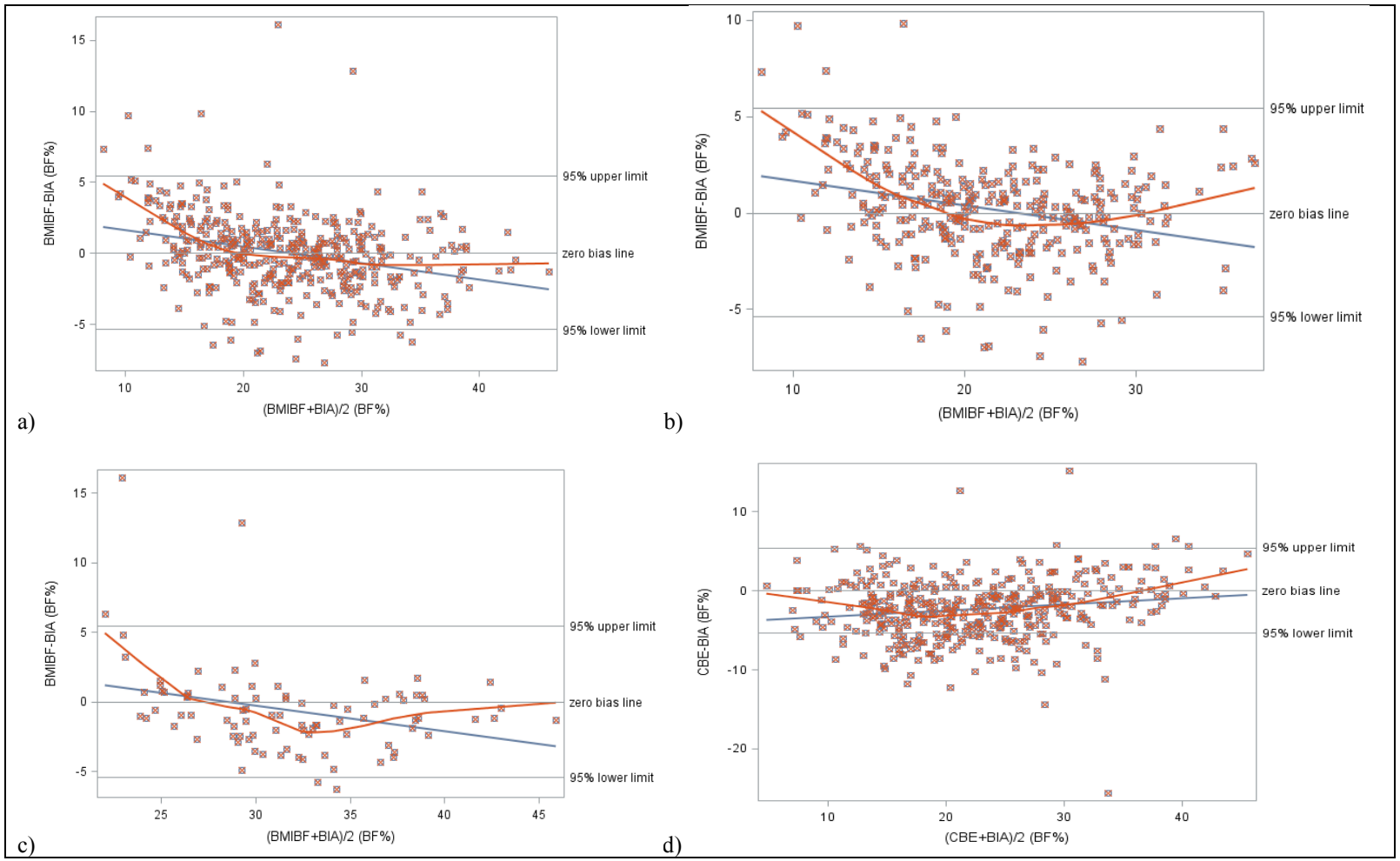


Figure 2.1 Participant inclusion process


a)
BMIBF-BIA (BF%)
(BMIBF+BIA)/2 (BF%)
95% upper limit
zero bias line
95% lower limit
b)
BMIBF-BIA (BF%)
(BMIBF+BIA)/2 (BF%)
95% upper limit
zero bias line
95% lower limit
c)
BMIBF-BIA (BF%)
(BMIBF+BIA)/2 (BF%)
95% upper limit
zero bias line
95% lower limit
d)
CBE-BIA (BF%)
(CBE+BIA)/2 (BF%)
95% upper limit
zero bias line
95% lower limit

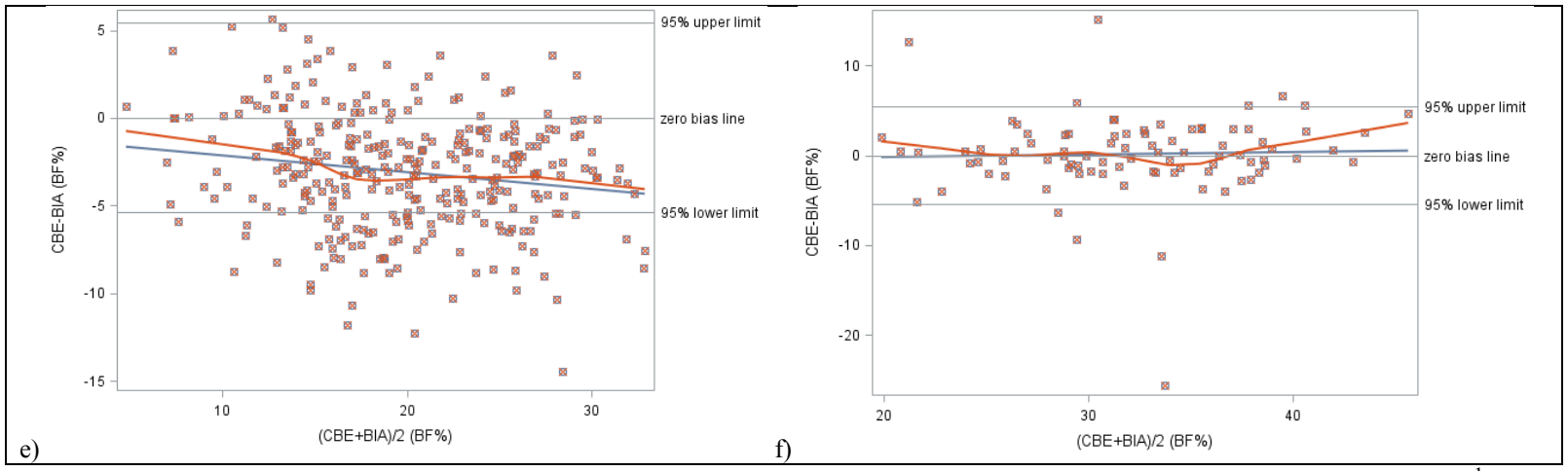


Figure 2.2 Bland-Altman plots comparing measures of body fatness in categorizing participants as normal vs. overfat[1]

[1]Deurenberg BMI equation vs. Segal bio-electrical impedance analysis (BIA) equation for a) total participants (N=389), b) male participants (N=303), and c) female participants (N=86); AR 600-9 circumference-based equations (CBEs) vs. Segal BIA equation for d) total participants, e) male participants, and f) female participants; Solid blue line: correlation between the mean and the differences of the methods; Solid red line: LOESS cure

Table 2.1 Participant characteristics from CHAMP's CSF2 study (N=389)[1]

Variables	**Total** (N=389)	**Males** (N=303)	**Females** (N=86)
Sex (%)	--	77.9%	22.1%
Age (years) *(Median (min-max))*	25.0 (18.0-58.0)	25.0 (18.0-58.0)	25.0 (18.0-56.0)
BMI (kg/m^2) *(Mean (SD))*	26.1 (3.7)	26.3 (3.7)	25.3 (3.5)
WC (in) *(Mean (SD))*	34.0 (4.0)	34.9 (3.8)	30.8 (3.0)
Body fat % (BF%)			
BIA (Segal sex-specific equations) *(Mean (SD))*	23.7 (7.7)	21.3 (6.3)	32.2 (6.0)
CBE (AR 600-9 equations) *(Mean (SD))*	21.4 (8.3)	18.3 (5.8)	32.3 (6.2)
BMI (Deurenberg equations) *(Mean (SD))*	23.8 (6.9)	21.6 (5.6)	31.5 (5.1)

[1] BF%, percent body fat; BIA, bioelectrical impedance analysis; BMI, body mass index; CBE, circumference-based equation; CHAMP, Consortium of Health and Military Performance; CSF2 Study, Comprehensive Soldier and Family Fitness Study; WC, waist circumference

Table 2.2 Proportion of participants categorized as overweight/obese using various anthropometric measures, stratified by sex (N=389)[1]

Anthropometric Measures	Overweight/Obese (%)			χ^2 statistic[2]
	Total (N=389)	**Males** (N=303)	**Females** (N=86)	
BMI, military (ht/wt^2)	155 (39.9)	111 (36.6)	44 (51.2)	5.90[3]
BMI, WHO (ht/wt^2)	229 (58.9)	185 (61.1)	44 (51.2)	2.71
WC (in)	43 (11.1)	35 (11.6)	8 (9.3)	0.345
BF% measures				
BMI (BF%, *Deurenberg*)	155 (39.9)	124 (40.9)	31 (36.1)	0.67
CBE (BF%, *AR 600-9*)	108 (27.8)	66 (21.8)	42 (48.8)	24.45[4]
BIA (BF%, *Segal*)	173 (44.5)	129 (42.6)	44 (51.2)	2.00
BMI+WC	41 (10.5)	33 (10.9)	8 (9.3)	0.18
WHO BMI+WC	43 (11.1)	35 (11.6)	8 (9.3)	0.34
BMI+CBE	93 (23.9)	57 (18.8)	36 (41.9)	19.56[4]
WHO_BMI+CBE	101 (26.0)	65 (21.5)	36 (41.9)	14.51[4]

[1] +, combined with; BF%, percent body fat; BIA, bioelectrical impedance analysis; BMI, body mass index; CBE, circumference-based equation; Ck, Cohen's kappa coefficient; WC, waist circumference
[2] p>0.05 unless otherwise indicated
[3] p=0.015
[4] p≤0.0001

Table 2.3 The level of agreement in categorizing participants as overweight/obese defined by BIA compared to other anthropometric measures[1]

Anthropometric Measures	C_k (p-value)		
	Total (N=389)	**Males** (N=303)	**Females** (N=86)
BMI vs BIA	0.737	0.711	0.814
WHO BMI vs BIA	0.627	0.578	0.814
WC vs BIA	0.246	0.270	0.178 (0.004)
CBE vs BIA	0.508	0.474	0.582
BMI+CBE vs BIA	0.509	0.447	0.676
WHO_BMI+CBE vs BIA	0.522	0.466	0.676
BMI+WC vs BIA	0.245	0.268	0.178 (0.004)
WHO_BMI+WC vs BIA	0.245	0.270	0.178 (0.004)

[1] BIA, bioelectrical impedance analysis; BMI, body mass index; CBE, circumference-based equation; C_k, Cohen's kappa coefficient; WC, waist circumference. p<0.0001 for comparisons unless otherwise noted in parentheses

Table 2.4 Comparison of anthropometric measures to BIA in categorizing overweight/obesity using standard screening measures (N=389)[1]

BIA vs.	BMI	WHO BMI	WC	CBE	BMI+WC	WHO BMI+WC	BMI+CBE	WHO BMI+CBE
Total Participants (N=389)								
Sensitivity (%)	**80.4**	**94.8**	**23.7**	**54.9**	**23.1**	**23.7**	**50.9**	**53.8**
Specificity (%)	92.6	69.9	99.1	94.0	99.5	99.1	97.7	96.3
PPV (%)	89.7	71.6	95.4	88.0	97.6	95.4	94.6	92.1
NPV (%)	85.5	94.4	61.9	72.2	61.8	61.9	71.3	72.2
FDR (%)	**10.3**	**28.4**	**4.7**	**12.0**	**2.4**	**4.7**	**5.4**	**7.9**
FOR (%)	14.5	5.6	38.2	27.8	38.2	38.2	28.7	27.8
Male Participants (N=303)								
Sensitivity (%)	**76.7**	**96.1**	**25.6**	**47.3**	**24.8**	**25.6**	**42.6**	**46.5**
Specificity (%)	93.1	64.9	98.9	97.1	99.4	98.9	98.9	97.1
PPV (%)	89.2	67.0	94.3	92.4	97.0	94.3	96.5	92.3
NPV (%)	84.4	95.8	64.2	71.3	64.1	64.2	69.9	71.0
FDR (%)	**10.8**	**33.0**	**5.7**	**7.6**	**3.0**	**5.7**	**3.5**	**7.7**
FOR (%)	15.6	4.2	35.8	28.7	35.9	35.8	30.1	29.0
Female Participants (N=86)								
Sensitivity (%)	**90.9**	**90.9**	**18.2**	**77.3**	**18.2**	**18.2**	**75.0**	**75.0**
Specificity (%)	90.5	90.5	100.0	81.0	100.0	100.0	92.9	92.9
PPV (%)	90.9	90.9	100.0	81.0	100.0	100.0	91.7	91.7
NPV (%)	90.5	90.5	53.9	77.3	53.9	53.9	78.0	78.0
FDR (%)	**9.1**	**9.1**	**0.0**	**19.1**	**0.0**	**0.0**	**8.3**	**8.3**
FOR (%)	9.5	9.5	46.2	22.7	46.2	46.2	22.0	22.0

[1] BIA, bioelectrical impedance analysis; BMI, body mass index; BMI+CBE: body mass index combined with circumference-based equation; BMI+WC, body mass index combined with waist circumference; CBE, circumference-based equation; Ck, Cohen's kappa coefficient; FDR, false discovery rate; FOR, false omission rate; NPV, negative predictive value; PPV, positive predictive value; WC, waist circumference

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Chapter 3. Investigating items to improve the validity of the five-item Healthy Eating Score (HES-5) compared with the 2015 Healthy Eating Index (HEI-2015) in a military population

3.1 Abstract

Background: Military researchers utilize a 5-item healthy eating score (HES-5) in the Global Assessment Tool (GAT) to quickly assess the overall diet of military personnel. Though the HES-5 is strongly associated with health-promoting nutrition behaviors, its development was based off of its correlation with the 2005 Healthy Eating Index (HEI-2005).

Objective: The aim was to determine whether modifications to the HES-5 could improve its validity compared with the recent 2015 Healthy Eating Index (HEI-2015). We hypothesized that modifying the HES-5 by adding items to address frequency of 1) breakfast consumption, 2) post-exercise recovery fueling snack (RFsnack) consumption, and 3) sugar-sweetened beverage (SSB) consumption, alone or in combination, would strengthen its correlation with the HEI-2015.

Methods: This is a secondary analysis of cross-sectional data from the Consortium of Health and Military Performance's Comprehensive Soldier and Family Fitness Study. Active duty military personnel who provided information on sex, dietary data, and plausible total energy intake values were retained for this study (N=333). A food frequency questionnaire was used to calculate HEI-2015 and to capture data on SSB intake. Nutrition questions from the military's online GAT questionnaire were used to calculate HES-5 scores and to capture data on breakfast and RFsnack frequencies. SSB consumption was calculated in 8-oz (SSB-8) and 12-oz (SSB-12) servings. Two scoring options were considered for the highest RFsnack category: "4" (RFsnack-A) vs. "5" (RFsnack-B). Potential candidates were added one, two, and three at a time to the HES-5; mean scores were calculated; and all scores were compared to the HEI-2015 with a

Pearson r coefficient. The scores with the highest correlations were formally compared to the HES-5 and HEI-2015 via a Z-score equation. Those with statistically significant Z-scores were then compared to one another to identify the simplest modification to the HES-5.

Results:

Compared to males, females had higher mean(SD) HEI-2015 scores (65.15 (11.05) vs. 60.24 (9.72)) and HES-5 scores (15.16(5.16)) vs.14.35(5.04)). The correlation between the scores in males and females were 0.445 and 0.317, respectively. Correlations were most improved by adding RFsnack-B, SSB-8, RFsnack-B+SSB-8, and RFsnack-B+SSB-8+breakfast. Though all four were significantly better than the HES-5, adding SSB-8+RFsnack-B performed best.

Conclusions: Adding SSB-8+RFsnack-B to the HES-5 strengthened its correlation to the HEI-2015. Scoring mechanisms, serving sizes, and question wording should be considered in future studies.

3.2 Introduction

An estimated 51.2% of all U.S. military are overweight or obese (1). In addition to its associated chronic disease burden and costs, obesity can negatively affect military personnel's operational readiness (e.g., increase their likelihood of combat injury or mortality) and jeopardize the long-term welfare of the US military and, thereby, our defense. (2-6). Diet can play a major role in reducing obesity risk and promoting the health and physical readiness of military personnel. However, results from the 2011 Department of Defense (DoD) Survey of Health-Related Behaviors Among Military Personnel (HRBS) indicated only 11.2%, 12.9% and 12.7% of military personnel met the objectives for fruit, vegetable and whole grain intake, respectively (7).

Although the 2011 HRBS results indicate a gap between nutritional recommendations and what military personnel generally consume, the nutritional determinants associated with overweight and obesity are still unclear. Findings across studies examining the associations between individual macronutrients and adiposity are inconsistent (8). Because individuals commonly eat foods together in meals rather than as nutrients or as single foods, a focus on dietary patterns may better capture the complexity of the diet, account for various nutrient interactions, and provide a clearer picture of the diet's association with adiposity (9).

Dietary patterns reflect a broader look at the various types, quantities, and/or combinations of different foods, beverages, and nutrients in diets, and the frequency with which they are typically consumed (10, 11). One common method used to summarize dietary data as dietary patterns is through a hypothesis-oriented approach, where one evaluates data using set criteria and aggregates dietary components as a score or index

(12). The USDA 2015 Healthy Eating Index (HEI-2015) takes this approach to assess the extent that an individual's diet follows key recommendations in the 2015-2020 Dietary Guidelines for Americans (DGA). This approach relies on data from a detailed quantitative or semi-quantitative dietary assessment instrument, such as a food frequency questionnaire (FFQ) or 24-hour recall (24HR), to characterize total diet. Though the HEI-2015 was only recently released, the earlier HEI-2010 has been used extensively in research to capture diet quality in relation to the 2010 DGA (13, 14). However, this comprehensive approach to dietary data collection may be impractical in a military context, clinically, or for administration in large studies due to the cost and time burden on participants. Methods to accurately and rapidly measure the diets of personnel are needed.

To address the need for an abbreviated dietary assessment tool, military researchers developed the five-item Healthy Eating Score (HES-5). The HES-5 is a modified version of the USDA HEI-2005 to quickly assess the overall diet; it looks at five dietary components via five questions (intake of fruit, vegetables, whole grains, dairy, and fish) as part of the updated Comprehensive Soldier and Family Fitness (CSF2) Global Assessment Tool (GAT) (7, 15). Though the HES-5 is strongly associated with health-promoting nutrition behaviors, its correlation with dietary quality is based on the HEI-2005 developed relative to the 2005 DGA. It has not been updated and examined with the most recent HEI-2015, which reflects the 2015-2020 DGA (7, 15).

The aim of this study was to determine whether modifications to the GAT HES-5 could improve its validity compared with the HEI-2015 and, thus, more accurately assess the most current nutrient DGA (14). We hypothesized that modifying the HES-5 by

adding items to address frequency of 1) breakfast consumption, 2) post-exercise recovery fueling snack (RFsnack) consumption, and 3) SSB consumption, alone or in combination, would strengthen its correlation with the HEI-2015. These additions may provide a more accurate tool to assess optimal nutrition than is currently available for future military researchers and clinicians.

3.3 Methods

This study is a secondary analysis of cross-sectional data from the Consortium of Health and Military Performance's (CHAMP's) CSF2 Study. Briefly, the study included 519 active duty military personnel to assess their physical fitness and nutritional status. Volunteers were recruited from June 2014 through November 2017 from Fort Bliss (TX) (N=301), Fort Bragg (NC) (N=104), Fort Myer (VA) (N=78), Fort Detrick (N=32), and Naval Support Activity Bethesda (MD) (N=4). Of the 519 participants included in CHAMP's CSF study, 333 were eligible for inclusion in this study. Participants were excluded if they had incomplete dietary data (N= 174) or, as proposed by Willett, if they reported energy intake values <800 kcal/day for males and <500 kcal/day for females (N=12) (16, 17). Because this military population may be more active than the civilian population and require higher caloric intakes, Willett's upper limit cut-offs of >4000 kcal for men and >3500 kcal for women were not applied. The main reason for incomplete dietary data was that participants did not complete the online GAT (i.e., they completed the FFQs in-person but did not complete the GAT online off-site). Approximately 74% of included participants were male (N=247). The study was approved by the Uniformed Service University (USU) and Tufts University Institutional Review Boards.

Dietary Assessment

Dietary data were collected from subjects through a FFQ in-person and the GAT off-site. A semi-quantitative 110-food item Block FFQ was administered via paper and pencil. Subjects specified the quantity of each item typically consumed over the past three months, aided by pictures provided to assist in portion size estimations. To represent usual SSB intake, data were collected on the number of times/week each SSB was typically consumed and the number of cans, bottles, or glasses consumed at each time. Items included in the SSB category are listed in **Appendix B**. Responses from the FFQ on frequency and quantity of each SSB item were used to calculate total SSB g/day for each participant. Because serving sizes varied by SSB item on the FFQ (e.g., 8-oz glasses vs. 12-oz cans), SSB g/day were used to calculate total SSB servings/day using both 8-oz (SSB-8) and 12-oz (SSB-12) servings. Both serving size versions were assessed as potential additions to the HES-5.

Dietary and behavior data were also collected online as part of the GAT, an online tool used to assess subjects' emotional, social, family, spiritual and physical dimensions of well-being (7). The physical dimension included the HES-5, which is comprised of the fruit, vegetable, whole grain, dairy and fish consumption items in the physical dimension (a question list can be found in Appendix B). The physical dimension of the GAT also assessed dietary behavior over the past 30 days with single questions on frequency of breakfast consumption ("How many times per week do you eat breakfast?") and RFsnack consumption within one hour post-exercise ("Do you typically consume a healthy snack within 60 minutes after a strenuous exercise session? (Examples include 1 piece of fruit,

a handful of nuts, 1 small yogurt container, 1 cup of milk, 1 granola bar, or 1 sports bar)").

Statistical Analysis

All analyses were conducted on the total sample and stratified by sex. FFQ and GAT data were used to calculate the HEI-2015 and HES-5 scores, respectively. The HEI-2015 utilizes 13 components to score a participant's diet on a scale from 0-100, with a higher score representing greater adherence to DGA and better diet quality (18). The HES-5 scores were calculated from the aforementioned five dietary components to score the quality of a participant's diet on a scale from 0-25. The components and scoring rubrics of the HEI-2015 and HES-5 are detailed in **Table 3.1**.

Next, we analyzed responses on breakfast and RFsnack items from the GAT and SSB consumption from the FFQ as potential new components to the HES-5 (i.e., candidate HES-5+). The response categories and scoring rubric used for each potential component can be found in **Table 3.2**. It is important to note that, for RFsnack, there were only five response categories compared to the six response categories for breakfast and the HES-5 components. Two different scoring rules were examined: with the highest category receiving a score of four (RFsnack-A) or five (RFsnack-B) (Table 3.2). As previously mentioned, SSB was analyzed as both SSB-8 and SSB-12.

All HEI-2015, HES-5, and candidate HES-5+ scores were plotted to assess normality. Given their distributions were normal, mean (SD) scores were calculated and all correlations between scores were examined with a parametric Pearson r coefficient. With the correlation between HES-5 and HEI-2015 as a starting point, we added potential

candidates one (HES-6), two (HES-7), and three (HES-8) at a time to the HES-5 to assess whether they increased its correlation with the HEI-2015.

Once the strongest candidates were identified, the items with the highest Pearson r coefficients were formally compared to the HES-5 and HEI-2015. The significant differences between their correlated correlations were examined using a Z-score equation proposed by Meng et al. (19). Lastly, the goal was to identify the most significant yet simplest modifications to the HES-5. If more than one candidate HES-5+ was significantly stronger than the HES-5 (e.g., both a six-item and seven-item HES), they were further compared with the Meng et al. equation to identify if they significantly differed from one another. All statistical analyses were two-sided with a significance level of 0.05 and conducted using SAS (version 9.4; SAS Institute, Cary, NC).

3.4 Results

The mean HEI-2015 and HES-5 scores among total participants were 61.5 (SD: 10.2) and 14.6 (SD: 5.1), respectively (**Table 3.3**). Mean scores were higher in females than males (HEI-2015 mean(SD): 65.2 (11.1) vs. 60.2 (9.7), respectively; HES-5 mean(SD): 15.2 (5.2)) vs.14.4 (5.0), respectively). As a comparison, the HES-2005 mean score was 67.9 (SD: 10.7) in total participants, 67.1 (SD:10.1) in males, and 70.4 (SD:11.9) in females. The mean scores for all candidate HES-5+ can be found in Table 3.3.

The correlations between the HEI-2015 and all variations of the HES-5 are included in **Table 3.4**. The correlation between the HES-5 and HEI-2015 in total participants, males, and females were 0.41, 0.45, and 0.32, respectively. Among the HES-

6 options, the correlations were slightly stronger when adding RFsnack-B or SSB-8 than RFsnack-A or SSB-12, respectively. Thus, all remaining candidate HES-5+ reported in Table 3.4 and for the remainder of this paper utilize RFsnack-B and SSB-8 (see **Appendix C** for a full list of correlation results including all candidate HES-5+ versions). Both the HES-6(+SSB-8) and HES-6(+RFsnack-B) correlations with the HEI-2015 were stronger than those seen with the HES-6(+breakfast). Among the HES-7 options, the addition of SSB-8 and RFsnack-B together was strongest. The highest correlations overall were seen with the HES-8 (+breakfast, SSB-8, & RFsnack-B) (Table 3.4).

The candidate HES-5+ with the strongest correlations (i.e., HES-6(+SSB-8), HES-6(+RFsnack-B), HES-7 (+SSB-8 & RFsnack-B), and HES-8(+breakfast, SSB-8, & RFsnack-B)) were formally compared to HES-5 using the Meng equation. All were significantly more highly correlated than the HES-5 with the HEI-2015 (**Table 3.5**). Next, they were tested to see if the addition of more items performed better than those with fewer items. The HES-8 was not found to be significantly different from the HES-7 in either males or females (Table 3.5). Among males, the HES-7 was significantly more highly correlated than the HES-6(+RFsnack-B) with the HEI-2015, but not significantly different from the HES-6(+SSB-8). Among females, the HES-7 was significantly more correlated than both HES-6 scores with the HEI-2015 (Table 3.5).

3.5 Discussion

The HES-5 is designed to assess the overall diet of military service members in relation to the DGA. The aim of this study was to identify such items that may strengthen the validity of the HES-5 compared with the HEI-2015 (and thus 2015-2020 DGA), while

still limiting the number of questions to keep it a short, quick dietary assessment tool. Our results suggest that all candidate HES-5+ performed better than the HES-5. However, the HES-6(+SSB-8) was the best option among males and the HES-7(+SSB-8 & RFsnack-B) was the best option among females to replace the HES-5. Given that the GAT is administered to both males and females, the results from this study suggest administering the HES-7(+SSB-8 & RFsnack-B) instead of the HES-5 due to its stronger correlation with the HEI-2015.

It is important for any questions added to the HES-5 to enhance the overall picture of one's diet and dietary behaviors. A previous 2013 study by Purvis et al. used bivariate analyses to examine the association between dietary behaviors and HES-5 scores among military service members (7). Participants in the highest HES-5 quartile were more likely to report eating breakfast six or more times/week, never drinking regular or diet sodas, and report a greater frequency of RFsnack patterns (7). These preliminary findings were promising as evidenced by the Cronbach α analysis showing the HES-5 to have good internal consistency (α=0.81) (7). The findings of Purvis et al. guided the decision to focus on breakfast frequency, RFsnack frequency, and SSB consumption as potential candidates to add to the HES-5. Additionally, breakfast and RFsnack frequency items are already included in the GAT, making them practical and more feasible options to add to the HES-5. SSB was also considered for inclusion because it is a major source of added sugars associated with obesity (20). Our findings align with those of Purvis et al.; adding items examining SSB consumption and RFsnack frequency strengthened the correlations between the HES-5 and the HEI-2015. Although the correlation between the HES-

6(+breakfast) with the HEI-2015 was higher than the HES-5, the improvement was not as great as seen with the inclusion of the other two candidate items.

Optimal nutritional fitness is defined by Montain et al. as the availability and consumption of quality food in appropriate quantities and proportions to ensure optimal mission performance and protect against disease and injury (21), The construct includes three components: diet quality, healthy food choices, and specific nutritional requirements (21). The accurate assessment of the nutritional fitness of military personnel is important to the military because it can contribute to our understanding of dietary factors' associations with health outcomes (22). Purvis et al. found that increased frequency of breakfast and RFsnack were associated with improved physical and cognitive performance, physical fitness and reduced stress, injuries, and anthropometric values (7). Additionally, they found increased RFsnack was associated with reduced fatigue post-exercise and faster recovery speed, both of which are important to military service members (7). Research in athletes similarly report that frequent RFsnack consumption immediately post-exercise can aid in replenishing muscle and liver glycogen stores, speed recovery, and have positive benefits on later performance (23-26). Items reflecting breakfast frequency and RFsnack dietary behaviors may represent key parts of the diet and health outcomes currently not captured in the HES-5.

Conversely, SSB intake is inversely associated with optimal nutrition. It is a major contributor to added sugars in US adult diet and is positively associated with weight gain and obesity (27-29). Findings from the 2011 HRBS reflect the high levels of SSB consumption in the military: 19.3% of military personnel consumed SSBs two or more times each day (1, 20). The addition of a SSB item thus may strengthen the HES-5

due to its frequency in the diet. However, its consumption may also be representative of overall unfavorable dietary behaviors. Mullie et al. found that SSB consumption was associated with a lower consumption of fruit and vegetables and higher consumption of meat and fast-food; the latter are not currently captured in the HES-5 (28). One may surmise that an SSB item may reflect these other dietary behaviors. Further research on SSB and dietary patterns is needed to test this hypothesis.

For researchers and clinicians utilizing the HES-5 outside of the GAT, both RFsnack-B and SSB-8 items may be useful if added to the HES-5. The addition of the RFsnack-B item to the HES-5 is ideal given that it is currently part of the GAT. Scoring the highest category of the RFsnack item as a five (+RFsnack-B) made it a stronger candidate than a score of four (+RFsnack-A). Results of this study also suggest that an item on SSB may be particularly useful if added to the GAT, as the HES-6(+SSB-8) performed even more strongly in this group of participants than the HES-6(+RFsnack-B). Though measuring SSBs in 8-oz servings strengthened the correlation with the HEI-2015 more than the 12-oz servings, this may be related to the fact that SSB other than soft drinks typically are measured in 8-oz servings. If the focus in future studies is only on sodas, using a 12-oz serving may be the best option.

There are a few limitations to this study. First, though the SSB item performed well, it was based on several FFQ items with differing serving sizes. It is uncertain if the distinction between the consumption of different SSBs seen in the multiple FFQ questions would be considered by participants when completing one SSB question. Future research is warranted to identify the phrasing needed to accurately capture the consumption of various SSB items in a single question. This study was also conducted in

a relatively small sample of military personnel volunteers. Future studies are needed in additional and larger military populations to confirm these findings.

However, a few strengths of this study are noteworthy. To the best of our knowledge, this is the first study to examine modifications to the HES-5 to improve its correlation with the HEI-2015. Results suggest that it is possible to significantly improve the correlation of the HES-5 with the addition of just two questions on SSB intake and RFsnack frequency. Additionally, the RFsnack and breakfast items are already currently part of the GAT. Inasmuch as the Army population completes the GAT annually, it should be possible to examine the addition of both items to the HES-5 in future studies to confirm these findings. Lastly, although previous studies in the military focused primarily on males, almost 26% of study participants were female military service members. It is promising that the improvement in scores was observed in both males and females.

3.6 Conclusions

The HES-5 correlated well with the HEI-2015, although not as well as with the HEI-2005. Results from this study suggest that adding items on the consumption of SSBs and frequency of RFsnack (i.e., HES-7) can strengthen the correlation of the HES-5 with the HEI-2015 for both males and females in the military. Scoring mechanisms, serving sizes, and question wording should be considered in future studies to ensure the ideal components are added to the HES-5.

3.7 Tables

Table 3.1 HEI-2015 and HES-5 components and scoring rubric[1,2]

HEI-2015[3] component	Score range	Standard for maximum score	Standard for minimum score of zero
Assessing Diet Adequacy *(higher score indicates higher consumption)*			
Total Fruits[4]	0-5	≥ 0.8 cup equiv./1000 kcal	No fruit
Whole Fruits[5]	0-5	≥ 0.4 cup equiv./1000 kcal	No whole fruit
Total Vegetables[6]	0-5	≥ 1.1 cup equiv./1000 kcal	No vegetables
Greens and Beans[6]	0-5	≥ 0.2 cup equiv./1000 kcal	No dark-green vegetables or legumes
Whole Grains	0-10	≥ 1.5 oz equiv./1000 kcal	No whole grains
Dairy[7]	0-10	≥ 1.3 cup equiv./1000 kcal	No dairy
Total Protein Foods[8]	0-5	≥ 2.5 oz equiv./1000 kcal	No protein foods
Seafood and Plant Proteins[8,9]	0-5	≥ 0.8 oz equiv./1000 kcal	No seafood or plant proteins
Fatty Acids[10]	0-10	(PUFAs+MUFAs)/SFAs >2.5	(PUFAs + MUFAs) / SFAs ≤ 1.2
To be consumed in moderation *(higher score indicates lower consumption)*			
Refined Grains	0-10	≤ 1.8 oz equiv/1000 kcal	≥ 4.3 oz equiv/1000 kcal
Sodium	0-10	≤ 1.1 g/1000 kcal	≥ 2.0 g/1000 kcal
Added Sugars	0-10	≤ 6.5% of energy	≥ 26% of energy
Saturated Fats	0-10	≤ 8% of energy	≥ 16% of energy
Total HEI-2015:	Maximum score: 100		Minimum score: 0

	Frequency of consumption and scores[11]					
HES-5 components	**≥4 serv/d**	**2-3 serv/d**	**1 serv/d**	**3-6 serv/wk**	**1-2 serv/wk**	**Rarely or Never**
Fruits[4]	5	4	3	2	1	0
Vegetables[12]	5	4	3	2	1	0
Whole Grains	5	4	3	2	1	0
Dairy[13]	5	4	3	2	1	0
Fish[14]	5	5	5	5	3	0
Total HES-5:	Maximum score: 25					Minimum score: 0

[1]The HEI-2015 table is adapted from an article the National Cancer Institute's Epidemiology and Genomics Research Program website (18). The HES-5 table is adapted from an article by Purvis et al published in the *US Army Medical Department Journal*(7).

[2] D, day; equiv, equivalent; HEI-2015, 2015 Healthy Eating Index, g, grams; HES-5, 5-item healthy eating score; kcal, kilocalories; MUFAs, monounsaturated fatty acids; oz, ounce; PUFAs, polyunsaturated fatty acids; SFAs, saturated fatty acids; wk, week

[3] Intakes between the minimum and maximum standards are scored proportionately.

[4] Includes 100% fruit juice.

[5] Includes all forms except juice.

[6] Includes legumes (beans and peas).

[7] Includes all milk products, such as fluid milk, yogurt, and cheese, and fortified soy beverages.

[8] Beans and peas are included here (and not with vegetables) when the Total Protein Foods standard is otherwise not met.

[9] Includes seafood, nuts, seeds, soy products (other than beverages), and legumes (beans and peas).

[10] Ratio of PUFAs and MUFAs to SFAs

[11] The HES-5 asks respondents about the frequency of consumption of the following foods/beverages over the past 30 days. A higher score indicates higher consumption.

[12] Includes legumes and starchy vegetables.
[13] Includes all milk products, as well as soy milk or other calcium-fortified foods (e.g., orange juice, breakfast cereals)
[14] Specifically, tuna, salmon, and non-fried fish

Table 3.2 Potential candidate HES-5+ components and scoring rubric[1]

	Frequency of consumption and scores[3]					
Potential HES-5 component	**7 times /wk**	**6 times /wk**	**4-5 times /wk**	**2-3 times /wk**	**1 time /wk**	**Never or NR**
Breakfast	5	4	3	2	1	0
		Most of the time	**Often**	**Sometimes**	**Rarely**	**Never or N/A**
RFsnack-A[2]		4	3	2	1	0
RFsnack-B[2]		5	3	2	1	0
	Never	**Up to 1 serv/d**	**>1-3 serv/d**	**>3-4 serv/d**	**>5-<7 serv/d**	**≥7 serv/d**
SSB-8 (serv/wk)[3]	5	5	1	0	0	0
SSB-12 (serv/wk)[3]	5	5	1	0	0	0

[1] Candidate HES-5+, updated healthy eating score with more than five items; N/A, not applicable; NR, not reported; RFsnack-A, post-exercise recovery fueling snack with scoring option A; RFsnack-B, post-exercise recovery fueling snack with scoring option B; serv, servings; SSB-8, sugar-sweetened beverages with 8oz/serving; SSB-12, sugar-sweetened beverages with 12 oz/serving; wk, week
[2] Scoring for the recovery fueling question was examined with "Most of the time" scored as a 4 (RFsnack-A) and as a 5 (RFsnack-B).
[3] Two other scoring variations were examined. 1) Scoring was compared with SSB item categories scored "Up to 1 serv/d"= 1, ">1-3 serv/d"=0 to see if it had a higher correlation with HEI-2015 scores. The above included version had a stronger correlation for both males and females.

Table 3.3 Mean eating index scores for CHAMP's CSF military participants (N=333)[1]

	Total (N=333)	**Males** (N=247)	**Females** (N=86)
	Mean (SD)	*Mean (SD)*	*Mean (SD)*
HEI-2015	61.5 (10.2)	60.3 (9.7)	65.0 (11.1)
HEI-2005	68.0 (10.7)	67.1 (10.1)	70.4 (11.9)
HES-5	14.6 (5.1)	14.4 (5.0)	15.2 (5.2)
HES-6:			
+ Breakfast	18.1 (5.7)	17.8 (5.6)	18.8 (5.8)
+ RFsnack-A	17.0 (5.5)	16.8 (5.5)	17.6 (5.8)
+ RFsnack-B	17.3 (5.7)	17.0 (5.6)	17.8 (6.0)
+ SSB-8	17.2 (5.8)	16.8 (5.7)	18.4 (5.9)
+ SSB-12	17.7 (5.7)	17.3 (5.6)	18.8 (5.7)
HES-7:			
+ Breakfast+ SSB-8	20.7 (6.4)	20.3 (6.3)	22.0 (6.7)
+ Breakfast + SSB-12	21.2 (6.3)	20.7 (6.1)	22.4 (6.5)
+ SSB-8 + RFsnack-A	19.7 (6.3)	19.3 (6.2)	20.9 (6.6)
+ SSB-8 + RFsnack-B	18.1 (6.1)	17.7 (6.0)	18.9 (6.6)
+ SSB-12 + RFsnack-A	20.1 (6.2)	19.7 (6.1)	21.2 (6.3)
+ SSB-12 + RFsnack-B	20.4 (6.4)	20.0 (6.2)	21.4 (6.6)
+ Breakfast + RFsnack-A	20.5 (6.2)	20.3 (6.1)	21.2 (6.5)
+ Breakfast + RFsnack-B	20.7 (6.4)	20.5 (6.2)	21.4 (6.8)
HES-8:			
+ Breakfast + SSB-8 + RFsnack-A	23.2 (6.9)	22.7 (6.7)	24.5 (7.4)
+ Breakfast + SSB-8 + RFsnack-B	23.4 (7.1)	23.0 (6.9)	24.7 (7.6)
+ Breakfast + SSB-12 + RFsnack-A	23.6 (6.8)	23.2 (6.6)	24.8 (7.1)
+ Breakfast + SSB-12 + RFsnack-B	23.9 (7.0)	23.4 (6.8)	25.0 (7.4)

[1] CHAMP, Consortium of Health and Military Performance; CSF2 Study, Comprehensive Soldier and Family Fitness Study; HEI-2005, 2005 Healthy Eating Index; HEI-2015, 2015 Healthy Eating Index; HES-5, 5-item Healthy Eating Score; HES-6, 6-item Healthy Eating Score; HES-7, 7-item Healthy Eating Score, HES-8, 8-item Healthy Eating Score, RFsnack-A, post-exercise recovery fueling snack with scoring option A; RFsnack-B, post-exercise recovery fueling snack with scoring option B; SSB-8, sugar-sweetened beverages with 8-oz/serving; SSB-12, sugar-sweetened beverages with 8-oz/serving

Table 3.4 Correlations between HEI-2015 and candidate HES-5+ scores among CHAMP CSF2 Study participants (N=333)[1]

	Total (N=333)	**Male** (N=247)	**Female** (N=86)
HEI-2015 vs.:	**r**	**r**	**r**
HES-5	0.41	0.45	0.32[2]
HES-6			
+ RFsnack-A	0.45	0.48	0.38[3]
+ RFsnack-B	**0.46**	**0.48**	**0.39[3]**
+ Breakfast	0.44	0.46	0.39[3]
+ SSB-8	**0.51**	**0.53**	**0.41**
+ SSB-12	0.50	0.53	0.41
HES-7			
+ Breakfast & RFsnack-B	0.48	0.49	0.44
+ SSB-8 & RFsnack-B	**0.53**	**0.55**	**0.47**
+ Breakfast & SSB-8	0.53	0.54	0.46
HES-8			
+ Breakfast, RFsnack-B, SSB-8	**0.55**	**0.56**	**0.50**

[1] Candidate HES-5+, updated healthy eating score with more than five items; CHAMP, Consortium of Health and Military Performance; CSF2 Study, Comprehensive Soldier and Family Fitness Study; HEI-2015, 2015 Healthy Eating Index; HES-5, 5-item Healthy Eating Score; HES-6, 6-item Healthy Eating Score; HES-7, 7-item Healthy Eating Score, HES-8, 8-item Healthy Eating Score, SSB-8, RFsnack-A, post-exercise recovery fueling snack with scoring option A; RFsnack-B, post-exercise recovery fueling snack with scoring option B; SSB-8, sugar-sweetened beverages with 8-oz/serving; SSB-12, sugar-sweetened beverages with 12 oz/serving. The candidate HES-5+ items with the strongest correlations are bolded. Unless noted all p-values were <0.0001.

[2] p=0.003

[3] p<0.001

Table 3.5 A formal comparison of correlated correlation coefficients among CHAMP's CSF military participants: HES-5 and HES 5+ vs. HEI-2015 (N=333)[1]

	Total (N=333)	Males (N=247)	Females (N=86)
Comparing candidate HES-5+ to HES-5 vs. HEI-2015:			
HES-6 (+SSB-8)			
r_x: HES-6 vs. HES-5	0.92	0.92	0.93
r_1: HES-5 vs. HEI-2015	0.41	0.45	0.32
r_2: HES-6 vs. HEI-2015	0.51	0.53	0.41
Z-score:	**-4.94[2]**	**-3.90[2]**	**-2.49[4]**
HES-6 (+RFsnack-B)			
r_x: HES-6 vs. HES-5	0.97	0.97	0.97
r_1: HES-5 vs. HEI-2015	0.41	0.45	0.32
r_2: HES-6 vs. HEI-2015	0.46	0.48	0.39
Z-score:	**-3.52[2]**	**-2.40[4]**	**-3.27[3]**
HES-7			
r_x: HES-7 vs. HES-5	0.90	0.89	0.91
r_1: HES-5 vs. HEI-2015	0.41	0.45	0.32
r_2: HES-7 vs. HEI-2015	0.53	0.55	0.47
Z-score:	**-5.62[2]**	**-4.21[2]**	**-3.54[2]**
HES-8			
r_x: HES-8 vs. HES-5	0.92	0.91	0.92
r_1: HES-5 vs. HEI-2015	0.41	0.45	0.32
r_2: HES-8 vs. HEI-2015	0.51	0.52	0.48
Z-score:	**-5.10[2]**	**-3.33[2]**	**-4.13[2]**
Comparing candidate HES-5+ versions vs. HEI-2015:			
HES-7 vs. HES-6 (+SSB-8)			
r_x: HES-7 vs. HES-6	0.98	0.97	0.98
r_1: HES-6 vs. HEI-2015	0.51	0.53	0.41
r_2: HES-7 vs. HEI-2015	0.53	0.55	0.47
Z-score	**-2.65[3]**	**-1.71**	**-2.78[3]**
HES-7 vs. HES-6 (+RFsnack-B)			
r_x: HES-7 vs. HES-6	0.94	0.94	0.95
r_1: HES-6 vs. HEI-2015	0.46	0.48	0.39
r_2: HES-7 vs. HEI-2015	0.53	0.55	0.47
Z-score	**-4.68[2]**	**-3.68[2]**	**-2.29[4]**
HES-6 (+SSB-8) vs. HES-8			
r_x: HES-8 vs. HES-6	0.91	0.90	0.93
r_1: HES-6 vs. HEI-2015	0.51	0.53	0.41
r_2: HES-8 vs. HEI-2015	0.51	0.52	0.48
Z-score	**-0.41**	**-0.34**	**-1.89**
HES-6 (+RFsnack-B) vs. HES-8			

	Total (N=333)	Males (N=247)	Females (N=86)
r_x: HES-8 vs. HES-6	0.96	0.96	0.96
r_1: HES-6 vs. HEI-2015	0.46	0.48	0.39
r_2: HES-8 vs. HEI-2015	0.51	0.52	0.48
Z-score	**-4.32[2]**	**-2.73[3]**	**-3.12[3]**
HES-7 vs. HES-8			
r_x	0.95	0.94	0.96
r_1	0.53	0.55	0.47
r_2	0.51	0.52	0.48
Z-score	**-1.29**	**-1.62**	**-0.54**

[1] Candidate HES-5+, healthy eating score with additional item(s); CHAMP, Consortium of Health and Military Performance; CSF2 Study, Comprehensive Soldier and Family Fitness Study; HEI-2015, 2015 Healthy Eating Index; HES-5, 5-item healthy eating score; HES-6, 6-item healthy eating score; HES-7, 7-item healthy eating score including SSB-8 and RFsnack-B items; HES-8, 8-item healthy eating score including breakfast, SSB-8 and RFsnack-B items; r_1, r_2, and r_x, Pearson r coefficients between scores; RFsnack-B, post-exercise recovery fueling snack with scoring option B; SSB-8, sugar-sweetened beverages with 8-oz/serving. All "HES-7" are referring to HES-7(+SSB-8 & RFsnack-B); all HES-8 refer to HES-8(+breakfast, SSB-8 & RFsnack-B). All correlations were used to calculate z-scores using equations proposed by Meng(19). Unless noted, $p > 0.05$

[2] $p < 0.001$

[3] $p < 0.01$

[4] $p < 0.05$

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Chapter 4. Lessons learned from the Creating Active Communities and Healthy Environments (CACHE) pilot: A mixed methods study

Lessons learned from the Creating Active Communities and Healthy Environments (CACHE) pilot: A mixed methods study

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Disclaimer: The views, opinions, and/or findings contained in this presentation are those of the authors and should not be construed as an official Department of the Army position, policy, or decision unless so designated by official documentation.

4.1 Structured summary

Introduction

Chronic conditions are costly health problems that can negatively impact military readiness and resilience. The built environment represents a modifiable target for promoting population-wide health behavior change. The U.S. Army Public Health Center (APHC) created the Creating Active Communities and Healthy Environments (CACHE) Toolkit to help military installations evaluate the relative quality of their built environments and identify and prioritize key areas of improvement. This study sought to improve the Toolkit implementation process, identify ways to better assist installations with Toolkit implementation, and assess the utility of the APHC's Action Plan Guides that recommend strategies to improve installations' built environments.

Materials and Methods

The APHC Public Health Review Board deemed this study as public health practice while Tufts University Institutional Review Board similarly found this study exempt from full research review. This study recruited five installations to implement the CACHE Toolkit. The Toolkit contained three tools to assess the built environment: the Military Nutrition Environment Assessment Tool (m-NEAT), the Promoting Active Communities (PAC) tool, and the Quantitative Indicators for Tobacco Systems (QITS) tool. The APHC reviewed completed Toolkits and provided installations with subsequent Action Plan Guides including tailored recommendations.

In this mixed methods study, the APHC collected quantitative baseline data via a knowledge, attitudes, and beliefs (KAB) survey and qualitative data via focus groups and interviews post-CACHE Toolkit implementation. The evaluation team conducted

univariate analyses to summarize participants' KAB related to the nutrition, physical activity, and tobacco environments and examined associations between participants' beliefs. Next, they analyzed qualitative data from 10 interviews and two focus groups. Survey topics and quantitative findings guided initial, deductive thematic coding, followed by inductive coding. Codes were iteratively categorized into metacodes until themes emerged.

Results

Thirty-four participants completed the KAB survey. Though over 80% of participants agreed or strongly agreed that the built environment impacts healthy living, only 44%, 53%, and 35% of participants agreed their installations' built environments promoted healthy eating, physical activity, and tobacco-free living, respectively. Approximately half the participants believed that their leadership prioritized improving the built environment for healthy living; there were positive associations between these beliefs and participants' perceptions that their built environments promoted healthy eating (ρ: 0.382, p=0.028) and exercise (ρ: 0.592, p=0.0003), but not tobacco-free living (ρ: 0.336, p=0.056). Three overarching themes emerged encompassing participants' experiences: 1) Opportunities to Improve Toolkit and Action Plan Guide Functionality; 2) the Sociopolitical Landscape Affects Toolkit Implementation; and 3) the Sociopolitical and Physical Landscapes Affect the CACHE Toolkit's Value and Utility.

Conclusions

With revisions to the tools and process, the CACHE Toolkit can be a valuable resource for military installations to assess and improve their built environments in support of healthy behaviors. Participants highlighted the need for: detailed manuals to

improve Toolkit and Action Plan Guide functionality; leadership's enforcement of policies and their prioritization of health promotion improvements to the built environment; and financial considerations for action plan recommendations. This study provides both concrete lessons to aid future CACHE Toolkit implementation and insights for other public health-based military initiatives to consider.

Keywords: military, built environment, physical activity, nutrition, tobacco

Funding: The Senior Military Medical Advisory Committee (SMMAC) as one of the Military Health System (MHS) Obesity Deep Dive innovations provided APHC funding for the development and evaluation of the CACHE Toolkit, including salary support for Ms. Cuccia. All other authors contributed their efforts without receiving funding or salary support.

Acknowledgments: The authors declare they have no potential conflicts of interest. The authors would like to thank the SMMAC for providing funding to APHC for the development and evaluation of the CACHE Toolkit. MSW, FO, PD, SB, KC, NM, and AM did not receive funding to conduct the study. We would like to thank Dr. Theresa Santo, Ph.D., MPH (APHC) and Ms. Laura Mitvalsky, MS (APHC) for their support during the development, execution, and reporting of this project. We would also like to thank Ms. Amy Cowell, MPH (former PAC Solutions Contractor in support of the APHC), Ms. Justine Springer, MPH (former Oak Ridge Institute for Science and Education (ORISE) Fellow in support of the APHC), Ms. Samantha Smith, MPH (former

ORISE Fellow in support of the APHC), Ms. Alyssa Coleman, MPH (ORISE Fellow in support of the APHC), and Ms. Chizoba Chukwura, MPH (former ORISE Fellow in support of the APHC) who assisted in the design, collection, cleaning, and reporting of the evaluation. We would like to extend our gratitude to our scientific reviewers, Ms. Jessica Korona Bailey, MPH (ORISE Fellow in support of the APHC) and Dr. Ericka Jenifer, Ph.D., MPH, MBA (APHC). Finally, we would like to thank Dr. Patricia Deuster, PhD, MPH, FACSM (Consortium for Health and Military Performance, A DoD Center of Excellence, Department of Military and Emergency Medicine, Uniformed Services University), Dr. Steven Cersovsky, MD, MPH (APHC), Dr. Amy Millikan Bell, MD, MPH (APHC), and Mr. John J. Resta, MS, MSE (APHC) for their review and expert guidance.

4.2 Introduction

Chronic diseases and conditions—such as heart disease, stroke, cancer, diabetes, obesity, and arthritis—are the most common and preventable of all health problems. An analysis of 2012 National Health Interview Survey data indicated 49.8% of US adults had one or more chronic medical conditions (1). Additionally, according to the Centers for Disease Control and Prevention (CDC), chronic diseases were seven of the top 10 causes of death in 2016 and their treatment accounted for 86% of all healthcare costs (2). Chronic disease conditions are burdensome to the military, both in terms of economic cost and military performance; they can hinder readiness and resilience of the force.

Though performing adequate physical activity, consuming a healthy diet, and eliminating tobacco use are three key behaviors that can help prevent chronic disease incidence (2-4), they are not widely practiced in the military. Specifically, results from the 2011 Department of Defense (DoD) Health Related Behaviors Survey of Active Duty Military Personnel indicate 63.1% of active duty service members met *Healthy People 2020* moderate physical activity recommendations (an average of 150 min/wk), but only 25.9% met vigorous physical activity recommendations (an average of 75 min/wk) (5). Poor diet is of similar concern, as only a small percentage of active duty service members reported eating three or more servings/day of fruit (11.2%), vegetables (12.9%) or whole grains (12.7%) (5). Rates of moderate to heavy smoking (18.3%) and smokeless tobacco use (19.8%) also remain high among service members (5).

Understanding factors that influence physical activity, diet, and tobacco use are of critical importance to military public health, particularly because the military is committed to making improvements in these areas (6-8). According to the Social-

Ecological Framework, multiple intrapersonal, interpersonal, community, environment, and policy-related factors can impact one's health risk behaviors (9, 10). Although many current military programs intervene at the intrapersonal and interpersonal levels, few have addressed the built environment. The built environment on military installations, defined as the "physical makeup of where we live, learn, work, and play" (11), is a modifiable aspect of military life that can help support population-wide health behavior change. To address the need for relevant, evidence-based resources for evaluating the relative quality of installations' built environments, the U.S. Army Public Health Center (APHC) created the Creating Active Communities and Healthy Environments (CACHE) Toolkit.

The goal of the CACHE Toolkit is to aid local leaders in 1) identifying improvement areas, 2) prioritizing community needs, and 3) developing action plans to maximize the promotion of healthy behaviors (12). From September 2014 through July 2015, a study was conducted with the following objectives: 1) to describe potential users' perceptions of and attitudes toward the built environment on military installations; 2) to understand users' experiences with using the CACHE Toolkit to assess their installations built environments and identify ways to substantially improve the tools and Action Plan Guides to meet users' needs; and 3) to identify additional factors that are important to consider when attempting to intervene with a military installation's built environment. The study focused on evaluating the Toolkit's implementation rather than any outcomes. This paper highlights CACHE Toolkit study findings that can inform other military studies, initiatives, and policies looking to assess and intervene within the installation built environment.

4.3 Materials and methods

The CACHE Toolkit and Action Plan Guides

The CACHE Toolkit has four components. First, the Military Nutrition Environment Assessment Tool (m-NEAT), adapted from the Nutrition Environment Measures Survey created at the University of Pennsylvania (13-15), assesses an installation's environment- including the workplace, public facilities, restaurants, and food stores- and policies towards healthy eating. Second, the Promoting Active Communities (PAC) tool, adapted from the Michigan Department of Community Health PAC (16), assesses an installation's environment, policies, and programs related to physical activity. Third, the Quantitative Indicators for Tobacco Systems (QITS) tool, adapted from the CDC Community Healthy Assessment and Group Evaluation tool (17), assesses an installation's policies and environment regarding the promotion of tobacco free living. Lastly, the APHC created supporting documents, including presentation templates, factsheets, an Excel spreadsheet, and a facilitator's guide for the CACHE Toolkit's implementation. The facilitators received the Toolkit components in PDF and Excel formats. Each tool was first completed via pencil and paper; answers were then entered into Excel sheets that automatically scored their results. Higher scores indicated a more supportive built environment. After each installation completed and submitted the CACHE Toolkit, the APHC analyzed their data to develop installation-specific Action Plan Guides. The Action Plan Guide included scores for each tool in the Toolkit, tool components that received the lowest scores, and specific recommendations for improving the scores.

Study Participants

The study included five installations. The APHC team (led by SB) selected four of the five study sites based on participation in concurrent and related health initiatives called Operation Kid Fit (OKF) and the Healthy Base Initiative (HBI). An OKF facilitator at each of the four installations served as points of contact (POCs) in the CACHE Toolkit implementation process. Health promotion staff at a fifth installation volunteered to participate in the study. The APHC team instructed the CACHE Toolkit POCs to develop a CACHE Toolkit coalition to collect data and return the completed Toolkit for review. The APHC team then provided installations with Action Plan Guides with recommended next steps to improve the built environment, which the CACHE Toolkit coalition could discuss, prioritize, and implement locally. An additional goal was for the CACHE Toolkit coalition to provide leadership with updates through semi-regular briefings at the Community Health Promotion Councils (CHPC) on Army installations and the Community Action Information Board (CAIB) on Air Force installations. Attendees of these groups have knowledge of installation health policies and resources that would facilitate the CACHE Toolkit's implementation.

Data Collection

The study utilized a mixed methods approach (18-21) to assess the implementation of the CACHE Toolkit through both process and program evaluation. The APHC team collected data quantitatively via a survey, as well as qualitatively via

focus groups and interviews. Both approaches were developed concurrently and emphasized equally in the study design. The APHC Public Health Review Board approved this project (#14-299) as Public Health Practice (i.e., program evaluation) and not research.

First, participants completed a baseline knowledge, attitudes, and beliefs (KAB) survey in Fall 2014. The survey assessed these constructs in relation to the built environment and policies supporting healthy eating, physical activity, and tobacco-free living. Aside from demographic questions, the majority of questions used five-point Likert scale response categories. The APHC team collected all surveys using Vovici® (version 6; Vovici Corporation, Herndon, VA, USA). Installations implemented the CACHE Toolkit through Spring 2015. After the CACHE Toolkit implementation, the qualitatively trained APHC team visited each installation between May and June 2015 to conduct semi-structured focus groups and in-depth interviews with CACHE Toolkit facilitators to discuss their experiences with the Toolkit. Installations who received Action Plan Guides prior to the site visits (n=4) also discussed Action Plan Guide usability and usefulness. One interviewer led each session and one note taker recorded it using digital audio recorders. The APHC team developed a semi-structured guide of 20 open-ended questions to facilitate discussion during interviews and modified it as needed for focus groups.

Post-CACHE Toolkit implementation, participants retook the KAB survey to examine any changes in responses. However, as only eight participants completed the post-survey, this paper only focuses on baseline survey results. Although the study's intended design was to equally weight qualitative and quantitative data, the robust

qualitative data was weighted more than the cross-sectional quantitative data in the analysis and results (18, 20, 21). Survey, focus group, and interview questions are provided in Supplemental Appendices.

Statistical Analysis

The APHC team transferred raw survey data to Excel files using the survey program Vovici®. They transcribed interviews and focus groups verbatim from audio-recordings. To ensure confidentiality, the APHC team de-identified survey data, coded participants and installations alpha-numerically, and redacted all identifying information in transcripts. Per a Data Use Agreement between the APHC and Tufts University to support the analysis, interpretation, and reporting of these evaluation data, the APHC then transmitted the data via secure, password-protected folders to the Tufts University evaluation team (MSW, FO, and AM) conducting the analyses. As the evaluation team received de-identified data, the Tufts University Institutional Review Board (IRB) deemed the analysis portion of the study exempt from full IRB review.

The evaluation team conducted univariate analyses of the categorical, quantitative data to summarize participants' demographic information, as well as to develop descriptive summary data on their KAB related to nutrition, physical activity, and tobacco use. Next, bivariate analyses of the ordinal data were conducted using Spearman's rank order correlation coefficients. Specifically, the evaluation team examined the associations between participants' beliefs regarding their leadership's priority to improve the built environment and their beliefs on 1) their own ability to influence the built environment and 2) if they perceive their installations' built

environments promote healthy eating, exercise, and tobacco-free living. Absolute values of Spearman's Rho (ρ) of 0.1-0.29, 0.3-0.49 and ≥0.50 were considered small, medium, and large associations, respectively (22). All statistical tests were two-sided with a significance level set at 0.05. All quantitative analyses were conducted using SAS (version 9.4; SAS Institute Inc., Cary, NC, USA).

Qualitative analysis

The evaluation team analyzed qualitative data from focus group and interview transcripts using a hybrid methodological approach (23). To orient the evaluation team to the data, one coder (MSW) developed the initial coding schema with deductive thematic coding guided by survey topics and quantitative findings. The quantitative results helped to iteratively guide initial qualitative analyses (18, 19, 24). Interview topics and discussions within four randomly selected transcripts also guided initial coding. Next, the coder conducted cycles of inductive coding and utilized axial coding for the second cycle of coding (25). After coding every second transcript, the coder reviewed all previous transcripts to achieve intra-coder agreement for internal consistency (>85%). A codebook was created during the hybrid coding approach and updated as needed throughout the coding process. A second coder reviewed each round of coding and two coders reviewed the codebook to check for consistency across transcripts. Through an iterative, weekly process, the evaluation team categorized codes into metacodes based on their frequency of occurrence, the underlying meaning across codes, and the relationship between codes. This process continued until themes and subthemes emerged. After themes were detailed, emblematic quotes for each subtheme were extracted into table matrices. Qualitative

analyses were conducted using NVivo (version 11; QSR International, Ltd, Burlington, MA, USA). Lastly, the evaluation team developed summary recommendations across all the subthemes based on participants' feedback.

4.4 Results

Thirty-four participants completed the baseline KAB survey pre-CACHE Toolkit implementation. Characteristics of these participants are detailed in Table 1. Most participants (79.4%) had no formal training in any components of the CACHE Toolkit prior to the study (Table 1). Two interviews were conducted on each of the five installations for a total of ten interviews. The APHC team held focus groups on the two installations that successfully formed working groups.

Quantitative Results

Over 80% of survey participants agreed or strongly agreed that the food, physical activity, and tobacco environments in their communities impact their behaviors in those realms (Figure 1a). However, fewer participants agreed their installations' built environments promoted healthy eating (44%), physical activity (53%), and tobacco-free living (35%) (Figure 1b). Most participants believed they had a strong understanding of how the built environment impacts nutrition (79.5%), physical activity (82.3%), and tobacco use (76.5%) (Figure 1c), and that evaluating the built environment can have a positive impact on these aspects of their installations (Figure 1d).

Only approximately half of the participants believed their leadership prioritized improving the built environment (Figure 1e). There were medium to large, positive correlations observed between participants' beliefs regarding their own ability to improve the built environment for healthy living and leadership's prioritization of improving the built environment for healthy eating (ρ: 0.449, p=0.009), physical activity (ρ: 0.588, p=0.0003), and tobacco-free living (ρ: 0.562, p=0.0007). Moreover, there were positive associations between participants' perceptions that leadership prioritizes improving the built environment for healthy eating and physical activity and their perceptions that their built environments promoted healthy eating (ρ: 0.382, p=0.028) and exercise (ρ: 0.592, p=0.0003), respectively. No significant association was observed regarding tobacco-free living (ρ: 0.336, p=0.056).

Qualitative Results

As previously mentioned, quantitative evidence provided a priori codes that resonated with emergent codes. Three overarching themes emerged from the iterative coding: Toolkit and Action Plan Guide functionality; the sociopolitical landscape affects Toolkit implementation; and the sociopolitical and physical landscapes affect the CACHE Toolkit's value and utility.

Overarching Theme #1: Opportunities to Improve Toolkit and Action Plan Guide Functionality

This theme encompasses the usability of the tools and Action Plan Guides themselves, internal factors affecting the Toolkit, and external factors that influence tool functionality. Most participants believed m-NEAT, PAC, and QITS were all important

and well-organized tools to assess their installation. They highlighted the importance of the user-friendly formats (e.g., numbering, labeling, and charts to organize Toolkit information) and evidence-based questions. Reported areas of concern are summarized below into four subthemes, with key participant quotes presented in Table 2.

Subtheme 1.1: The need to address question relevancy

This subtheme encompasses participants' perspectives regarding the relevancy of questions in the Toolkit for their installations. Overall, participants expressed the need for tailored questions in all three tools based on the context of their installation or for a "non-applicable" response option. Some participants also shared that the nature and complexity of their worksites made it difficult for them to adequately respond to questions. Additionally, participants felt questions were not relevant if they addressed areas too difficult to impact at the interviewee's level.

Subtheme 1.2: The need for guidance

The majority of participants expressed a need for guidance to complete the CACHE Toolkit. However, those who had previous experience with a tool (e.g. the Air Force completes m-NEAT yearly) or previously collected some information requested in the tools found implementing the Toolkit to be straightforward and quick. Conversely, those who lacked experience with the tools or were in situations where no data were collected for any similar projects found Toolkit implementation more challenging. The participants who reported struggles with the Toolkit expressed confusion due to the large size of the installations or diversity of buildings, the use of civilian rather than military terms in the Toolkit, and/or the uncertainty of whom to ask to obtain requested

information. They expressed that installations would benefit from additional guidance overall if the Toolkit is implemented throughout the military.

Subtheme 1.3: The need to include subject matter experts (SMEs)

Many participants expressed the importance of involving SMEs during Toolkit implementation. They believed that some portions of the Toolkit required knowledge beyond the Toolkit facilitators' level of understanding and that SME inclusion ensured the accuracy of collected information. Examples of SMEs provided by participants included registered dieticians to assist with the m-NEAT, community planners or an employee from the safety office to assist with the PAC, and a tobacco cessation nurse to assist with the QITS. Those who utilized trained SMEs reported that implementing the Toolkits was quick and easy. However, some participants highlighted three main barriers to involving SMEs that they experienced and believed may be potential barriers to future installations. First, due to high job turnover, SMEs new to their positions may not have the contextual knowledge to answer some questions in the Toolkit. Second, some SMEs may be unreceptive when contacted by CACHE Toolkit facilitators and disinclined to assist in implementing the Toolkit. Lastly, SME's busy schedules and existing duties impeded most installations from forming CACHE Toolkit coalitions; the successful formation and meeting of coalitions may promote SME participation.

Subtheme 1.4: The need to address the Action Plan Guide's formatting and scoring

Four of the five installations received Action Plan Guides from the APHC team and the participants remarked that the overall format of the reports was clear and informative. Moreover, they appreciated the evidence-based information provided in the Action Plan Guides. However, the scoring used in the tools garnered mixed reviews, as

some reported scores included in the Action Plan Guide results to be clear and self-explanatory, while others found scores difficult to decipher and recommended providing increased scoring transparency. Additionally, a few participants believed the scoring was too unforgiving with unfair penalizations for specific components; they recommended revisiting the strictness of the scoring criteria.

Overarching Theme #2: The Sociopolitical Landscape Affects Toolkit Implementation

This overarching theme encompasses the social and political interactions and networks on an installation that affected the timely implementation of the CACHE Toolkit. It is described below in three subthemes, with key participant quotes presented in Table 3.

Subtheme 2.1: Installation complexity

Participants on large installations expressed that collecting data on the whole installation for the Toolkit was daunting and time-consuming at times. Additionally, installations with a variety of workers and, as one participated coined it, "hodge podge" worksites (e.g., active duty service members of different branches, union workers), can have various policies and viewpoints that may conflict with one another and make answering policy-related questions challenging.

Subtheme 2.2: Leadership and key players' support

The degree of leadership support, degree of key player support, extent of leadership prioritization, and the extent of key players' prioritization all affected Toolkit implementation. Almost all participants emphasized the importance of garnering leadership support to help propagate important information, create environments conducive to change, and promote key players' support. Once leadership and key players

are on board, it is then important to have them prioritize improving the built environment to increase the potential impact of the CACHE Toolkit.

Subtheme 2.3: Leveraging social networks

Leveraging social networks to build coalitions and collect information aided some participants in collecting data in a timely fashion. As one participant summarized, "Most of it is word of mouth and getting people." However, Toolkit implementation took longer for those who did not leverage social networks, as well as those challenged by shrinking social networks and increased workloads due to position cuts.

Overarching Theme #3: Sociopolitical and Physical Landscapes Affect the CACHE Toolkit's Value and Utility

The final theme addresses the sociopolitical interactions, networks, and physical landscape of an installation that affect the feasibility and successful implementation of Action Plan Guide recommendations. Seven subthemes emerged that affected the utility of the CACHE Toolkit as summarized below. Key participant quotes are presented in Table 4.

Subtheme 3.1: Policies support enforcement

An important topic that came up in all the interviews and focus groups was how detailed policies can drive impactful changes. Most participants discussed the lack of policies and initiatives to improve the built environment on their installations, as well as the need for mandates from leadership to enforce existing policies.

Subtheme 3.2: "Tobacco is the culture"

Though the aforementioned subtheme addresses tobacco policies, the pervasiveness of tobacco use on military installations and the frequency of its discussion in interviews should be acknowledged. As one participant summarized, "Tobacco is the culture." Participants described the easy access enlisted Soldiers have to tobacco products, the use of tobacco breaks to form relationships with leaders, and the presence of officers modeling tobacco-promoting behaviors as large barriers to changing tobacco policies on military installations.

Subtheme 3.3: Entities with competing interests

Participants discussed how the goals of the CACHE Toolkit currently conflict with the interests of several entities on installations. These entities may include Army and Air Force Exchange Services (AAFES), food vendors with contracts with the installations, unions, and schools.

Subtheme 3.4: High vs. low traffic food locations

Though changes can be implemented to improve the food environment, the physical location of food-serving outlets can impact the value of making these changes. Some changes in high-traffic locations, like at dining facilities (DFACs), can positively impact the nutritional choices of service members. Conversely, some installations offer healthier food options in low-traffic locations, which is a waste of resources, or lack food establishments entirely, forcing service members to leave the installation to purchase food, respectively.

Subtheme 3.5: The landscape for physical activity

Similar to food-serving locations, the location of physical activity resources impacts the value of changes to the physical activity environment. Participants discussed how some walking and hiking paths are hidden due to a lack of signage and how the presence or absence of biking lanes, bike racks, and sidewalks affected the popularity and safety of biking and walking on installations.

Subtheme 3.6: Budget limitations

As is commonly experienced with many public health interventions, the implementation of many action plan recommendations was impeded by budget limitations. Though some small recommendations were feasible, almost every participant via interviews and focus groups reported many recommendations were too costly. Action Plan Guide recommendations to change the built environment therefore need to take into account the potentially limited finances available to installations.

Subtheme 3.7: Local vs. centralized changes

Given that the goal is to have the tools in the CACHE Toolkit utilized across the military, and given the differences in policies among Services, participants noted that Action Plan Guide recommendations need to be tailored to the specific military branch of the installation assessed. Participants primarily cited the differences between the Army and Air Force and how they can make changes at the local versus centralized level.

4.5 Discussion and Conclusions

The goals of this study were to understand CACHE Toolkit users' perceptions of and attitudes toward the built environment on their military installations, evaluate the process of implementing the CACHE Toolkit, assess the efficacy of subsequent APHC Action Plan Guides, and identify ways to improve upon both for future implementation. This study concludes that with revisions to the tools and process, the CACHE Toolkit can be a valuable resource for military installations.

Survey results highlighted the importance of the CACHE Toolkit, as the majority of participants believed that evaluating installations' built environments can guide improvements. Additionally, although most participants believed installations' food, physical activity, and tobacco environments impact employees' healthy eating, physical activity, and tobacco-free living, fewer than half agreed that their installations' built environments promoted these positive behaviors. As interventions assessing military installations' built environments are currently limited, those conducting similar initiatives may learn from the experiences from this study.

One important conclusion is Toolkit-specific: respondents highlighted the importance of providing detailed assessment tools and Action Plan Guides to improve their functionality. Specifically, carefully chosen questions with clear, military service-appropriate verbiage; adequate support to facilitators via the APHC, SMEs, and working groups; and transparent scoring of questions in the guides are essential.

Second, participants highlighted the importance of leadership support and their prioritization to improve the built environment to propagate healthy changes. Approximately half of survey respondents believed their leadership prioritized improving the built environment for healthy living. Qualitative findings corroborated these quantitative findings. The overarching theme that the sociopolitical landscape affects Toolkit implementation captured the idea that timely and accurate Toolkit implementation can be impacted by leadership's support and prioritization. That is, if leadership creates a milieu that encourages positive changes to the built environment, key players, SMEs, and others are more likely to commit their time and effort to working groups and providing timely responses.

The third main conclusion is that higher command must create policies that detail how to make and enforce positive changes to the built environment. Only about one-third of survey participants believed their installations' built environments promoted tobacco-free living. Qualitative analyses further supported this: many respondents emphasized the lack of enforcement of tobacco-related policies and the barriers to changing the culture surrounding tobacco use on the installations. Smith et al. also examined the barriers in the military to change tobacco controls, and similar to our findings, highlighted the tobacco culture, lack of policy enforcement, and the tobacco rights of civilian personnel on installations (26). Participants in our study expressed that both policy interventions from DoD level command and policy enforcement from installation-level command represent the only ways to impact the "tobacco culture" on military installations. Smith et al. also highlight the need for updated regulations (26), despite inevitable pushback. Moreover,

policies can also be established to impact relationships with entities with competing interests (i.e., AAFES, unions, food contractors, schools).

Fourth, the locale of food and physical activity promoting locations can affect their perceived value. Only 44% and 59% of survey participants agreed or strongly agreed that their environments promoted healthy eating and physical activity, respectively. Qualitative findings highlighted that making healthy food changes to Shoppettes (i.e., installation convenience stores), vending machines, and other food serving facilities will have less impact in low-traffic locations. Similarly, employees must be aware of the presence of walking trails and safe areas with sidewalks and bike lanes to increase foot and bike traffic.

Lastly, financial, service-specific, and installation-specific limitations require consideration in Action Plan Guide recommendations. Due to budget constraints, smaller, less costly recommendations are more likely to be feasible in the short-term than larger, costly recommendations. The APHC should consider the receptivity and feasibility of recommendations made to individual installations, as well as the readiness and capacity of installations to implement changes.

This study has a few limitations worth noting. First, we were unable to examine changes in KAB following the CACHE Toolkit intervention due to the limited number of participants who completed the post-survey (n=8). This affected our ability to give greater weight to our quantitative findings. Second, changes in the built environment emerging from the CACHE Toolkit Action Plan Guide recommendations could not be evaluated, as none of the installations had implemented these recommendations prior to the interviews and focus groups. However, the study did provide an opportunity for the

APHC to identify key barriers and facilitators to the CACHE Toolkit Action Plan implementation processes and, thus, still offers valuable lessons. Third, two of the five recruited installations already implemented m-NEAT and PAC as part of overlapping initiatives (e.g., HBI), while other CACHE Toolkit facilitators recruited community planners to implement PAC. In both instances, some participants did not have experiences to share regarding the full CACHE Toolkit's utility. For this reason, rather than comparing the tools' utility across all recruited installations, the focus was on the process of each tool individually when applicable. Lastly, findings from these recruited installations may not be generalizable to other military installations given the range of facilitators' experiences and variable installation policies and leadership support. However, the goal of this study was not an outcome evaluation or to test a theory, but rather a process evaluation.

This study had many strengths as well. Quantitative and qualitative data were leveraged: the qualitative approach utilized quantitative findings in initial deductive coding and helped corroborate and elaborate upon the survey findings. Additionally, though most facilitators did not report previous experiences with any of the CACHE Toolkit tools, some of the installations had legacy tool facilitators (e.g., an AFI requires Air Force installations to implement m-NEAT annually) that provided support and guidance to facilitators when needed. Lastly, few studies and initiatives to date examine the built environment on military installations; this study provides concrete feedback to aid the future implementation of the CACHE Toolkit as well as insights for other military public health initiatives.

Recommendations

The recommendations address the aforementioned subthemes and are categorized into short, medium, and long-range recommendations based on the time and effort needed for implementation (Tables 5-7). Focus group and interview participants noted specific recommendations to improve the Toolkit and make it more user-friendly which the APHC can immediately address (Table 5). They also emphasized recommendations to guide the CACHE Toolkit and Action Plan implementation processes. These included both obtaining initial leadership buy-in from the start to aid Toolkit implementation and prioritizing Action Plan Guide recommendations that align with the priorities of installation leaders (Table 5). The medium-range recommendations, focused on building up the APHC's website and funding mechanisms (Table 6), may take more effort and time to accomplish, but can contribute to the future success of the CACHE Toolkit when implemented throughout the military. Lastly, long-range recommendations (Table 7) encompassed the importance of creating the "right committee" and the need for DoD to develop policies to support the implementation of both the CACHE Toolkit and Action Plan Guide goals. Regarding the latter, policies should include specific steps on how higher command can execute and enforce the recommended policy changes in an effort to increase engagement in behaviors (27).

4.6 Figures and tables

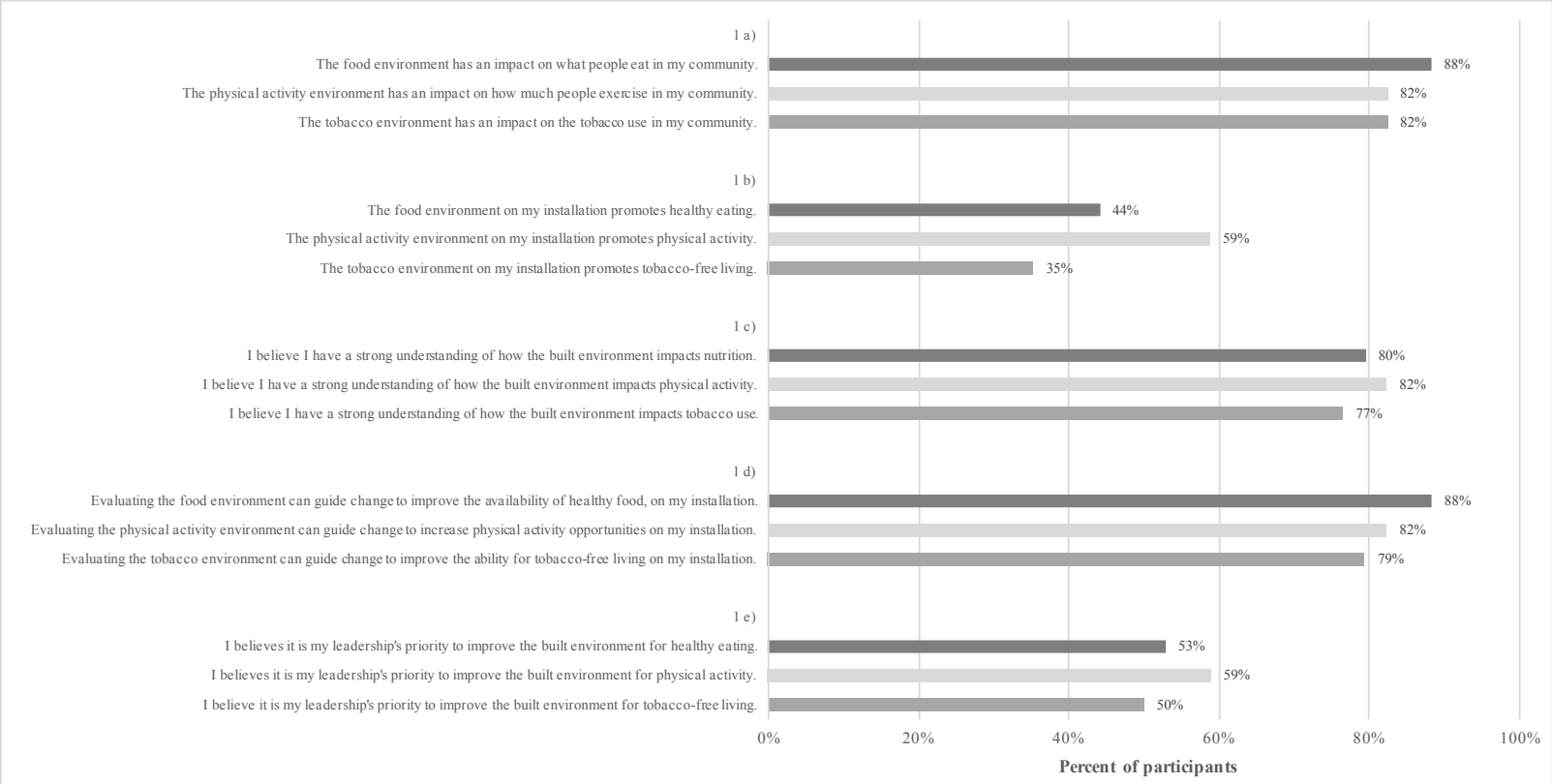

Figure 4.1 Participants' beliefs from the Knowledge, Attitudes, and Beliefs survey at baseline- Percent of participants who selected- Likert scale responses "Agree" or "Strongly Agree."[1] Participants' beliefs: a) about the built environment's impact on food, exercise, and tobacco use in their communities; **b)** on if their installations' built environments promote healthy eating, physical activity, and tobacco-free living; **c)** regarding their understanding of how the built environment impacts nutrition, physical activity, and tobacco use; **d)** about the effect that evaluation of their installations' built environments can have on improving healthy food availability, physical activity opportunities, and tobacco-free living; and **e)** regarding their leadership's priority to improve the built environment for healthy eating, physical activity, and tobacco-free living. (N=34)

[1] As opposed to participants who selected "Neutral," "Agree," or "Strongly Agree."

Table 4.1 Characteristics at baseline for all participants (N=34)[1]

	All (N=34)
	N (%)
Frequency attend Army installation's CHPC or Air Force installation's CAIB meetings	
Never	9 (26.5)
Rarely	5 (14.7)
Sometimes	4 (11.8)
Often	3 (8.8)
Always	13 (38.2)
Participate in CACHE working group	
Yes	29 (85.3)
No	1 (2.9)
Working group undetermined	4 (11.8)
Received formal training to date on the tools in CACHE	
Yes	6 (17.7)
No	27 (79.4)
Not reported	1 (2.9)

[1]AFB, Air Force Base; CAIB, Community Action Information Board; CHPC, Community Health Promotion Council

Table 4.2 Overarching theme: Opportunities to improve Toolkit and Action Plan Guide functionality

	Key Quotes from Participants	
Approval of Toolkit format and evidence-based questions	Your little charts were helpful on here…[and] your labeling…When I was out collecting the data…and then plugging it into the [Toolkit assessment] sheet- I know that's a simple thing but when you have all this information, that was extremely helpful.	They got the PAC questions…from research, so I do like the questions.
Subtheme 1: The need to address question relevancy		
• *Not applicable questions*	And even on the PAC, I remember too--. Do you remember all the questions on there about snow? [Laughter] …and no N/A cuz we came to that section and I'm like, 'Well there'… No it doesn't apply, …so what do we do. There were a lot of questions like that on there	I mean overall…I think like some of the parts…weren't really applicable here… I don't know if it was even needed. But I'm sure there's other bases where that is.
• *Hodge-podge worksite questions*	The worksites were hard [because] it's like, who even knows this? For one, identifying the worksites we wanted to do and then for another there's not even one POC [point of contact] that knows the policies. So it was-it was kinda just a rat race trying to find someone who might know…	There's so much inconsistency [here]...each facility was kind of different, and maybe had reasons or things of why their policy was this or they did these things for this reason.
• *Higher level questions*	All the questions about the policy was pretty much, 'we don't have a policy yet,' so that was really boring to fill out.	I think the policy questions were really confusing for people cuz they did not know if you were talking about their policies or the installation policy, which there isn't one, but there is DoD-wide shared policies, so I think that's confusing...
Subtheme 2: The need for guidance		
• *Having/Lacking past tool-related experience(s) can affect process/functionality*	I mean the m-NEAT we've done before that was pretty easy…once we all had everything she put the data into the tools	…the QITS [was the most challenging] because it was—that was the only tool that didn't have anything already completed, so you know we just had to start from scratch. It--. We just really didn't know kinda how to tackle it at first.
• *Installation complexity*	[T]he PAC was tough, because the PAC is huge, especially at Joint Base, we're 150,000 plus people… I'm the one that was making sure [the facilitator] for the people [she] needed and we're huge.	Well even like asking about the tobacco areas on [the] property is like, okay not only is there [the Medical Treatment Facility], then there's all these outlying clinics and did you want to include the outlying clinics that are off post?...[A]nd then the veterinary clinics and all this stuff...[it's a challenge to] even think about trying to assess such a large place.
• *Confusion*	There's just a lot of information in [the PAC] that…I wasn't familiar with. Even the community planners [filling] this out…had a hard time with the verbiage.	It was difficult trying to get the information and get it from the right people...it just kept getting filtered and filtered to different people. It was just confusing trying to figure out who were the right people to go get the information, and them finding the information.

	Key Quotes from Participants	
• *Public Health Command guidance*	When we got stumbled, we did the conference calls and we kinda just went through the issues. I mean that was really what was really most helpful was just kinda having that guidance to help explain things, especially with the worksheet.	I think what you're doing, the assessments, it's going to be a lot of just questions and clarifications on different things that you're looking for, different aspects.
Subtheme 3: The need to include subject matter experts (SMEs)		
• *SME participation*	Some of those questions are, like on the commissary and dining facility…they are more engaged toward a registered dietician in filling out those things. Even the Air Force has recommended, if you have an RD to help engage on that in those areas there…or have an RD overlook it…-like you need a quality check expert…[because] some places don't have an RD.	I was also in contact with…the Tobacco cessation nurse…she gave me all the policy information…[and] was very helpful.
• *Turnover*	I've noticed things take time. You know because there's just so much going on. It's the end of March and I'll be done mid-July and so then whatever [the health promotion coordinator] and the group decide to do, it'll be all up to them. I'll be gone.	When we called…the safety office [and asked] 'how many buildings are there on MEDCEN,' he had no clue! He…was new and he had no idea how many buildings were associated with [the military treatment facility].
• *Unreceptive contacts*	She didn't shake my hand and she didn't look up to look at me...Her assistant…[is] who I talk to normally, but I sent her an email, too and no one ever responded. So it's like gettin' that data, we still didn't get the school data.	She did all of the assessments and all she did was- there was more complaints than actual work getting done. It's, "I'm so busy. I'm so busy. I'm so busy. I'm so busy." The amount of times you told me that, you could be doing something.
• *The need for working groups*	[K]inda give a heads up, this isn't something you're gonna do in a few weeks…you need to carve out some time here cuz this is not going to be…a bunch of checklists. It's a lot of research involved too where you gotta figure out where things are and get the right people to assist you.	It's always a tough sale when you're trying to get people to volunteer for more committees and more responsibility when they already tend to be overwhelmed [a] little bit.
Subtheme 4: The need to address Action Plan Guides' formatting and scoring		
• *Format success*	I liked your background information, that was really good. And having statistics is always really helpful. Any background information… like that we need to talk to the key stakeholders about…to sell the program, so to speak, is always really helpful. And then the general action plan…I liked how you put the steps down on it, the details…the different recommendations were also really helpful.	[Y]ou get the results back and you know it's kind of a double-edged sword there because it's like yes you want to make these changes but…it's so easy to point out…what the barriers are going to be. You're just like 'this is great, but there's nothing I can do about this.' So there has to be a different format when you get these results back.
• *Scoring: helpful and understood vs. scoring transparency*	And some of them I don't like that- like you've got a section and you answer and one question could make or break you when everything else is good.	I had no idea how many points any question- I couldn't decipher it. So that was to me the most difficult, understanding the weight of the questions because there wasn't like a key like the m-NEAT had...You know [the QITS and m-NEAT] are two different tools- but being able to understand the numbers a little bit better [is important] or at least what these numbers mean at the end of the day.

Table 4.3 Overarching theme: Sociopolitical landscape affects toolkit implementation

	Key Quotes from Participants	
Subtheme 1: Installation complexity		
	[We p]robably just [need] more awareness about kinda like the policies and regulations. I know when I was doing the worksite worksheet for the Soldier Support Center in that particular worksite it was confusion about what policy they go by... It turned out to be a lot of gray areas within the building, so maybe just ensuring that every building, every worksite knows the policy and they're being enforced.	
Subtheme 2: Leadership and Key Players' Support		
• *Degree of Leadership Support*	You want…people that are engaged in policies and stuff that can get the policies rolling in the units and squadrons, so you need some type of commander aspects of it in the groups as well, so they can help with…getting things out.	Biggest lesson learned get the commander's support. You have to get the Commander's support or else nothing's gonna be changed, whatsoever. No one else cares about it. If the Commanders care then you start to care. Yeah. Absolutely.
• *Extent of Leadership Prioritization;*	He's very, very passionate about nutrition and exercise and so he was like mortified. He's already like, "this is terrible," but then when he found [the score] really was so bad he was like, "I'm making changes." This became a huge motivating factor for him.	Now I'm hoping that they do poke their individuals, like the [restaurant scored] 40% and it's supposed to be a healthy place. I'm hoping [the Support Commander I contacted] does poke them. Or with the [other restaurant, asking] "Have you sent those recipes to the dieticians yet so you can get Go for Green off the ground?" I'm just- it's just a hope. I can't see that from my perspective.
• *Degree of Key Player Support*	I was there when this working group started and it was like pulling teeth getting- and people were at the first meeting kinda like grunting about why they should be there.	Unless [our DFAC Affiliate's] commander says, "This is important you need to be on this committee or you're going to be doing this," is he really going to take his time out to do it? Probably not.
• *Extent of Key Players' Prioritization*	You know you try to get everybody involved and then they just don't show up anymore. Kinda what happened [with m-NEAT in the past]. They just don't show up anymore and so consequentially, ...[our dieticians] ended up doing the whole thing.	I mean people are just so busy...Just people don't want to take on extra tasks and if there's not going to be any value in it and it's just going to be busy work, people don't have time for that.
Subtheme 3: Leveraging Social Networks		
• *Receptiveness of contacts*	The superintendent of [the installation's] schools...[told us] the different principals and which school is the biggest [to evaluate]. And the same thing with…Army Public Health Nursing so she could tell us which daycares were the biggest ones to evaluate, that kind of thing. So a lot of it is just getting information from people.	[The manager] comes out and like straight off the bat she was like, "what do you want?" Okay I just wanted to ask you a few questions. "Who are you? What are you doing here?" You know really confrontational. We're like, "we're just like collecting data it isn't gonna go anywhere or anything." Just trying to make light of it. Yeah she was like "I don't understand what this is for. Why are you collecting this?" (they continue with questions and she gave them a hard time

	Key Quotes from Participants	
		with each question.) It was just off-putting...[we] walked out the front door and were like "oh my gosh! That was the worst person ever."...It was definitely like, "She was here trying to catch me in something" and I'm not.
• *Failure to leverage social networks increases time to implementation*	I know I tend to feel overwhelmed sometimes. They just keep throwing stuff at me and you took away 6 of my people, now am I going to do all this?...I don't know if it needs to come from the top where it's appointed or maybe go back to the Health Promotion Working Group or Committee or whatever you want to call it that that group would take care of that. I don't know; I don't know what the answer is but I just know most of the people in my position are by themselves. And it doesn't matter the size of the base...A few of the bases have a dietician but a lot of them-we're by ourselves.	

Table 4.4 Overarching theme: Sociopolitical and physical landscapes affect and the CACHE Toolkit's value and utility

	Key Quotes from Participants	
Subtheme 1: Policies Support Enforcement	The AFI just was rewritten and…it did assign duties more specifically to-like CE will be doing the [designated tobacco area] maps and coordinating all that. It says what my role is… it has more specific[s on what] different organizations are responsible for, which is good…because before it didn't and it still has the tobacco free [military treatment facilities] in there and once again- I can't do anything with that.	I mean our [our Health Promotion Coordinator] and I can have all the different health promotion events that we want. We can do the tobacco training...and a tasting event. Those are simple things that we definitely have control over, but as far as implementing any type of policy change, I think that that's going to be tough; that's going to be the tough thing. Just seems to be a lot of barriers. It seems like local policy change is limited, it has to go higher up, up the chain.
Subtheme 2: "Tobacco is the culture"	[O]ne of the things you talk about is triggers-- avoiding triggers. You know don't go out to the Smoke Pit and the First Sergeant will say, 'but that's where the work gets done.' Everybody goes out to the Smoke Pit…He was a First Sergeant but most of them even when they quit they still go out to the Pit. Another good example, okay you tell people don't go out to the Smoke Pit, we had a soldier go to the kitchen to make himself a snack instead of going outside with all his buddies and his squad leader's like, 'what the heck are you doing in here? Get back to work!' Because going out to smoke is acceptable but doing anything else is not.	[A] company commander just next door said, 'Hey you're not allowed to dip in Department of Army buildings.' And then his friend, his leading commander, was in the office and he had his bottle of dip…[H]is soldier looked over at his commander and was like, 'I'm just following.' At the end of the day it's all about who's making the decisions, what their view is. Maybe they use tobacco, you know. So it can be-- what's that word? Influenced… Biased.
Subtheme 3: Entities with competing interests		
• *AAFES*	I think changing anything at the AAFES is a big tree to bark up. I've heard a lot about that.	I mean it's a lot of time spent with the assessment with the return on investment not that much because you think about, "well okay, I can't change AAFES,…I can't change these fast food menus, I can't"- [e]ven the little thing that we thought we could have some influence on was the snack shops and we found out we really can't...in the end...[our] hands are kinda tied in a lot of areas.
• *Contracts*	So eating right-...they were really talking about, when I was there, the cafeteria food that they get. I forgot who their provider is but like a lot of things they can't get around. So they were talking about how they'd love to change the menu around but they can't 'cause their suppliers won't allow them to with the contract that they have [at the MTF cafeteria].	'Cause I know some of the things like contracts they have in place for the food-- like yeah it's probably not going to change. The Army is like pull their contract with Burger King. That's not going to change anytime soon I understand that. I wish it was different but you know.
• *Unions*	You know it's funny. When you look up unions and stuff it's funny because most unions fight for tobacco cessation for their employees and a healthy workforce. So here we have the opposite. So I haven't figured that out. Well also, [MTF B Union President] the president of the union like-- they're all smokers too so that doesn't help.	We have the highest…command of civil service workers. So…they have a lot of clout with what happens and what's negotiated and things like that. So I don't foresee [becoming tobacco free] anytime soon. Maybe but it has to happen at that upper level of the union so-

	Key Quotes from Participants	
		but there are other MTFs in other commands that are tobacco free
• *Schools*	The education system right now is going through their standardized testing. They've got rid of one and they're instituting another one. [The principal] just didn't want to add any new changes…[H]e did look at each of the evidence-based recommendations for programs. And he just said this one's going to require a teacher to do it and they all require funding and…it was just not feasible at this time.	*In relation to unions and tobacco-free areas:* …and the schools have the same problem. Cuz that's what we're [mumbles]-- we were like, 'oh my gosh! Nowhere on [State B] can you smoke on school property. Except here because of the union
Subtheme 4: High vs. Low Traffic Food Locations	[The ability snack shops] don't- they're not in it for the money…they actually lose money on a lot of it because…the only people that will come in and buy some of the items or somebody coming in late at night, don't have a vehicle, couldn't get anywhere else so they'll buy something…they have decreased their sales tremendously.	[I]f you're sitting in the ER X amount of hours at 6 in the evening or something like that, it would be nice to know where that [healthy] vending machine is located…Unless you know where it is…Maybe put some signage up, some kinda marking to let people know it's there…But really, where is there anywhere to put that?
Subtheme 5: The Landscape for Physical Activity	I thought of…little signs and footprints on the sidewalk to show you if you walked this way it was this far…[and] would equate to this [distance]…'Cause sometimes when people see that or it's already mapped out for 'em, they're more likely to do it. But then of course [the civil engineer] said "Well you can't paint on the sidewalk." And I'm like darn…it would really entice people to go on that pathway… I ended up… doing a map which just wasn't the same…you know I had a brochure, I had maps, I did them on posters and put them around the facilities but… people aren't going to be out there with their map trying to figure out where they're going.	And I know there's been a lot of talk about people wanting to bike but it's just not-it's not accessible, it's not safe…the safety would probably be something that can be addressed and is very relevant for [this installation].
Subtheme 6: Budget Limitations	I think the very first reaction will be budget-wise. Like of course that's where we start with everything is how much is this going to cost us.	Even though you can bike on base, it's allowed, it's [just] not really promoted...and there's no place to put your bike. But then that comes down to funding.
Subtheme 7: Local vs. Centralized Changes	[T]he challenge with me is...everything is centralized out in San Antonio for us... a lot of our stuff is pushed out of one central location. So...when we were doing the m-NEAT and they come through with the recommended changes that we need to make to meet those nutritional health standards there's nothing we can do actually. We had to push it back up the chain and they would have to go through SG and they'd work it from San Antonio then [push it]...back down to us....I cannot make a change locally here at all anymore.	[W]e went after some Nutrigrain power bars. We got those put into our catalogue. And unless Air Force puts those in catalogue we cannot order them.

Table 4.5 Short-range recommendations: The APHC edits and facilitator guidance

Recommendations	Details
1. The APHC edits	
Create adaptable worksheets	• Add "not applicable" as a response option to questions. • Allow for the skipping of irrelevant questions without scoring penalties. • Add a notes section for response elaboration for when ideal responses to questions are not provided (e.g., questions encapsulating "hodge-podge worksites").
Define terms	• Define key terms to clear up confusion regarding who to ask for information or how to respond to questions (e.g., define "healthy option" and "meal") • Ensure correct, military and branch-specific terms are used for each question (e.g., rather than civilian terms or, for Air Force installations, Army terms).
Rethink question inclusion/ wording	Reassess questions and remove irrelevant questions • Examine questions in relationship to the establishment (e.g., apply to poster base) and determine what are appropriate, meaningful questions. • Put in place a quality assurance (QIQAQC process) mechanism. • Consider removing "higher level questions" that CACHE facilitators have little control over influencing at their level. Alternatively: o Retain questions for installations with initiatives/local policies that warrant routine evaluation (i.e., assess their utility each time the CACHE is implemented in the future), but include "N/A" as a response and remove scoring penalizations related to them (i.e., not skew scoring results for installations choosing "N/A"). o For policy questions, specify if questions are directed at the installation or DOD-level to clear up confusion.
Clarify and/or rethink scoring mechanism	• Make scoring weight for each of the included questions transparent. • Consider changing scoring penalizations from set, black-and-white numerical percentages. Suggestions: o Progress scores over time. Allow installations to focus on the smaller recommendations first and grant time for bigger changes to be implemented o Consider a low, medium and high continuum for scoring instead of percentages to be more translatable.
Develop a more detailed Information Guide	• Supply examples of which SMEs and key players should be contacted to participate and/or provide information for each set of questions. o Include tips for effectively communicating with unreceptive contacts. o Share more detailed information to guide new facilitators or key players due to job turnover or lack of previous experience with the Toolkit. • Elaborate on Toolkit scoring.

2. **CACHE Toolkit Facilitator guidance**	
Get buy-in from the start	• Get key leaders on installation on board before starting to aid momentum and timely responses from key players and SMEs • Get key players on board (i.e., in working group) before starting o If they're invested in the working group, the main facilitator will not have to implement the Toolkit alone, allowing for a timelier implementation of the Toolkit o Key players on board can help troubleshoot/decide on optimal paths for tool implementation and share recommendations' feasibility/best approaches
Segment Toolkit implementation over time	Allow for adequate time to implement the Toolkit (e.g., 3-6 months) • Break the Toolkit down into components and make a timeline for implementation • Consider recruiting a contractor who has the time to be the key facilitator and be, in a way, the project manager
Communicate scoring intentions	Make intentions of assessment/scoring clear prior to visiting sites: clear. Send emails, for example, to commanders, schools, community organizations, worksites and building managers, and DFACs explaining what you will be doing.
Be persistent	• As the facilitator, many participants advised to be persistent: "be willing to jump in," go out and start asking until you can find informants needed.
3. **CACHE Toolkit Action Plan Guide Implementation Guidance**	
"Choose your battles"	Prioritize and "choose your battles" rather than focusing on all recommendations at once. • Choose to focus on areas where commanders may be more invested in and can start making changes • Recognize it is okay to focus on smaller goals, not just the large-scale goals. Go for the "little wins," for example: o Work with AAFES representatives to make vending machine changes o Work with DECA to post nutrition information o Add bike racks for safe bike storage o Hold 30-min school education programs (e.g., led by external educator to prevent pushback due to teachers' workloads) and community events

Table 4.6 Medium-range recommendations: The APHC website and funding

Recommendations	Details
1. Build upon the APHC's website: to aid CACHE Toolkit and CACHE Action Plan Guide implementations	
Online Q&A/FAQs page	Include Q&A and web forum to answer commonly asked questions by installations. • Allows for revised lists of suggestions to be accessible to facilitators as more solutions are strategized by both facilitators and the APHC • E.g., SMEs who participated on their respective installations can share experiences/tips, for example with those who may lack access to a SME, those who are new to their position and not fully trained, and/or with facilitators unable to form successful working groups yet.
List of recommended substitutions during roadblocks	• Provide recommended substitutions to roadblocks facilitators and their teams may encounter while collecting information. • Update list of recommendations on a regular basis as solutions are strategized by the APHC/working teams/web forum users • Applies to Toolkit implementation process (e.g., unreceptive contacts, unable to locate data) and Action Plan Guide recommendations (e.g., substitutions for larger-scale recommendations-such as policy changes, sidewalk and bike lane installations, food offering recommendations)
Online web forum	Include a web forum to help those on large installations clarify areas of concern/connect with others in similar situations to get the help they need. (*allows for a two-way, timely, dynamic exchange of information, as opposed to one-way sharing by the APHC through the information guide and FAQs page*) • Facilitators and SMEs can ask questions and share experiences and tips with one other • Installations with legacy facilitators of tools (e.g., Air Force installations and m-NEAT) can provide support/guidance in the forum • The APHC can highlight solutions discovered via the forums on the FAQs and "list of recommended substitutions" pages
Interactive online map and/or app for smartphone	As part of the Action Plan Guide implementation it can help educate users. For example, it can: • Provide an interactive, Google or "Map My Run"-type online map for walking trails and safe walking and biking areas (i.e., routes with sidewalks and bike lanes) • Provide nutrition facts and tobacco policy updates for different areas of each installation
2. Address funding limitations for the CACHE Toolkit Action Plan Guide recommendations	
• Conditional APHC funding opportunities	Consider offering conditional funding to installations to carry out Action Plan Guide recommendations. Require timeline and goals that must be met to secure and retain funding.

• List of recommended substitutions for funding limitations	• Separate recommendations by smaller vs. larger recommendations based on time, policy and/or funding; include gradation of recommendations • Offer an alternate path to achieve larger recommendations (i.e., how to build upon it over time to accomplish larger goal) • Offer a list of recommended substitutions in the Action Plan Guide or the APHC website for less costly interventions • Hold healthy snack bar competitions in the work environments to raise awareness about nutritious foods

Table 4.7 Long-range recommendations: Improve the CACHE Toolkit and Action Plan Guide recommendations' implementation process

Recommendations	Details
1. Create the right committee	
Don't do it alone	• Recommend against implementing Toolkit alone: break it up into components and include a team with training in key areas to help implement it (see "Include SMEs") • Include key people who know what is feasible vs. unfeasible with Action Plan Guide, as well as who know what is most vs. least impactful, e.g., include: o Those who use and work in built environment (runners/bikers, former tobacco users, spouses involved in installation's community, staff at DFACs/AAFES) o Include SMEs who know limitations of installation (see next recommendation)
Include Subject Matter Experts (SMEs)	• Based on the assessment information that needs to be gathered, coordinate with SMEs to get access to information that would otherwise be hard to find • Include SMEs in working group to help implement Toolkit, ensure accurate reporting, and ensure suggestions/avenues chosen are feasible o E.g., community planners, RDs, tobacco cessation nurse, Defense Commissary Agency, dining facility manager • Provide a list of SMEs on installations by branch for facilitators to recruit (e.g., to include on the APHC website and/or information guide)
Leverage existing coalitions	• Try to join an existing coalition (i.e., working group(s)) with key members already recruited, instead of forming a new one
Turnover: have transition process	• Create transition process for facilitators and working group members (e.g., schedule overlap to allow shadowing of new employee) • Provide detailed guides for future CACHE facilitators and working group members o Provide details in Information Guide and on website o Create log of minutes from meetings/notes from facilitators to pass down to future position holders
2. Policies needed to aid the CACHE Toolkit implementation	
DoD-wide policy needed (vs. by branch)	• Policies need to be made across branches to allow for healthy built environments across military branches. This should be done: o To allow for quicker, routine process evaluations o To share successes in one branch (e.g., AFIs and tobacco-free environments) with other branches

Recommendations	Details
	• To engage at all levels of the pyramid, not just one portion (e.g., as happens on joint Air Force-Army installations, since Air Force and Army focus on engagement at the bottom (i.e., population level) vs. middle and top of the pyramid (i.e., one-on-one interventions), respectively
3. Policies needed to aid the CACHE Toolkit Action Plan Guide implementation	
Policy and higher command impact to aid enforcement	• Policies are needed to provide guidelines to execute and enforce DoD's vaguer, tobacco-related policies • Detailed guides are needed for leadership, building managers, etc. on how to enforce policies to aid employees involved in tobacco cessation in reaching goals
New policy to create new changes	New policies are needed at installation and especially DoD level to promote: • Physical activity-friendly environments (e.g., add sidewalks and bike lanes for safe walking/biking) • Tobacco-free environments (e.g.., negotiations with unions, creating uniform policies on installations)

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Chapter 5. Summary

5.1 Summary

Accurate measurements of adiposity and obesity-related factors are a priority need for the military. The main objective of this dissertation was to evaluate lifestyle and environmental assessment tools currently in use by military researchers and propose evidence-based improvements to strengthen these existing tools. We conducted studies to assess measures of adiposity in **Aim 1**, the overall diet in **Aim 2**, and the built environment of military installations in **Aim 3**.

The Military Healthy System began reassessing the utility of body mass index (BMI) in 2016 as a measure of body fatness among military personnel (1, 2). With this need in mind, **Aim 1** examined the extent of agreement of BMI, percentage body fat (BF%) by circumference-based equations (CBEs), and waist circumference (WC) with BF% by bioelectrical impedance analysis (BIA) in classifying military personnel as overweight/obese. We also assessed whether a composite approach that uses BMI along with a circumference-based measurement (i.e., WC or BF% by CBE) could better categorize military personal as overweight/obese. We found that BMI combined with BF% by CBE was the best combination to categorize overweight/obesity in our study sample, as it had relatively high sensitivity, low FDR, and a moderate level of agreement with BF% by BIA.

In **Aim 2**, our objective was to improve the validity of the 5-item Healthy Eating Score (HES-5) that is currently part of the military's Global Assessment Tool (GAT) compared with the 2015 Healthy Eating Index (HEI-2015). Although the HES-5 is strongly associated with health-promoting nutrition behaviors, it was developed relative to the 2005 Healthy Eating Index and not the most recent HEI-2015, which reflects the

2015-2020 Dietary Guidelines for Americans (3, 4). For males, we found that the best approach to strengthen its correlation with the HEI-2015 was to add a score to reflect the consumption of sugar-sweetened beverages in 8-oz servings (+SSB-8). For females, the best option was to add items on both the SSB-8 and the frequency of post-exercise recovery fueling snacking (RFsnack). Given that the GAT is administered to both sexes military-wide, our findings support adding both SSB-8 and RFsnack-B to the HES-5.

Lastly, the U.S. Army Public Health Center (APHC) developed the Creating Active Communities and Healthy Environments (CACHE) Toolkit to help military installations evaluate their built environments in relation to healthy eating, physical activity, and tobacco use, and to identify and prioritize key areas for improvement. **Aim 3** was a mixed-methods study that sought to improve the CACHE toolkit implementation process, identify ways to better assist installations with toolkit implementation, and assess the utility of APHC's action plan guides that recommend strategies to improve the built environment on installations. Although most participants agreed that the built environment impacts healthy eating, we found that less than half believed their built environments promoted healthy eating and tobacco-free living, and that just over half believed it promoted physical activity. Our qualitative findings highlighted three overarching themes from the experiences of those who administered the CACHE toolkits: 1) Toolkit and Action Plan Guide Functionality; 2) the Sociopolitical Landscape Affects Toolkit Implementation; and 3) the Sociopolitical and Physical Landscapes Affect the CACHE Toolkit's Value and Utility. When asked to identify ways to improve upon their CACHE Toolkit and action plan guide experiences, participants highlighted the need for: detailed manuals to improve toolkit and action plan guide functionality; leadership's

enforcement of policies and their prioritization of health-promoting improvements to the built environment; and financial considerations related to the recommendations in action plan guides.

5.2 Public health relevance

More than 60% of all U.S. military personnel are currently estimated to be overweight or obese (5). Overweight and obesity are associated with increased risk of musculoskeletal injuries and heat-related illnesses among military personnel, thereby negatively impacting their safety and operational readiness and, thus, our national security (6-9). Due to the anthropometric and fitness standards military personnel are held to, failure to meet these standards can also jeopardize military careers (9). Of note, these risks are above and beyond the well-known health risks of overweight and obesity.

It is important for the military and for military researchers to utilize accurate measures of adiposity to categorize military personnel as overweight and obese. This can ensure not only that fitness standards are upheld, but also that military personnel- particularly individuals with high muscle mass- are not unfairly penalized by false positive screenings (10-13).

It is also important for military researchers to have access to comprehensive, yet expeditious tools that assess factors associated with obesity and related health risks. The social-ecological framework posits that multiple intrapersonal, inter-personal, community, environment, and policy-related factors can impact one's health risk behaviors (14, 15). Since optimal nutrition is important to the health and physical readiness of military personnel, diet represents a key intrapersonal factor associated with

obesity. However, the degree to which the diets of military personnel adhere to the current recommendations set forth by the 2015-2020 Dietary Guidelines for Americans (DGA) is unknown. On the environmental and policy levels, the built environment on military installations and the policies currently in place that affect it may contribute to current obesity and health trends. To the best of our knowledge, the built environment on military installations has been assessed in only a few studies and initiatives to date.

5.3 Considerations and future directions

The limitations and strengths within this dissertation help highlight future directions for research. First, in **Aim 1**, BIA was used as the criterion measure rather than dual-energy x-ray absorptiometry (DEXA). Although BIA is less expensive, more portable, can yield complete measurements more quickly than DEXA, and has been well correlated with DEXA measures (16, 17), it is also affected by the hydration status of participants. A key limitation of this aim was that hydration status was not assessed prior to taking any BIA measurements. As such, future studies should account for the adequate hydration of participants prior to taking BIA measurements or select a different gold standard. Second, our sample size was limited. This precluded stratifying our analyses by age or race/ethnicity. Age-related decreases in testosterone levels may affect intra-abdominal fat distribution in older military personnel (11) and the accuracy of body composition cut-offs and the association between visceral fat and health risks may differ by race or ethnicity (18, 19). However, a key strength of our study was that 22% of our participants were female and, thus, we were able to provide estimates for women and begin to address the current dearth of information about women in the military. An

additional strength was the quality of the anthropometry: trained laboratory personnel took all anthropometric measures used in our analyses. Future studies comparing anthropometric measures should similarly use trained personnel to collect anthropometric measures, as well as consider larger sample sizes and aim for greater sex, age, and racial/ethnic variations during recruitment to allow for stratification by these characteristics.

In **Aim 2**, breakfast and RFsnack frequency may represent aspects of the diet not currently captured by the HES-5. Both items are currently included in the GAT, which is completed annually by all new and non-deployed active duty Army personnel. Therefore, their addition to the HES-5 offers an opportunity to improve the measure for future research that uses the larger GAT dataset. Additionally, our SSB item was a composite score of multiple FFQ items. Future studies should consider the phrasing of this question in an effort to maximize its ability to capture the same information in a single item. Similar to Aim 1, with females comprising 26% of participants in **Aim 2**, our findings also contribute to the limited literature currently available on women in the military. Future studies on the HES-5 should continue to target female recruitment to help highlight any potential key differences by sex.

In **Aim 3**, our main limitation was the small sample size. Although we explored changes in the Knowledge, Attitudes, and Beliefs (KAB) Survey responses pre- and post-CACHE toolkit implementation, we did not conduct statistical tests or inferential analyses on quantitative data. As researchers at Army Public Health Center work towards offering the CACHE toolkit to a greater number of installations and, eventually, military-wide, process evaluations should continue to utilize the KAB Survey to further our

understanding of how the CACHE toolkit contributes to changes in these areas. Additionally, though qualitative findings from this study may not be generalizable to all military installations, it is important to emphasize our focus was on process evaluation rather than on outcome evaluation or testing a theory. Our findings may help inform other military studies, initiatives, and policies. Once the CACHE toolkit is finalized, future research can also consider a shifted focus to tool outcomes.

Lastly, an important consideration is that the focus of this dissertation was solely on the evaluation and improvement of tools currently used in the military. Overall, from population health and research perspectives, the military is a large population for which a rich array of high quality data is available. Military personnel also have many similar lifestyle and environmental exposures that may help "control for" known and unknown confounders when studied, which may help elucidate associations. Future research should investigate and provide new insights on the associations between foods (e.g., components of the HES-5) or dietary scores (e.g., the HES-5) and obesity.

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Chapter 6. Appendices

Appendix A. Body Fat Standards by Service Branch

CREATED BY THE HUMAN PERFORMANCE RESOURCE CENTER / HPRC-ONLINE.ORG / FROM THE CONSORTIUM OF HEALTH AND MILITARY PERFORMANCE (CHAMP)

Body Fat Standards by Service Branch

The U.S. Armed Forces uses body composition (a measure of a person's body fat) as one component to determine the fitness of a service member. If a service member is "overfat," it can adversely affect his or her career, including the ability to be promoted and even stay in the military. Each service branch has its own standards within DoD guidelines 1308.1.

This chart is only intended for service members or healthcare providers to compare one service's standards to another.

Four services use a set of circumferences to calculate an estimated percentage of body fat:

A service member is "overfat" * if the measure of body fat exceeds the % below.		
Army (current standard AR 600-9 as of 28 June 2013)		
Age	**Men**	**Women**
17–20	> 20%	> 30%
21–27	> 22%	> 32%
28–39	> 24%	> 34%
≥ 40	> 26%	> 36%
Coast Guard (current standard COMDTINST M1020,8H as of 5 Sept 2015)		
Age	**Men**	**Women**
< 30	> 22%	> 32%
30–39	> 24%	> 34%
≥ 40	> 26%	> 36%
Marines (current standard order 6110.3 as of 8 August 2008)		
Age	**Men**	**Women**
17–26	> 18%	> 26%
27–39	> 19%	> 27%
40–45	> 20%	> 28%
≥ 46	> 21%	> 29%
Public Health Service (current standards as of 1 Jan 2016) **		
Age	**Men**	**Women**
All	> 26%	> 36%
**Note: At this time the PHS body fat standards are used only for commissioning.		

Two services have different criteria:

Air Force (current standard order AFI 36/2905 as of 27 August 2015)		
A service member is "overfat" is his or her abdominal circumference exceeds the measurements below.		
Age	**Men**	**Women**
All	≥ 40 inches	≥ 35 inches
Navy (current standard NAVADMIN 178/15 as of 1 January 2016)		
Step 1	**Compare body weight to chart, then if body weight is greater...**	
Age	**Men**	**Women**
Step 2	**Abdominal circumference must be less than...**	
All	39 inches	35.5 inches
Step 3	**If circumference exceeds the above, then a service member is "overfat" if his or her measure of body fat exceeds the % below.**	
18–21	> 22%	> 33%
22–29	> 23%	> 34%
30–39	> 24%	> 35%
≥ 40	> 26%	> 36%

Reference:

hprc-online.org. Body Fat Standards by Service Branch. *Human Performance Resource Center*: Consortium of Health and Military Performance; 2016

Appendix B. Aim 2: Questions used to calculate HEI-2015, HES-5, and candidate HES-5+ scores

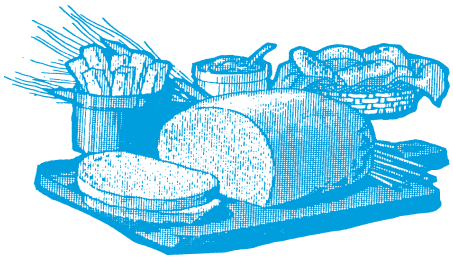
B1. 110-item Block FFQ used to calculate the HEI-2015 scores and SSB item

FOOD QUESTIONNAIRE

RESPONDENT ID #

TODAY'S DATE

	DAY	YEAR		
Jan				
Feb				
Mar	0 0	2005	2015	
Apr	1 1	2006	2016	
May	2 2	2007	2017	
Jun	3 3	2008	2018	
Jul	4	2009	2019	
Aug	5	2010	2020	
Sep	6	2011	2021	
Oct	7	2012	2022	
Nov	8	2013	2023	
Dec	9	2014	2024	



ABOUT THIS SURVEY

This form is about the foods you usually eat.
It will take about 30 - 40 minutes to complete.
Please answer each question as best you can.
Estimate if you aren't sure.

- **USE ONLY A NO. 2 PENCIL.**
- **Fill in the circles completely, and erase completely if you make any changes.**

Please write your name in this box.

ABOUT YOU

SEX
- Male
- Female

If female, are you pregnant or breast feeding?
- No
- Yes
- Not female

AGE

WEIGHT pounds

HEIGHT ft. in.

INSTRUCTIONS

There are usually two kinds of questions to answer for each food:

1. **HOW OFTEN,** on average, did you eat the food during the past year?
   *Please DO NOT SKIP any foods. Mark "Never" if you didn't eat any of the food in the question.
2. **HOW MUCH** did you usually eat of the food?
   *Sometimes we ask how many you eat, such as 1 egg, 2 eggs, etc., ON THE DAYS YOU EAT IT.
   *Sometimes we ask "how much" as A, B, C or D. **LOOK AT THE ENCLOSED PICTURES.**
   For each food, pick the picture (bowls or plates) that looks the most like the serving size you usually eat. (If you don't have pictures: A=1/4 cup, B=1/2 cup, C=1 cup, D= 2 cups.)
3. **EXAMPLE:** This person drank apple juice twice a week, and had one glass each time.
   Once a week he ate a "C"-sized serving of rice (about 1 cup).

	HOW OFTEN IN THE PAST YEAR									HOW MUCH ON THOSE DAYS (SEE PORTION SIZE PICTURES FOR A-B-C-D)				
	NEVER	A FEW TIMES per YEAR	ONCE per MONTH	2-3 TIMES per MONTH	ONCE per WEEK	2 TIMES per WEEK	3-4 TIMES per WEEK	5-6 TIMES per WEEK	EVERY DAY					
Apple juice	○	○	○	○	○	●	○	○	○	How many glasses each time	● 1	○ 2	○ 3	○ 4
Rice	○	○	○	○	●	○	○	○	○	How much each time	○ A	○ B	● C	○ D

PLEASE DO NOT WRITE IN THIS AREA

SERIAL #

This section is about your usual eating habits in the past year or so. This includes all meals or snacks, at home or in a restaurant or carry-out. We will ask you about different TYPES (low-fat, low-carb) at the end of the survey. Include all types (like low-fat, sugar-free). Later you can tell us which type you usually eat.

	NEVER	A FEW TIMES per YEAR	ONCE per MONTH	2-3 TIMES per MONTH	ONCE per WEEK	2 TIMES per WEEK	3-4 TIMES per WEEK	5-6 TIMES per WEEK	EVERY DAY	HOW MUCH ON THOSE DAYS (SEE PORTION SIZE PICTURES FOR A-B-C-D)
Breakfast sandwiches with eggs, like Egg McMuffins	○	○	○	○	○	○	○	○	○	How many sandwiches in a day: ○ 1 ○ 2
Other eggs like scrambled, boiled or omelets (not egg substitutes)	○	○	○	○	○	○	○	○	○	How many eggs a day: ○ 1 ○ 2 ○ 3
Breakfast sausage, including in sausage biscuits, or in breakfast sandwiches	○	○	○	○	○	○	○	○	○	How many pieces: ○ 1 ○ 2 ○ 3
Bacon	○	○	○	○	○	○	○	○	○	How many pieces: ○ 1 ○ 2 ○ 3 ○ 4
Pancakes, waffles, French toast or Pop Tarts	○	○	○	○	○	○	○	○	○	How many pieces: ○ 1 ○ 2 ○ 3
Cooked cereals like oatmeal, grits or cream of wheat	○	○	○	○	○	○	○	○	○	Which bowl: ○ B ○ C ○ D
Cold cereals, ANY KIND, like corn flakes, fiber cereals, or sweetened cereals	○	○	○	○	○	○	○	○	○	Which bowl: ○ B ○ C ○ D
Milk or milk substitutes on cereal	○	○	○	○	○	○	○	○	○	
Yogurt or frozen yogurt	○	○	○	○	○	○	○	○	○	Which bowl: ○ B ○ C
Cheese, sliced cheese or cheese spread, including on sandwiches	○	○	○	○	○	○	○	○	○	How many slices: ○ 1 ○ 2 ○ 3
How often do you eat the following foods all year round? Estimate your average for the whole year.										
Bananas	○	○	○	○	○	○	○	○	○	How many each time: ○ 1/2 ○ 1
Apples or pears	○	○	○	○	○	○	○	○	○	How many each time: ○ 1/2 ○ 1 ○ 2
Oranges or tangerines	○	○	○	○	○	○	○	○	○	How many each time: ○ 1/2 ○ 1 ○ 2
Grapefruit	○	○	○	○	○	○	○	○	○	How much: ○ A little ○ 1/2 ○ 1
Peaches or nectarines, fresh	○	○	○	○	○	○	○	○	○	How many: ○ 1/2 ○ 1 ○ 2
Other fresh fruits like grapes, plums, honeydew, mango	○	○	○	○	○	○	○	○	○	How much: ○ A ○ B ○ C
Canned fruit like applesauce, fruit cocktail, canned peaches or canned pineapple	○	○	○	○	○	○	○	○	○	How much: ○ A ○ B ○ C
How often do you eat each of the following 3 fruits, just during the summer months when they are in season?										
Cantaloupe, in season	○	○	○	○	○	○	○	○	○	How much: ○ 1/8 ○ 1/4 ○ 1/2
Strawberries or other berries, in season	○	○	○	○	○	○	○	○	○	How much: ○ A ○ B ○ C
Watermelon, in season	○	○	○	○	○	○	○	○	○	How much: ○ A ○ B ○ C ○ D
How often do you eat each of the following vegetables all year round, including fresh, frozen, canned or in stir-fry, at home or in a restaurant?										
Broccoli	○	○	○	○	○	○	○	○	○	How much: ○ A ○ B ○ C
Carrots, or mixed vegetables with carrots	○	○	○	○	○	○	○	○	○	How much: ○ A ○ B ○ C
Corn	○	○	○	○	○	○	○	○	○	How much: ○ A ○ B ○ C

	NEVER	A FEW TIMES per YEAR	ONCE per MONTH	2-3 TIMES per MONTH	ONCE per WEEK	2 TIMES per WEEK	3-4 TIMES per WEEK	5-6 TIMES per WEEK	EVERY DAY	HOW MUCH ON THOSE DAYS (SEE PORTION SIZE PICTURES FOR A-B-C-D)
Green beans or green peas	○	○	○	○	○	○	○	○	○	How **much** ○ A ○ B ○ C
Spinach (cooked)	○	○	○	○	○	○	○	○	○	How **much** ○ A ○ B ○ C
Greens like collards, turnip greens, mustard greens	○	○	○	○	○	○	○	○	○	How **much** ○ A ○ B ○ C
Sweet potatoes, yams	○	○	○	○	○	○	○	○	○	How **much** ○ A ○ B ○ C
French fries, home fries, hash browns	○	○	○	○	○	○	○	○	○	How **much** ○ A ○ B ○ C ○ D
Potatoes <u>not</u> fried, including mashed, boiled, baked, or potato salad	○	○	○	○	○	○	○	○	○	How **much** ○ A ○ B ○ C ○ D
Cole slaw, cabbage, Chinese cabbage	○	○	○	○	○	○	○	○	○	How **much** ○ A ○ B ○ C
Green salad, lettuce salad	○	○	○	○	○	○	○	○	○	How **much** ○ B ○ C ○ D
Raw tomatoes	○	○	○	○	○	○	○	○	○	How **much** ○ 1/4 ○ 1/2 ○ 1
Salad dressing, any kind, regular or low-fat	○	○	○	○	○	○	○	○	○	How many **tablespoons** ○ 1 ○ 2 ○ 3 ○ 4
Any other vegetable, like squash, cauliflower, okra, cooked peppers	○	○	○	○	○	○	○	○	○	How **much** ○ A ○ B ○ C ○ D
Refried beans or <u>bean</u> burritos	○	○	○	○	○	○	○	○	○	How much of the **beans** ○ A ○ B ○ C
Pinto beans, black beans, chili with beans, baked beans	○	○	○	○	○	○	○	○	○	How **much** ○ A ○ B ○ C ○ D
Vegetable stew (without meat)	○	○	○	○	○	○	○	○	○	Which **bowl** ○ B ○ C ○ D
Vegetable soup, vegetable-beef soup, or tomato soup	○	○	○	○	○	○	○	○	○	Which **bowl** ○ B ○ C ○ D
Split pea, bean or lentil soup	○	○	○	○	○	○	○	○	○	Which **bowl** ○ B ○ C ○ D
Any other soup including chicken noodle, cream soups, Cup-A-Soup, ramen	○	○	○	○	○	○	○	○	○	Which **bowl** ○ B ○ C ○ D
Pizza	○	○	○	○	○	○	○	○	○	How many **slices** ○ 1 ○ 2 ○ 3 ○ 4
Spaghetti, lasagna or other pasta <u>with tomato sauce</u>	○	○	○	○	○	○	○	○	○	How **much** ○ B ○ C ○ D
Macaroni and cheese	○	○	○	○	○	○	○	○	○	How **much** ○ B ○ C ○ D
Other noodles like egg noodles, pasta salad, sopa seca	○	○	○	○	○	○	○	○	○	How **much** ○ B ○ C ○ D
Tofu or tempeh	○	○	○	○	○	○	○	○	○	How **much** ○ A ○ B ○ C
Meat substitutes like veggie burgers, veggie chicken, vegetarian hot dogs or vegetarian lunch meats	○	○	○	○	○	○	○	○	○	How many **patties or dogs** ○ 1 ○ 2
Do you ever eat chicken, meat or fish? ○ Yes ○ No IF NO, SKIP TO BREADS ON NEXT PAGE										
Hamburgers, cheeseburgers, at home or in a restaurant	○	○	○	○	○	○	○	○	○	How **much** ○ 1 sm ○ 1 lrg ○ 2
Hot dogs, or sausage like Polish, Italian or chorizo	○	○	○	○	○	○	○	○	○	How many **hotdogs** ○ 1 ○ 2 ○ 3

PLEASE DO NOT WRITE IN THIS AREA

	NEVER	A FEW TIMES per YEAR	ONCE per MONTH	2-3 TIMES per MONTH	ONCE per WEEK	2 TIMES per WEEK	3-4 TIMES per WEEK	5-6 TIMES per WEEK	EVERY DAY	HOW MUCH ON THOSE DAYS (SEE PORTION SIZE PICTURES FOR A-B-C-D)
Lunch meat like bologna, sliced ham, turkey bologna, or any other lunch meat	○	○	○	○	○	○	○	○	○	How many **slices** ○ 1 ○ 2 ○ 3 ○ 4
Meat loaf, meat balls	○	○	○	○	○	○	○	○	○	How **much** ○ B ○ C ○ D
Steak, roast beef, or beef in frozen dinners or sandwiches	○	○	○	○	○	○	○	○	○	How **much** ○ A ○ B ○ C ○ D
Tacos, burritos, enchiladas, tamales, with meat or chicken	○	○	○	○	○	○	○	○	○	How **much** ○ A ○ B ○ C ○ D
Ribs, spareribs	○	○	○	○	○	○	○	○	○	How **much** ○ A ○ B ○ C ○ D
Pork chops, pork roasts, cooked ham (including for breakfast)	○	○	○	○	○	○	○	○	○	How **much** ○ A ○ B ○ C ○ D
Veal, lamb, deer meat	○	○	○	○	○	○	○	○	○	How **much** ○ A ○ B ○ C
Liver, including chicken livers or liverwurst	○	○	○	○	○	○	○	○	○	How **much** ○ A ○ B ○ C
Pigs feet, neck bones, oxtails, tongue	○	○	○	○	○	○	○	○	○	How **much** ○ A ○ B ○ C
Menudo, pozole, caldo de res, sancocho, ajiaco	○	○	○	○	○	○	○	○	○	Which **bowl** ○ B ○ C ○ D
Any other beef or pork dish, like beef stew, beef pot pie, corned beef hash, Hamburger Helper	○	○	○	○	○	○	○	○	○	How **much** ○ B ○ C ○ D
Fried chicken, including chicken nuggets, wings, chicken patty	○	○	○	○	○	○	○	○	○	How many **medium pieces** ○ 1 ○ 2 pcs/6 nugts ○ 3
Roasted or broiled chicken or turkey	○	○	○	○	○	○	○	○	○	How **much** ○ A ○ B ○ C
Any other chicken dish, like chicken stew, chicken with noodles, chicken salad, Chinese chicken dishes	○	○	○	○	○	○	○	○	○	How **much** ○ B ○ C ○ D
Oysters	○	○	○	○	○	○	○	○	○	How **much** ○ A ○ B ○ C
Shellfish like shrimp, scallops, crabs	○	○	○	○	○	○	○	○	○	How **much** ○ A ○ B ○ C ○ D
Tuna, tuna salad, tuna casserole	○	○	○	○	○	○	○	○	○	How much **of the tuna** ○ A ○ B ○ C
Fried fish or fish sandwich	○	○	○	○	○	○	○	○	○	How **much** ○ A ○ B ○ C
Other fish, not fried	○	○	○	○	○	○	○	○	○	How **much** ○ A ○ B ○ C
BREADS										
Biscuits, muffins, croissants (not counting breakfast sandwiches with eggs)	○	○	○	○	○	○	○	○	○	How **many** ○ 1 sm ○ 1 med ○ 2
Hamburger buns, hotdog buns, hoagie buns, submarines	○	○	○	○	○	○	○	○	○	How **many** ○ 1 ○ 2
Bagels, English muffins, dinner rolls	○	○	○	○	○	○	○	○	○	How **many** ○ 1/2 ○ 1
Tortillas (not counting those eaten in tacos or burritos)	○	○	○	○	○	○	○	○	○	How many **in a day** ○ 1 ○ 2 ○ 3 ○ 4
Corn bread, corn muffins, hush puppies	○	○	○	○	○	○	○	○	○	How many **pieces in a day** ○ 1/2 ○ 1 ○ 2
Any other bread or toast, including white, dark, whole wheat, and what you have in sandwiches	○	○	○	○	○	○	○	○	○	How many **slices in a day** ○ 1 ○ 2 ○ 3 ○ 4
Rice, or dishes made with rice	○	○	○	○	○	○	○	○	○	How much **in a day** ○ B ○ C ○ D

	NEVER	A FEW TIMES per YEAR	ONCE per MONTH	2-3 TIMES per MONTH	ONCE per WEEK	2 TIMES per WEEK	3-4 TIMES per WEEK	5-6 TIMES per WEEK	EVERY DAY	HOW MUCH ON THOSE DAYS (SEE PORTION SIZE PICTURES FOR A-B-C-D)
Margarine (not butter) on bread or on vegetables	○	○	○	○	○	○	○	○	○	How many **pats (tsp)** ○ 1 ○ 2 ○ 3 ○ 4
Butter (not margarine) on bread or on vegetables	○	○	○	○	○	○	○	○	○	How many **pats (tsp)** ○ 1 ○ 2 ○ 3 ○ 4
Energy bars, like Power Bars, Clif bars, Balance, Luna, Atkins bars	○	○	○	○	○	○	○	○	○	How **many** ○ 1 ○ 2
Breakfast bars, cereal bars, granola bars (not energy bars)	○	○	○	○	○	○	○	○	○	How **many** ○ 1 ○ 2
Peanuts, sunflower seeds, other nuts or seeds	○	○	○	○	○	○	○	○	○	How **much** ○ A ○ B ○ C
Peanut butter	○	○	○	○	○	○	○	○	○	How many **tablespoons** ○ 1/2 ○ 1 ○ 2 ○ 3
Snack chips like potato chips, tortilla chips, Fritos, Doritos, popcorn (not pretzels)	○	○	○	○	○	○	○	○	○	How **much** ○ A ○ B ○ C ○ D
Crackers, like Saltines, Cheez-Its, or any other snack cracker	○	○	○	○	○	○	○	○	○	How **much** ○ A ○ B ○ C
Jelly, jam	○	○	○	○	○	○	○	○	○	How many **tablespoons** ○ 1/2 ○ 1 ○ 2
Mayonnaise, sandwich spreads	○	○	○	○	○	○	○	○	○	How many **tablespoons** ○ 1/2 ○ 1 ○ 2
Catsup, salsa or chile peppers	○	○	○	○	○	○	○	○	○	How many **tablespoons** ○ 1/2 ○ 1 ○ 2 ○ 3
Mustard, barbecue sauce, soy sauce, gravy, other sauces	○	○	○	○	○	○	○	○	○	How many **tablespoons** ○ 1/2 ○ 1 ○ 2 ○ 3
Donuts	○	○	○	○	○	○	○	○	○	How **many** ○ 1 ○ 2 ○ 3
Cake, or snack cakes like cupcakes, Ho-Hos, Entenmann's, or any other pastry	○	○	○	○	○	○	○	○	○	How many **pieces** ○ 1 sm ○ 1 med ○ 2 ○ 3
Cookies	○	○	○	○	○	○	○	○	○	How **many** ○ 1-2 ○ 3-4 ○ 5-6 ○ 7+
Ice cream, ice cream bars	○	○	○	○	○	○	○	○	○	How **much** ○ B ○ C ○ D
Chocolate syrup or sauce (like in milk or on ice cream)	○	○	○	○	○	○	○	○	○	
Pumpkin pie, sweet potato pie	○	○	○	○	○	○	○	○	○	How many **pieces** ○ 1/2 ○ 1 ○ 2
Any other pie including fast food pies or snack pies	○	○	○	○	○	○	○	○	○	How many **pieces** ○ 1/2 ○ 1 ○ 2
Chocolate candy like candy bars, M&Ms, Reeses	○	○	○	○	○	○	○	○	○	How **much** ○ 1 mini ○ 1 med ○ 1 lrg ○ 1 king
Any other candy, not chocolate, like hard candy, Lifesavers, Skittles, Starburst	○	○	○	○	○	○	○	○	○	How **much** in a day ○ 1-2 pcs ○ 1/2 pkg ○ 1 pkg

	NEVER	A FEW TIMES per YEAR	ONCE per MONTH	2-3 TIMES per MONTH	ONCE per WEEK	2 TIMES per WEEK	3-4 TIMES per WEEK	5-6 TIMES per WEEK	EVERY DAY	HOW MUCH on the days you drink it?
Glasses of milk (any kind, including soy), not counting on cereal or coffee	○	○	○	○	○	○	○	○	○	How many **GLASSES** ○ 1 ○ 2 ○ 3
Drinks like Slim Fast, Sego, Slender, Ensure or Atkins	○	○	○	○	○	○	○	○	○	How many **CANS OR GLASSES** ○ 1 ○ 2
Tomato juice or V-8 juice	○	○	○	○	○	○	○	○	○	How many **GLASSES** ○ 1/2 ○ 1 ○ 2
Real 100% orange juice or grapefruit juice. Don't count orange soda or Sunny Delight	○	○	○	○	○	○	○	○	○	How many **GLASSES** ○ 1/2 ○ 1 ○ 2
Apple juice, grape juice, pineapple juice or fruit smoothies	○	○	○	○	○	○	○	○	○	How many **GLASSES** ○ 1/2 ○ 1 ○ 2

	NEVER	A FEW TIMES per YEAR	ONCE per MONTH	2-3 TIMES per MONTH	ONCE per WEEK	2 TIMES per WEEK	3-4 TIMES per WEEK	5-6 TIMES per WEEK	EVERY DAY	HOW MUCH on the days you drink it?
Hi-C, Cranberry Juice Cocktail, Hawaiian Punch, Tang	○	○	○	○	○	○	○	○	○	How many GLASSES: ○ 1/2 ○ 1 ○ 2 ○ 3
Drinks with some juice, like Sunny Delight, Knudsen	○	○	○	○	○	○	○	○	○	How many GLASSES: ○ 1/2 ○ 1 ○ 2 ○ 3
Iced tea, homemade, instant, or bottled like Nestea, Lipton, Snapple, Tazo	○	○	○	○	○	○	○	○	○	How many GLASSES OR BOTTLES: ○ 1 ○ 2 ○ 3 ○ 4
Kool-Aid, lemonade, sports drinks like Gatorade, or fruit flavored drinks (not including iced teas)	○	○	○	○	○	○	○	○	○	How much IN A DAY: ○ 1 glass ○ 1 20-ounce bottle ○ 2 glasses ○ 2 20-ounce bottles
Any kind of soft drink, like cola, Sprite, orange soda, regular or diet	○	○	○	○	○	○	○	○	○	How much IN A DAY: ○ 1 can ○ 1 20-ounce bottle ○ 2 cans ○ Big Gulp or 3 cans
Beer or non-alcoholic beer	○	○	○	○	○	○	○	○	○	How much IN A DAY: ○ 1 can ○ 2 cans ○ 3-4 cans or small pitcher ○ 5+ cans or large pitcher
Wine or wine coolers	○	○	○	○	○	○	○	○	○	How many GLASSES in a day: ○ 1/2 glass ○ 1 glass ○ 2 glasses or half bottle ○ 3 glasses
Liquor or mixed drinks	○	○	○	○	○	○	○	○	○	How many DRINKS: ○ 1 ○ 2 ○ 3 ○ 4
Glasses of water, tap or bottled	○	○	○	○	○	○	○	○	○	How many GLASSES: ○ 1 ○ 2 ○ 3-4 ○ 5+
Coffee, regular or decaf	○	○	○	○	○	○	○	○	○	How many CUPS: ○ 1 ○ 2 ○ 3 ○ 4+
Hot tea (not including herbal teas)	○	○	○	○	○	○	○	○	○	How many CUPS: ○ 1 ○ 2 ○ 3 ○ 4+

What do you usually add to **coffee?** **MARK ONLY ONE:**
○ Cream or half & half ○ Nondairy creamer ○ Milk ○ None of these ○ Don't drink it

What do you usually add to **tea?** **MARK ONLY ONE:**
○ Cream or half & half ○ Nondairy creamer ○ Milk ○ None of these ○ Don't drink it

Do you usually add sugar (or honey) to **coffee?** ○ No ○ Yes IF YES, how many teaspoons each cup? ○ 1 ○ 2 ○ 3 ○ 4

Do you usually add sugar (or honey) to **tea?** ○ No ○ Yes IF YES, how many teaspoons each cup? ○ 1 ○ 2 ○ 3 ○ 4

	RARELY	1-2 PER WEEK	3-4 PER WEEK	5-6 PER WEEK	1 PER DAY	1 1/2 PER DAY	2 PER DAY	3 PER DAY	4+ PER DAY
About how many servings of vegetables do you eat, per day or per week, not counting salad or potatoes?	○	○	○	○	○	○	○	○	○
About how many servings of fruit do you eat, not counting juices?	○	○	○	○	○	○	○	○	
How often do you use fat or oil in cooking?	○	○	○	○	○	○	○	○	

PLEASE DO NOT WRITE IN THIS AREA

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If you eat the following foods, what type do you usually eat? MARK ONLY ONE ANSWER FOR EACH QUESTION

Milk	○ Whole milk ○ Reduced-fat 2% milk	○ Low-fat 1% milk ○ Non-fat milk	○ Soy milk ○ Rice milk	○ Don't drink
Slim Fast, Sego, Slender or Ensure		○ Low-Carb like Atkins	○ Regular	○ Don't drink
Orange juice	○ Calcium-fortified	○ Not calcium-fortified	○ I don't know	○ Don't drink
Soda or pop	○ Diet soda, low-calorie	○ Regular	○ Don't drink	
Iced tea	○ Homemade, no sugar	○ Homemade, w/sugar	○ Bottled, no sugar	○ Bottled, regular ○ Don't drink
Beer	○ Regular beer	○ Light beer	○ Low-Carb beer	○ Non-alcoholic beer ○ Don't drink
Hamburgers or cheeseburgers		○ Hamburgers	○ Cheeseburgers	○ Don't eat
Hot dogs	○ Low fat or turkey dogs	○ Regular hot dogs	○ Don't eat	
Lunch meats	○ Low-fat or turkey lunch meats	○ Regular lunch meats	○ Don't eat	
Spaghetti or lasagna	○ Meatless	○ With meat sauce or meatballs		○ Don't eat
Cheese	○ Low Fat	○ Not Low Fat	○ Don't eat	
Salad dressing	○ Low-Carb	○ Low-fat	○ Regular	○ Don't use
Energy bars like Power Bar, Clif, Atkins	○ Low-Carb, low sugar	○ Low-fat	○ Regular	○ Don't eat
Breakfast bars, cereal bars, or granola bars	○ Low-Carb, low sugar	○ Low-fat	○ Regular	○ Don't eat
Bread	○ 100% whole wheat	○ Low-Carb	○ Regular	○ Don't eat
Tortillas	○ Corn	○ Flour	○ Don't know or don't eat	
Chocolate candy or chocolate candy bars	○ Low-Carb, low sugar	○ Low-fat	○ Regular	○ Don't eat
Cookies	○ Low-Carb, low sugar	○ Low-fat	○ Regular	○ Don't eat
Cake, snack cakes, and other pastries	○ Low-Carb, low sugar	○ Low-fat	○ Regular	○ Don't eat
Ice cream	○ Low-Carb, low sugar	○ Low-fat or ice milk	○ Regular	○ Don't eat
Jelly or jam	○ Low-Carb, low sugar	○ Regular	○ Don't use	
Beef or pork	○ Avoid eating the fat	○ Sometimes eat the fat	○ Often eat the fat	○ Don't eat
Chicken or Turkey	○ Avoid eating the skin	○ Sometimes eat the skin	○ Often eat the skin	○ Don't eat

What kinds of **fat or oil** do you usually use in cooking? **MARK ONLY ONE OR TWO**

- ○ Don't know, or Pam
- ○ Butter
- ○ Butter/margarine blend
- ○ Stick margarine
- ○ Soft tub margarine
- ○ Low-fat margarine
- ○ Corn oil, vegetable oil
- ○ Olive oil or canola oil
- ○ Lard, fatback, bacon fat
- ○ Crisco

If you eat **cold cereals**, what do you eat? Choose one or two that you eat most often. (If you usually just eat one kind, just choose one.)

- ○ Low-carb cereals like Atkins, Low-Carb Special K
- ○ Cheerios, Grape Nuts, Shredded Wheat, Wheaties, Wheat Chex
- ○ Total
- ○ Fiber One
- ○ Product 19, Complete
- ○ All Bran, Bran Buds
- ○ Other fiber cereals like Raisin Bran, Fruit-n-Fiber
- ○ Sweetened cereals like Frosted Flakes, Froot Loops
- ○ Other cold cereals, like Corn Flakes, Rice Krispies, Special K

What vitamin supplements do you take fairly regularly?

Multiple Vitamins. Did you take...	HOW OFTEN: DIDN'T TAKE	A FEW DAYS per MONTH	1-3 DAYS per WEEK	4-6 DAYS per WEEK	EVERY DAY	FOR HOW MANY YEARS? LESS THAN 1 YEAR	1 YEAR	2 YEARS	3-4 YEARS	5-9 YEARS	10+ YEARS
Prenatal vitamins	○	○	○	○	○	○	○	○	○	○	○
Regular Once-A-Day, Centrum, Theragran, "senior" vitamins or house brands of multiple vitamins	○	○	○	○	○	○	○	○	○	○	○
Stress-tabs or B-Complex type	○	○	○	○	○	○	○	○	○	○	○
Single Vitamins, not part of multiple vitamins											
Vitamin A (not beta-carotene)	○	○	○	○	○	○	○	○	○	○	○
Beta-carotene	○	○	○	○	○	○	○	○	○	○	○
Vitamin C	○	○	○	○	○	○	○	○	○	○	○
Vitamin E	○	○	○	○	○	○	○	○	○	○	○
Folic Acid, Folate	○	○	○	○	○	○	○	○	○	○	○
Calcium or Tums	○	○	○	○	○	○	○	○	○	○	○
Vitamin D, alone or combined with calcium	○	○	○	○	○	○	○	○	○	○	○
Zinc	○	○	○	○	○	○	○	○	○	○	○
Iron	○	○	○	○	○	○	○	○	○	○	○
Selenium	○	○	○	○	○	○	○	○	○	○	○
Omega-3, fish oil, flax seed oil	○	○	○	○	○	○	○	○	○	○	○

If you took Once-a-day, Centrum or Thera-type multiple vitamins, did you usually take types that
○ contain minerals, iron, zinc, etc. ○ do not contain minerals ○ Don't know

If you took vitamin C, how many milligrams of **vitamin C** did you usually take, on the days you took it?
○ 100 ○ 250 ○ 500 ○ 750 ○ 1000 ○ 1500 ○ 2000 ○ 3000+ ○ Don't know

If you took vitamin E, how many IUs of **vitamin E** did you usually take, on the days you took it?
○ 100 ○ 200 ○ 300 ○ 400 ○ 600 ○ 800 ○ 1000 ○ 2000+ ○ Don't know

Did you take any of these supplements at least once a week?
○ Ginkgo ○ St. John's Wort ○ Echinacea ○ DHEA ○ Didn't take these
○ Ginseng ○ Kava Kava ○ Melatonin ○ Glucosamine/Chondroitin

SOME LAST QUESTIONS ABOUT YOU

Would you say your health is ○ Excellent ○ Very good ○ Good ○ Fair ○ Poor

Are you currently trying to lose weight? ○ Yes ○ No

Was there ever a time in your life when you often drank more beer, wine or liquor than you do now? ○ Yes ○ No

Do you smoke cigarettes now? ○ Yes ○ No
IF YES, On average about how many cigarettes a day do you smoke now? ○ 1-5 ○ 6-14 ○ 15-24 ○ 25-34 ○ 35+

Are you ○ Hispanic or Latino ○ Not Hispanic or Latino

What race do you consider yourself to be? (MARK ALL THAT APPLY)
○ White ○ Asian ○ Native Hawaiian or Other Pacific Islander
○ Black or African American ○ American Indian or Alaska Native ○ Do not wish to provide this information

Thank you very much for filling out this questionnaire.
Please take a minute to go back and fill in anything you may have skipped.

PLEASE DO NOT WRITE IN THIS AREA

SERIAL #

B2. GAT items to calculate HES-5 and candidate HES-5+ scores

a. HES-5 components:

21 [[Nutrition] 01-04]

Think about the past 30 days.

Examples (Note: only a few examples of each are listed to remind you of the types of food in each category - many more are possible):

FRUIT - ***fresh, frozen, canned or dried, or 100% fruit juices. A serving is 1 cup of fruit, or 1/2 cup of fruit juice***

VEGETABLES - ***fresh, frozen, canned, cooked or raw: dark green vegetables (broccoli, spinach, most greens), orange vegetables (carrots, sweet potatoes, winter squash, pumpkin), legumes (dry beans, chick peas, tofu), starchy vegetables (corn, white potatoes, green peas), and other (tomatoes, cabbage, celery, cucumber, lettuce, onions, peppers, green beans, cauliflower, mushrooms, summer squash, etc). A serving is 1 cup of raw vegetables, or ½ cup of cooked vegetables***

WHOLE GRAINS - ***rye, whole wheat, or heavily seeded bread, brown or wild rice, whole wheat pasta or crackers, oatmeal, or corn tacos. A serving is 1 slice of bread, or ½ cup of grains***

DAIRY - ***regular/whole fat milk; low or reduced fat milk (2%, 1%, 1/2 % or skim), yogurt, cottage cheese, low fat cheese, frozen low fat yogurt, soy milk or other calcium fortified foods (orange juice, soy/rice milk, breakfast cereals, etc). A serving is 8 ounces of liquid or 1 ounce of cheese***

How often did you eat/drink the following foods/beverages?

Please select one response per row.

*

Please choose the appropriate response for each item:

	4 or More Servings per Day	2 to 3 Servings per Day	1 Serving per Day	3 to 6 Servings per Week	1 or 2 Servings per Week	Rarely or Never	No Answer
FRUIT	○	○	○	○	○	○	○
VEGETABLES	○	○	○	○	○	○	○
WHOLE GRAINS	○	○	○	○	○	○	○
DAIRY	○	○	○	○	○	○	○

25 [[Nutrition] 08]

Think about the past 30 days.

How often did you eat the following food?

*

Please choose the appropriate response for each item:

	4 or More Times per Week	2 to 3 Times per Week	1 Time per Week	2 Times per Month	1 Time per Month	Rarely or Never	No Answer
FISH: tuna, salmon, or other non-fried fish.	○	○	○	○	○	○	○

b. Candidate HES-5+ items from the GAT:

22 [[Nutrition] 05]Think about the past 30 days. *

Please choose the appropriate response for each item:

	7 Times per Week	6 Times per Week	4 to 5 Times per Week	2 or 3 Times per Week	1 Time per Week	Never	No Answer
How many times per week do you eat breakfast?	○	○	○	○	○	○	○

24 [[Nutrition] 07]Think about the past 30 days. *

Please choose the appropriate response for each item:

	Most of the Time	Often	Sometimes	Rarely	Never	Not Applicable (do not participate in strenuous exercise sessions)	No Answer
RECOVERY FUELING: Do you typically consume a healthy snack within 60 minutes after a strenuous exercise session? (Examples include 1 piece of fruit, a handful of nuts, 1 small yogurt container, 1 cup of milk, 1 granola bar, or 1 sports bar)	○	○	○	○	○	○	○

Appendix C. Aim 2: Correlations between the HEI-2015, HES-5, and candidate HES-5+ scores

Supplemental Table. Pearson correlations between HEI-2015 and all candidate HES-5+ scores among CHAMP's CSF military participants (N=333)[1]

	Total (N=333)	**Male** (N=247)	**Female** (N=86)
	r	**r**	**r**
Corr HEI-2005 vs. HES-5	0.42	0.46	0.30[3]
Corr HEI-2015 vs.:			
HES-5	**0.41**	**0.45**	**0.32**[3]
HES-6:			
+ RFsnack-A	0.45	0.48	0.38[2]
+ RFsnack-B	**0.46**	**0.48**	**0.39**[2]
+ Breakfast	0.44	0.46	0.39[2]
+ SSB-8	**0.51**	**0.53**	**0.41**
+ SSB-12	0.50	0.53	0.41
HES-7			
+ Breakfast & RFsnack-A	0.47	0.49	0.43
+ Breakfast & RFsnack-B	0.48	0.49	0.44
+ SSB8 & RFsnack-A	0.53	0.55	0.46
+ SSB8 & RFsnack-B	**0.53**	**0.55**	**0.47**
+ SSB12 & RFsnack-A	0.53	0.55	0.46
+ SSB12 & RFsnack-B	0.53	0.55	0.47
+ Breakfast & SSB-8	0.49	0.50	0.44
+ Breakfast & SSB-12	0.49	0.50	0.44
+ Breakfast & SSB-8	0.53	0.54	0.46
+ Breakfast & SSB-12	0.52	0.54	0.46
HES-8			
+ Breakfast, RFsnack-A, SSB-8	0.55	0.56	0.49
+ Breakfast, RFsnack-B , SSB-8	**0.55**	**0.56**	**0.50**
+ Breakfast, RFsnack-A, SSB-12	0.54	0.55	0.49
+ Breakfast, RFsnack-B , SSB-12	0.55	0.56	0.50

[1] Corr, correlation; HES-5, 5-item Healthy Eating Score; HES-6, 6-item Healthy Eating Score; HES-7, 7-item Healthy Eating Score, HES-8, 8-item Healthy Eating Score, RFsnack-A, post-exercise recovery fueling snack with scoring option A; RFsnack-B, post-exercise recovery fueling snack with scoring option B; SSB-8, sugar-sweetened beverages with 8-oz/serving; SSB-12, sugar-sweetened beverages with 8-oz/serving. Unless noted all p-values were <0.0001

[2] p<0.001

[3] p<0.01

Appendix D. CACHE Toolkit Questions

D1. CACHE Toolkit Survey Questions

For the survey questions) below, answer choices, unless otherwise noted, utilize a 5-point Likert scale: Strongly disagree, Disagree, Neutral, Agree, Strongly Agree

1. What is your date of birth? (this information will only be used to determine changes in responses, but not identify you as an individual).

    a. Month (MM) _____
    b. Day (DD) _____
    c. Year (YYYY) _____

2. At which installation are you located? (*A list of installations was provided to choose from*)

3. How often do you attend your Army installation's Community Health Promotion Council (CHPC) or Air Force installation's Community Action Information Board (CAIB) meetings?

    - Never
    - Rarely
    - Sometimes
    - Always

4. Will you participate in the CACHE working group?

    - Yes
    - No
    - We haven't determined our working group yet

5. Have you, to date, attended any formal training on the tools in CACHE?

    - Yes
    - No

.

How strongly do you agree or disagree with the following statements?

6. I have a strong understanding of how the built environment impacts nutrition.

7. I have a strong understanding of how the built environment impacts physical activity.

8. I have a strong understanding of how the built environment impacts tobacco use.

Please choose the answer which is most true.

9. Which of the following responses reflects the most mature stage of tobacco policy use?

    - Not identified as a problem
    - Evaluation of policy adherence
    - Policy formulation and adoption

- Problem identification/gaining agenda status
- Policy implementation
- I don't know

10. Which of the following planning documents are used in planning the built environment?

- IDG
- Master Plan
- Area Development Plan
- Master Plan and Area Development Plan
- IDG, Master Plan and Area Development Plan
- I don't know

11. Which of the following is NOT considered part of the food environment?

- Types of food outlets available
- Price of food
- Sanitation grade of restaurants
- Community gardens available
- I don't know

12. Which of the following is NOT considered part of the physical activity environment?

- Street lighting
- Weather of community
- Public transportation
- Quality of playground equipment
- I don't know

13. Which of the following is NOT considered part of the tobacco environment?

- Smoking policy in public places
- Popularity of smoking among teens
- Price of cigarettes in the community
- Cessation tools available in the community
- I don't know

How strongly do you agree or disagree with the following statements?

14. The food environment has an impact on what people eat in my community.

15. The physical activity environment has an impact on how much people exercise in my community.

16. The tobacco environment has an impact on the tobacco use of people in my community.

17. Evaluating the food environment can guide change to improve the availability of healthy food on my installation.

18. Evaluating the physical activity environment can guide change to increase opportunities for physical activity on my installation.

19. Evaluating the tobacco environment can guide change to improve the ability for tobacco-free living on my installation.

20. The food environment on my installation promotes healthy eating.

21. The physical activity environment on my installation promotes exercise.

22. The tobacco environment on my installation promotes tobacco-free living.

How strongly do you agree or disagree with the following statements?

23. The CHPC [U.S. Army Community Health Promotion Council] or CAIB [Community Action Information Board] on my installation has the ability to improve the built environment for healthy living on my installation.

24. The CACHE Coalition has the ability to improve the built environment for healthy living on my installation.

25. I have the ability to improve the built environment for healthy living on my installation.

26. It is my leadership's priority to improve the built environment for healthy eating.

27. It is my leadership's priority to improve the built environment for physical activity.

28. It is my leadership's priority to improve the built environment for tobacco-free living.

29. Is there anything else you'd like to share about CACHE?

D2. CACHE Toolkit Focus Groups and Interview Questions

1. What did you view as your role in CACHE?
2. Who was involved in completing the CACHE? Why were those individuals selected and/or involved?
3. Which tools were the most challenging to complete? Which tools were the least challenging? Why? What would you have needed in order to complete the tools easily?
4. Thinking through all sections of the tools, which parts were the most relevant to making change at your installation? What parts of the CACHE will be the greatest influence for chance? Which tools/sections were the least relevant? Why do you think so?
5. What leadership at your installation was informed about CACHE? How where they informed? What was briefed? What was their response to the CACHE?
6. What aspects of the m-NEAT do you believe can be improved the most and why? What aspects of the PAC do you believe can be improved the most and why? What aspects of the QITS do you believe can be improved the most and why?
7. How can Public Health Command improve the process of collecting data for CACHE? What resources would be helpful to CACHE facilitators?
8. What advice would you give other installations completing the CACHE? What surprised you most about collecting data for CACHE? What are your biggest lessons learned from the process?
9. We are expecting a lot of change to this CACHE Toolkit after this pilot. In fact, everything in the CACHE and supporting materials can change. Based on your experience, what do you think should change?

Now we'll talk a bit about your CACHE action plan.

10. Tell us about creating the CACHE coalition. How have you used the working group? How were people brought on to the working group? How would you rate their level of engagement/interest in making changes to the built environment?
11. We'd like to learn about the action plan recommendations that PHC provided you. What'd you think about the recommendations? Were you surprised by any? What do you think of the level of detail that was provided? How did you use or not use these recommendations?
12. What is the status of your action plan? (Prompt: What items have been started? What items have been completed? What items are on schedule, and what items are off schedule?)
13. What are the facilitators to implementing this action plan? (Prompts: Time, people, willingness to change, enthusiasm for work)
14. What are the barriers to implementing this action plan? (Prompts: Time, people, willingness to change, enthusiasm for work)

15. How do you feel about the progress made on your action plan? (Prompts: Are you surprised by the progress you've made? Are you surprised by the lack of progress you've made?)
16. What advice would you give to other installations who want to complete the CACHE/develop an action plan/implement an action plan?
17. How has the food/physical activity/tobacco environment changed on your installation?
18. Do you feel that you personally have a better understanding of the built environment on your installation? Do you think that your workgroup/leadership has a greater understanding? Do you feel that this is important? How?
19. What policy changes, if any, have been made on your installation regarding food/physical activity/tobacco that were not prompted by the CACHE action plan?
20. What environmental changes, if any, have been made on your installation regarding food/physical activity/tobacco that were not prompted by the CACHE action plan?