RAND CORPORATION

Research Report

SEAN ROBSON, MATTHEW WALSH, MIRIAM MATTHEWS, CARRA S. SIMS, JOSHUA SNOKE

Is Today's U.S. Air Force Fit?

It Depends on How Fitness Is Measured

Physical fitness is an important element of military readiness and is the responsibility of every airman (Department of Defense Directive [DoDD] 1308.1, 2004; DoDD 1308.2, 2005). Reflected in U.S. Department of Defense (DoD) and U.S. Air Force (USAF) policies, physical fitness is viewed as "a vital component of combat readiness [that] is essential to the general health and well being for Armed Forces personnel" (DoDD 1308.2, 2005, p. 2). DoD's position is firmly grounded and supported by decades of research that has established clear linkages between physical fitness and a wide variety of adverse health outcomes, such as hypertension and heart disease (Benjamin et al., 2018; Jayedi et al., 2018). Obesity is associated with higher rates of injuries among active duty personnel and contributes to illnesses that cost DoD about $1.5 billion annu-

KEY FINDINGS

- Physical fitness is vital to military readiness and linked to a wide variety of health outcomes, such as hypertension and heart disease, sleep, cognitive functioning, and mental health.
- Since 2012, less than 1 percent of airmen have exceeded the U.S. Air Force (USAF) abdominal circumference (AC) standards.
- On average, airman fitness has been improving over time.
  - The average AC has been decreasing over time.
  - The average 1.5-mile run time has steadily decreased through 2016.
  - The average number of push-ups and sit-ups completed during regular USAF fitness assessments has increased.
- Conclusions about healthy body composition depend heavily on the specific measure and standard being used.
  - Body mass index classifies 60 percent of airmen as overweight or obese.
  - Waist-to-height ratio indicates that between 14 and 22 percent of airmen have an increased risk of an adverse health condition.
  - AC indicates that less than 1 percent of airmen are at an increased risk of an adverse health condition.
- It is possible that each fitness measure assesses an independent risk factor, and the metrics should be considered together when evaluating the health and fitness of the force.

ally to treat.[1] Research has also shown that physical exercise and fitness have other benefits with ties to improved sleep, cognitive functioning, and mental health (Kredlow et al., 2015; Papasavvas et al., 2016; Fernandes M. de Sousa et al., 2019; Correll, 2020).

Considering the role of fitness in promoting general health and well-being, the Department of the Air Force asked the RAND Corporation to evaluate its Tier 1 fitness assessment. As part of this evaluation, we compare results from the 2018 DoD Health Related Behaviors Survey with data collected as part of the regular USAF fitness assessment. This type of comparison is needed to ensure that policymakers have a more accurate and comprehensive understanding of the current fitness levels of today's airmen. Otherwise, resources and policies could be applied in ways that are misaligned with program objectives. That is, resources could be used to address problems that may not truly exist.

This Report Compares Common Fitness Metrics

This report focuses on measures used to monitor the general fitness of airmen, which guide personnel actions and reports on the health of the force. Data from the 2018 DoD Health Related Behaviors Survey indicated that almost 50 percent of today's airmen are overweight and as many as 13.5 percent are obese (Meadows et al., 2021). Notably, these estimates were based on survey responses from a sample of airmen who reported their own height and weight. Although using surveys to collect health information can be a reasonable approach when objective measures (e.g., medical data) are either unavailable or difficult to obtain, self-reported data can be prone to error and influenced by social desirability bias. Another limitation is that obesity estimates based on body mass index (BMI) can be misleading as a standalone measure of fitness.

To provide a more comprehensive evaluation of fitness, we examined airmen fitness between 2005 and 2018 as part of a larger study evaluating linkages between fitness and health outcomes. Specifically, we conducted statistical analyses using data collected on airmen at least once a year during their regular fitness evaluations.[2] We used these data, consisting of more than 4 million observations, to explore the accuracy of overweight and obesity estimates provided in recent reports. In addition, we report on the status and analyze trends of other fitness measures used by USAF and available in the data, including body composition, cardiorespiratory fitness, and muscular fitness. Our analyses focus specifically on fitness measures as indicators of health risk. Other factors to consider when evaluating fitness measures, such as perceived fairness and measure reliability, are beyond the scope of this report (Hall et al., 2019; Robson et al., 2021).

We present evidence to suggest that BMI, although commonly used as a sole indicator of overweight or obesity status in surveys and health assessments, can be misleading when used alone. Specifically, BMI may misclassify service members as overweight or obese when they are not; it may be less accurate than other easily obtained measures, such as abdominal circumference (AC) or waist-to-height ratio (WHtR); it points to negative fitness trends, while other fitness metrics suggest that fitness has improved over the same period; and it could be combined with other body composition measures to provide a more accurate assessment of health risk across subgroups (e.g., gender, race). Unless otherwise indicated, figures in this report present our analysis based on data from the USAF fitness assessments from fiscal year (FY) 2005 through FY 2019.

Abbreviations

AC	abdominal circumference
BMI	body mass index
CDC	Centers for Disease Control and Prevention
DoD	U.S. Department of Defense
DoDD	Department of Defense Directive
FY	fiscal year
USAF	U.S. Air Force
WHtR	waist-to-height ratio

BMI Alone Can Be Misleading

There is a long history of developing and refining categories to differentiate healthy and unhealthy weight levels. The current concepts and definitions used to classify people as *overweight* or *obese* are based on BMI,[3] which is calculated using a person's height and weight. Table 1 contains example BMI and CDC categories for different combinations of height and weight.

From 2017 to 2018, 40 percent of the U.S. population ages 20–39 was obese according to BMI (Hales et al., 2020). Moreover, estimates indicate that the prevalence of obesity in the United States has been steadily increasing over the past decade from 31 percent in 2000 to 42 percent in 2018. Although USAF does not use BMI as part of its Tier 1 fitness assessment, obesity rates based on BMI are often reported by the media. Classifying airmen by CDC categories, Figure 1 illustrates three main findings: (1) The percentage of overweight or obese airmen has changed very little over the past decade, (2) the percentage of overweight or obese male airmen is greater than the percentage of overweight or obese female airmen, and (3) the overall percentages of overweight or obese airmen are generally consistent with recent survey results. That is, CDC categories indicate that more than 50 percent of today's airmen are overweight or obese. In 2018, 14 and 50 percent of male airmen would be classified as overweight and obese, respectively, and 10 and 38 percent of female airmen would be classified as overweight and obese, respectively.

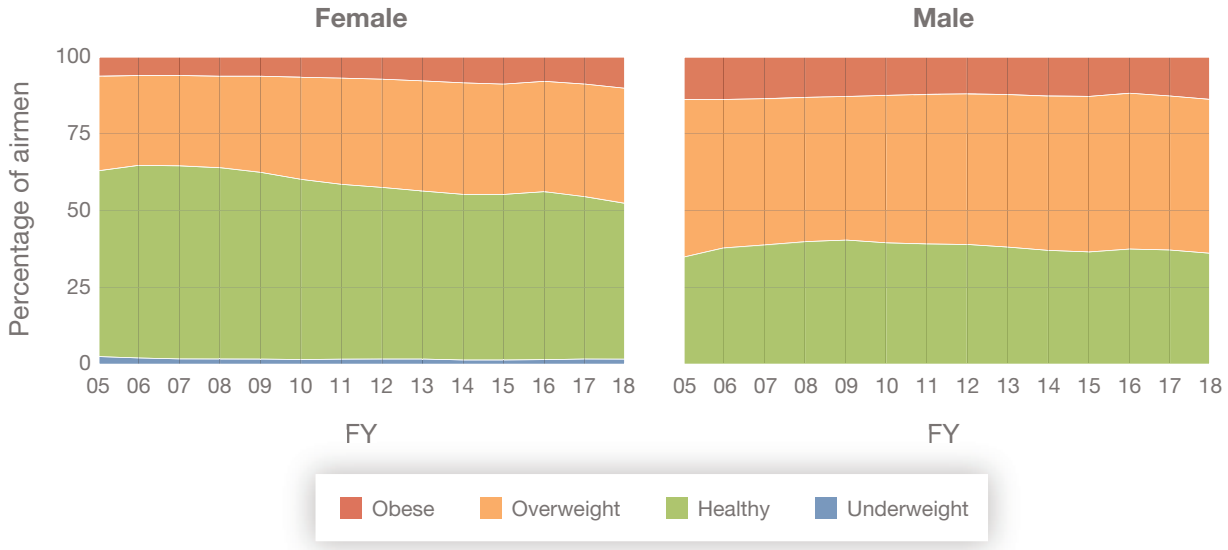
Although these findings may raise concerns, BMI as a stand-alone measure can be misleading. The CDC notes that "for individuals, BMI is [a] screening tool, but it does not diagnose body fatness or health" (CDC, 2021). This is not the only limita-

TABLE 1
Example BMI and CDC Categories

Height	Weight	BMI	CDC Category
5'5"	110 lb	18.3	Underweight
	130 lb	21.6	Healthy
	150 lb	25.0	Overweight
	180 lb	30.0	Obese
5'11"	130 lb	18.1	Underweight
	150 lb	20.9	Healthy
	180 lb	25.1	Overweight
	220 lb	30.7	Obese

SOURCE: CDC, 2021.

FIGURE 1
Change in BMI for USAF Active Component (FY 2005–FY 2018)



tion of BMI. Rothman (2008, p. 556) notes that "as a measure of body fat . . . BMI has serious flaws."

Two critical limitations of BMI are widely recognized among health experts:

- First, BMI does not differentiate between fat mass and other characteristics contributing to a person's weight, such as muscle and bone. Consequently, individuals with large muscle mass relative to fat can be misclassified as being overweight or even obese. Furthermore, at any given BMI level, there is wide variation in actual percentages of body fat. Therefore, individuals with widely different body fat percentages may have the exact same BMI. The strength of the relationship between body fatness and BMI may also vary across racial groups; for example, Black individuals generally have less body fat at a given BMI compared to White individuals (Wagner and Heyward, 2000).
- Second, BMI does not account for the location of fat distribution in the body. Research has shown that central adiposity (abdominal fat) results in higher risk of adverse health conditions compared with fat located in lower regions of the body (e.g., thighs).

Recognizing some of these limitations, researchers have suggested that using BMI to estimate rates of overweight and obese military personnel may be imprecise, especially for military personnel who are physically fit (Meadows et al., 2018). Addressing results from the 2015 DoD Health Related Behaviors Survey on which recent media reports have relied, specifically, researchers noted that "muscular service members may have been misclassified as overweight or obese" (Meadows et al., 2018, p. 47). *Consequently, any conclusions based solely on BMI may be insufficient to guide policy decisions about airmen's health and fitness.*

Furthermore, to the extent that muscle mass varies by career field, BMI and alternative measures such as WHtR (discussed later in this report) may lead to different classifications of individuals as *overweight* in different career fields. Table 2 shows the percentage of officers by career group classified as overweight based on BMI (greater than or equal to 25) and WHtR (greater than or equal to 0.50). Strikingly, the Special Warfare career group contained the greatest percentage of officers classified as overweight based on BMI (69 percent), but it contained the lowest percentage of officers classified as overweight based on waist-to-height ratio (15 percent).

TABLE 2

Percentage of USAF Officers by Career Group Classified as Overweight per BMI and Waist-to-Height Ratio Measures

Career Group	BMI (%)	WHtR (%)
Air Operations	58	25
Combat Support	58	30
Cyber/Intelligence	54	28
Force Modernization	54	27
Nuclear/Missile	56	20
Space Operations	58	30
Special Warfare	69	15

In Contrast to BMI, USAF Fitness Metrics Show Improvement over Time

Recognizing the criticisms of BMI, USAF requested and received a policy exemption from DoD in 2010 to replace BMI with AC as a measure of body composition. AC measures fat around the waist (central adiposity), which has been shown to be an important risk factor for several health conditions, including type 2 diabetes, high blood pressure, and cardiovascular disease (Janssen, Katzmarzyk, and Ross, 2002). USAF has adopted current CDC guidelines for cutoffs on AC (CDC, 2020), which indicate an increased risk of these conditions for females who have an AC greater than 35 inches and for males who have an AC greater than 39 inches. To promote general health and well-being, USAF uses a Tier 1 fitness assessment consisting of a 1.5-mile run, push-ups, sit-ups, and AC measurement (Table 3).

Since 2012, less than 1 percent of airmen have exceeded these gender-specific standards. Moreover, the average AC has been decreasing over time, sug-

TABLE 3

USAF Fitness Components and Measures

Component	Measure
Cardiorespiratory fitness	• 1.5-mile run
Muscular fitness	• sit-ups • push-ups
Body composition	• AC • WHtR[a] • BMI[a]

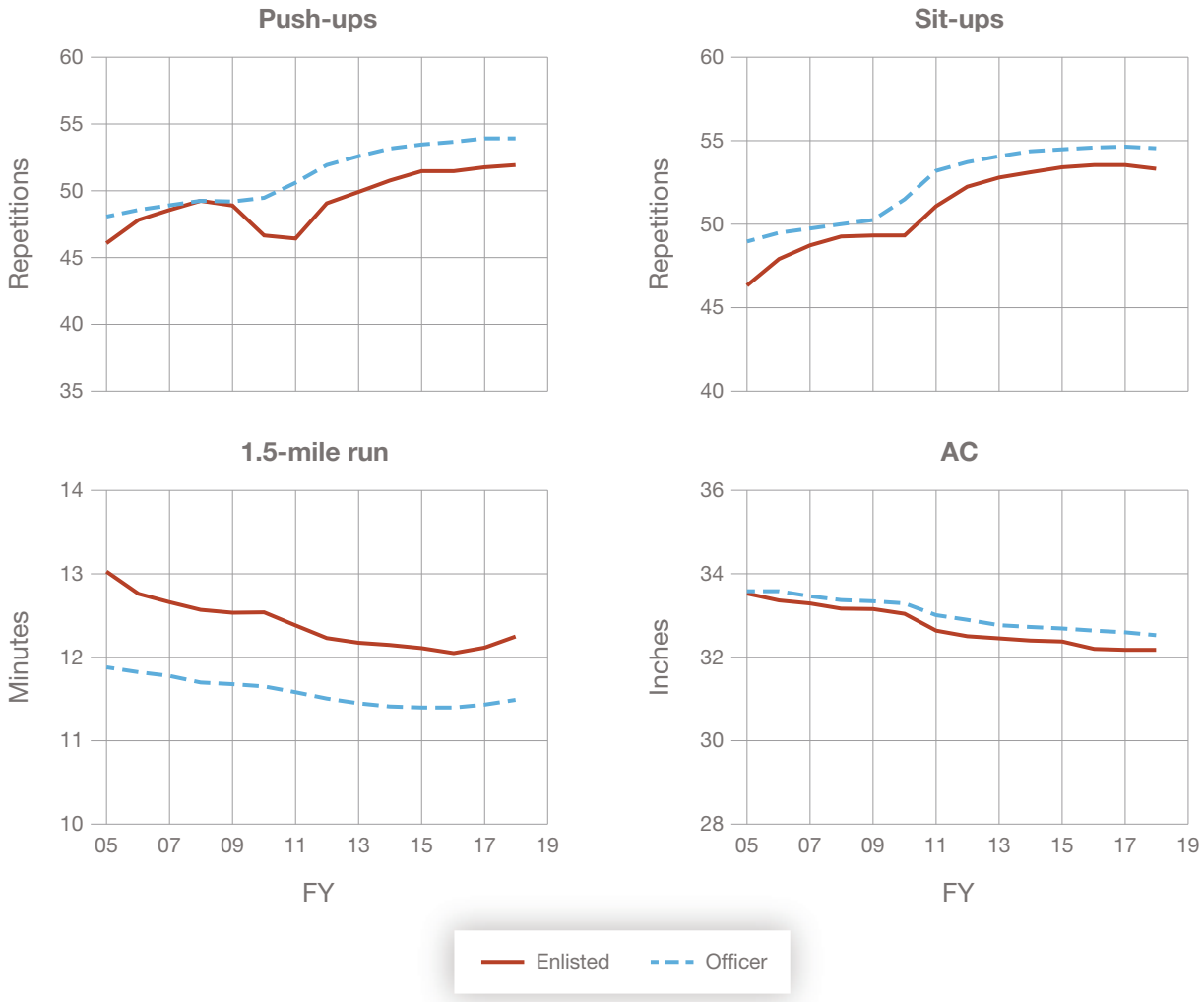
[a] Alternative measure not currently used by USAF.

gesting that USAF fitness is improving. In general, the same trends toward improved fitness are observed in measures of cardiorespiratory and muscular fitness (Figure 2). That is, the average 1.5-mile run time steadily decreased through 2016, and airmen, on average, completed more push-ups and sit-ups.

Despite these improvements, the number of exemptions for specific components has also increased during this time.[4] This increase is concerning because it raises the question of whether the apparent improvement in fitness performance could be an artifact of less-fit individuals receiving exemptions. To exclude this possibility, we repeated

FIGURE 2

USAF Fitness Assessment Results over Time (FY 2005–2018)



NOTE: USAF implemented new standards and assessment procedures in 2010, which may partially account for the relatively sharper changes in average results (e.g., enlisted push-ups in top-left panel).

the analysis using fitness results only from individuals who had *never* received a component exemption (Figure 3). Improvements in average fitness component scores for this sample of airmen resembled improvements in the USAF population.

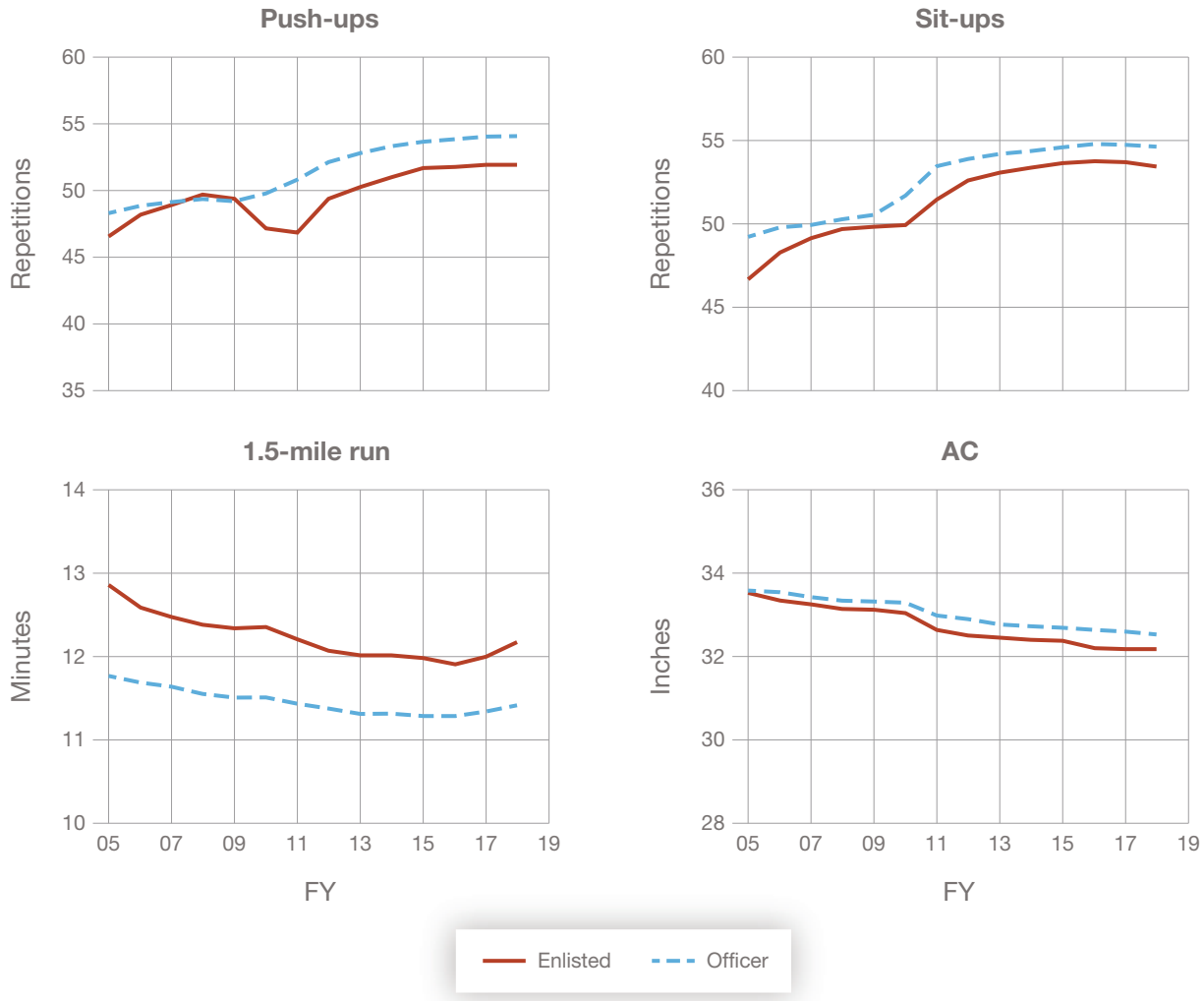
Waist-to-Height Ratio as a Measure of Body Composition Has Advantages over BMI

Although AC is a valid measure of fat accumulated around the waist, WHtR and other measures not only account for risks of increased abdominal fat but are gender-neutral. That is, a single cutoff point can be used for both males and females. General guidelines suggest that individuals with a WHtR greater than 0.5 are at an increased risk of adverse health outcomes (Ashwell and Gibson, 2016). Research also shows that WHtR can be a more effective screening measure for some health outcomes (Ashwell, Gunn, and Gibson, 2012). Considering this line of research, we calculated WHtRs using USAF assessment data as an additional indicator of fitness.

The WHtRs for female and male airmen over time illustrate trends consistent with other USAF fitness

FIGURE 3

Average Fitness Component Results for Airmen with No Exemptions (FY 2005–2018)



NOTE: USAF implemented new standards and assessment procedures in 2010, which may partially account for the relatively sharper changes in average results (e.g., enlisted push-ups in top-left panel).

measures (Figure 4). That is, the percentage of airmen meeting the recommended WHtR threshold of less than 0.5 has been improving over time. In FY 2018, the rate of airmen exceeding this threshold was 22 percent among males and 14 percent among females.

Combining Body Composition Measures Improves the Accuracy of Risk Estimates

We explored the relationship between BMI, AC, WHtR, and two health outcomes for airmen over their career using survival analysis.[5] The two health outcomes that we modeled—hypertension and musculoskeletal injuries (excluding overuse)—reflect different types of health. For fitness measures, we separated individuals into two groups per metric based on each metric's standard cutoffs.[6] We use the term *low* to indicate airmen who do not exceed the recommended cutoffs and *high* to indicate airmen who exceed the cutoffs. To assess the interplay of different body composition measures, we conducted one analysis using the interaction of AC and BMI as our predictor of interest and one with the interaction of WHtR and BMI as our predictor. We then estimated the relative risk of being in the high category for one or both health outcomes.

Figure 5 shows the results for the two different predictors and two different health outcomes. The baseline group—the individuals who do not exceed the cutoffs of either pair of measures—is shown by the vertical line at 1. A value slightly more than 2 in the top-left panel indicates that airmen who have high BMI and low AC/WHtR (in blue) have slightly more than double the risk of receiving a hypertension diagnosis compared with the risk of baseline individuals, while airmen with high BMI and high AC/WHtR (in red) have almost five times the risk relative to that of baseline individuals.

We see that all body composition measures are predictive of both health diagnoses, but different measures are more predictive for different outcomes. For example, for hypertension, failing to meet the AC or WHtR cutoffs while meeting the BMI cutoffs (shown in green) results in higher relative risk than that of those who fail to meet the BMI cutoffs but meet the AC or WHtR cutoffs (shown in blue). This is reversed for predicting the relative risk of musculoskeletal injuries. We also see that the estimates in green for individuals who fail to meet AC but meet BMI cutoffs are not precise (shown by the very wide confidence intervals) because this represents a small group of people. As shown in this report, significantly different percentages of individuals fail

FIGURE 4

Percentage of Airmen Meeting Recommended Waist-to-Height Ratio

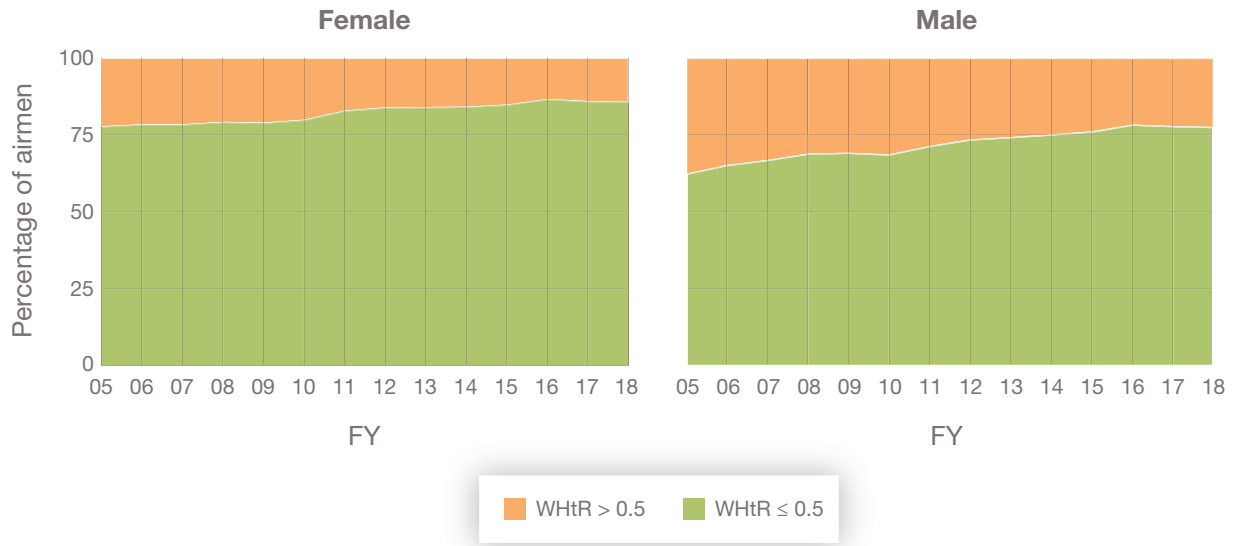
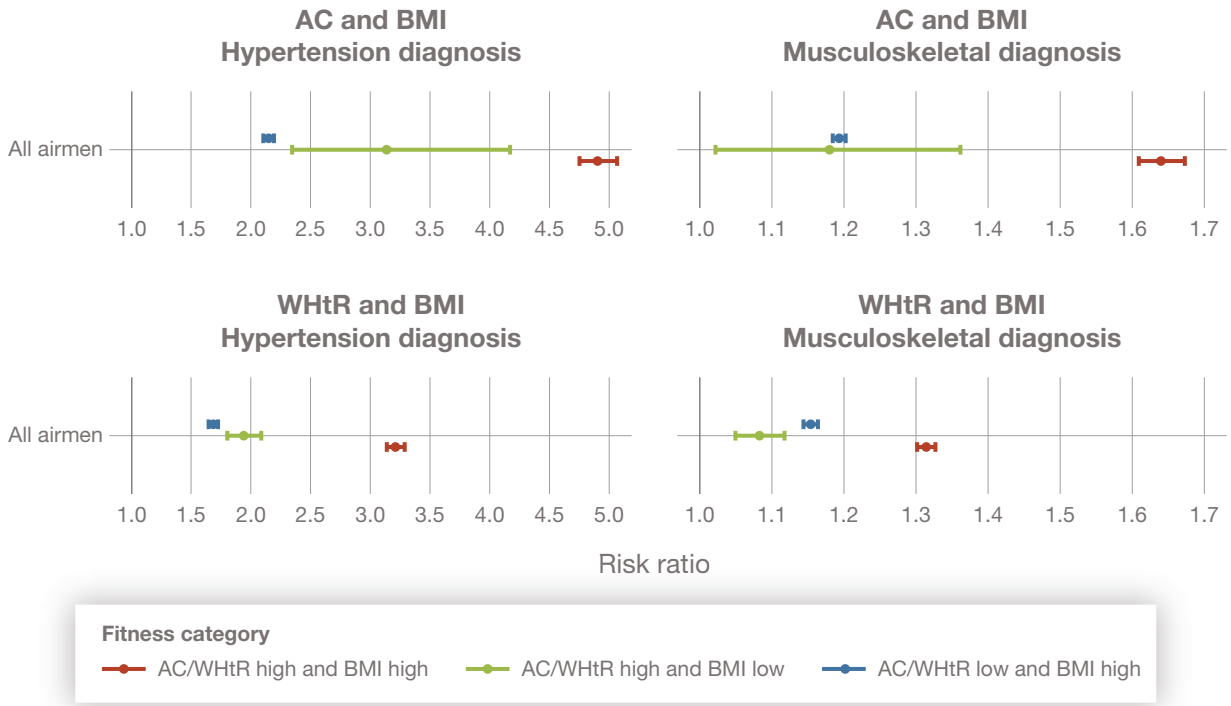


FIGURE 5

Relative Risk Estimates of Health Outcomes for All Airmen Based on Body Composition Measures



NOTE: Because the relative risk still varies by fitness category for musculoskeletal diagnosis but is less pronounced compared with increases in relative risk for hypertension diagnosis, we chose to use a different range of risk ratios to illustrate the more-subtle changes in relative risk for musculoskeletal diagnosis.

to meet the cutoffs for the three body composition measures. To some degree, the differences in relative risk may reflect different degrees of unfitness that are measured by the different types of body composition measures. In other words, failing to meet AC or WHtR cutoffs is relatively rare compared with failing to meet BMI cutoffs but potentially more severe in terms of health risks (Table 2 provides the proportions of USAF officers who meet BMI and WHtR cutoffs).

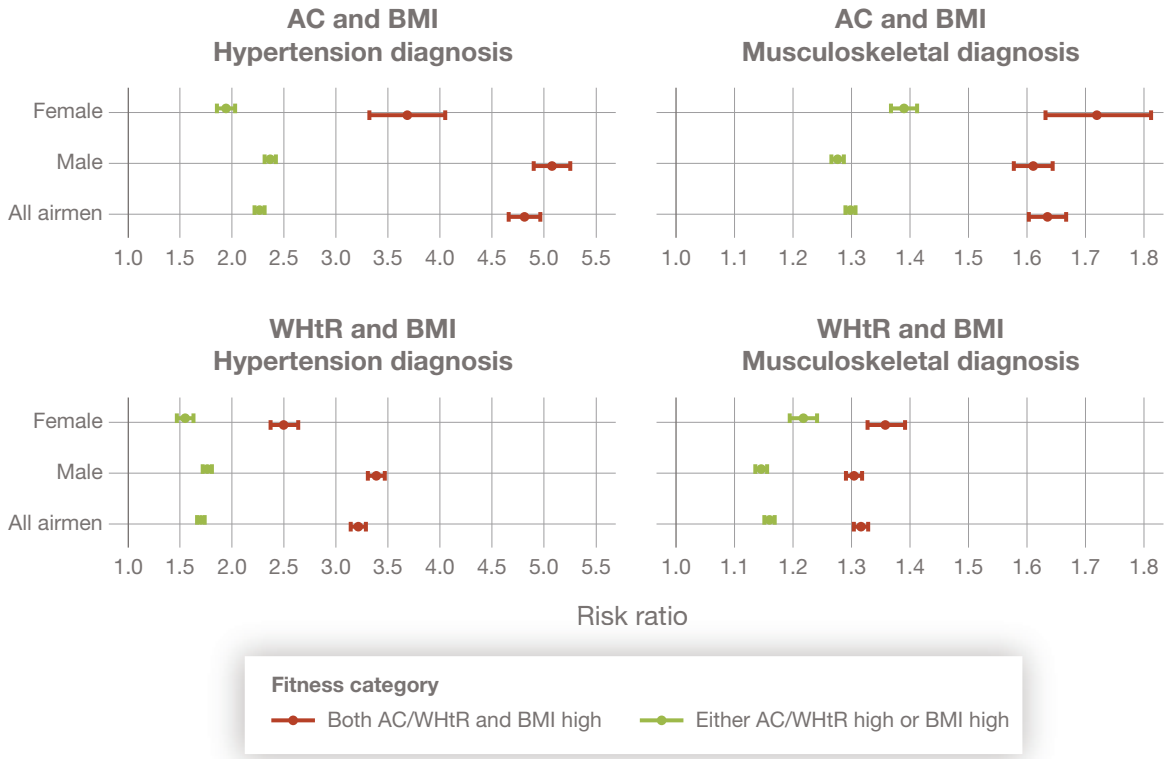
Most clearly, we see that the airmen who fail to meet cutoffs for all three measures (AC, BMI, and WHtR) have much higher relative risks (shown in red). These findings strongly suggest that there is value in using multiple measures of body composition, both because different measures are correlated with different health outcomes and because failing to meet the cutoffs of multiple measures is a clear cause for concern, more so than failing to meet the cutoffs of only one.

Next, we estimated relative risks separately for male and female airmen and for different racial and ethnic groups of airmen. Because estimates were very imprecise for smaller subgroups, we combined those who failed to meet all cutoffs (both AC/WHtR and BMI high) or failed to meet the cutoff for *either* BMI or the other measure in question (either AC/WHtR high or BMI high). Figure 6 provides the results by gender, and Figure 7 provides the results by race and ethnicity.

The findings are consistent with what we found for all airmen: The airmen who fail to meet cutoffs for multiple body composition measures show much higher relative risks than the airmen who fail to meet cutoffs for only one measure. These findings also highlight the differences in relative risk by

FIGURE 6

Relative Risk Estimates of Health Outcomes for All Airmen Based on Body Composition Measures, by Gender

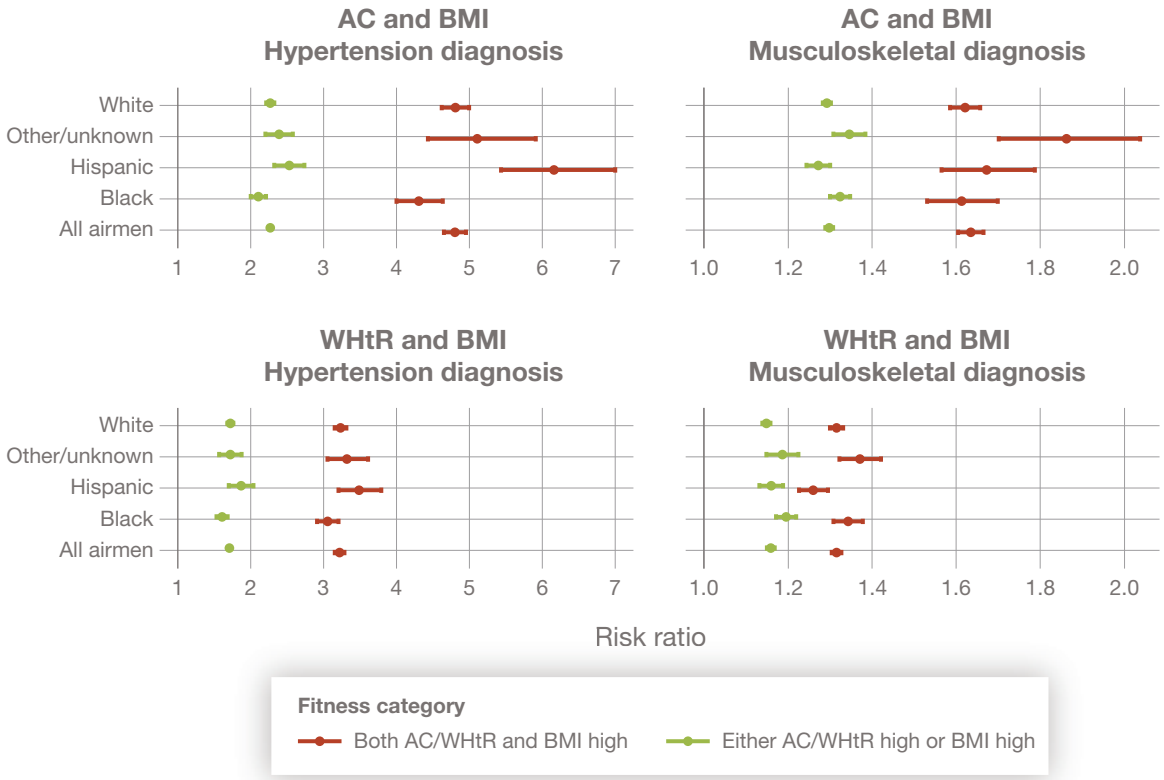


NOTE: Because the relative risk still varies by fitness category for musculoskeletal diagnosis but is less pronounced compared with increases in relative risk for hypertension diagnosis, we chose to use a different range of risk ratios to illustrate the more-subtle changes in relative risk for musculoskeletal diagnosis. N's differ between the outcome types because we did not consider airmen who had a prior diagnosis. Data indicated that 884,130 female airmen and 3,637,024 male airmen had received a hypertension diagnosis, and 497,818 female airmen and 2,214,362 male airmen had received a musculoskeletal diagnosis.

gender and by race and ethnicity. When looking only at results of all airmen, the estimates most closely reflect the risk estimates for the largest groups (i.e., male airmen and White airmen). When estimated separately, we find that failing to meet both WHtR and BMI cutoffs is related to a 2.5 times increased risk of hypertension for women, but failing to meet the same cutoffs is related to an almost 3.5 times increased risk for men. Similarly, failing to meet both AC and BMI cutoffs is associated with a 4.3 times higher risk of hypertension for Black individuals and a 6.2 times increased risk for Hispanic individuals. These results suggests that different cutoffs may be needed to be equally predictive of health risk for both men and women or for individuals of different races or ethnicities.

FIGURE 7

Relative Risk Estimates of Health Outcomes for All Airmen Based on Body Composition Measures, by Race and Ethnicity



NOTE: Because the relative risk still varies by fitness category for musculoskeletal diagnosis but is less pronounced compared with increases in relative risk for hypertension diagnosis, we chose to use a different range of risk ratios to illustrate the more-subtle changes in relative risk for musculoskeletal diagnosis. N's differ between the outcome types because we did not consider airmen who had a prior diagnosis. The breakdown for hypertension diagnoses by racial/ethnic group is as follows: 3,089,163 White; 307,186 other/unknown; 483,163 Hispanic; and 641,642 Black airmen. The breakdown for musculoskeletal diagnoses by racial/ethnic group is as follows: 1,862,064 White; 187,846 other/unknown; 284,711 Hispanic; and 377,559 Black airmen.

Conclusions and Recommendations

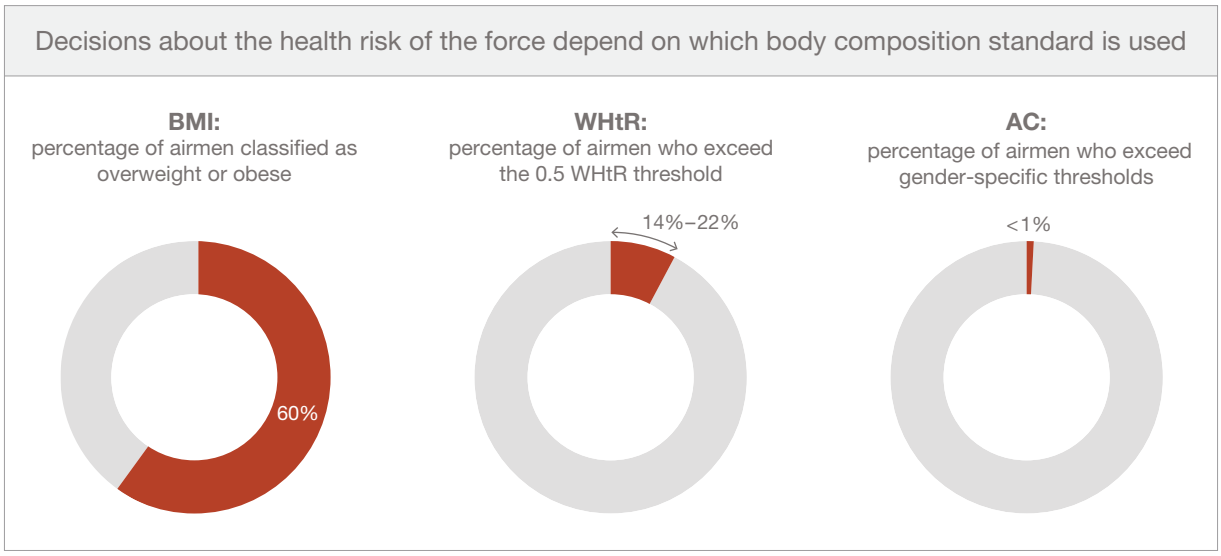
Using only BMI, we would conclude that airmen appear to be generally unfit and have been for more than a decade. However, when we examine muscular fitness, cardiorespiratory fitness, and alternative measures of body composition, we conclude that USAF fitness, on average, has been improving over time. Furthermore, conclusions about healthy body composition depend heavily on the specific measure and standard being used (Figure 8).

Some public health guidelines suggest using a combination of different measures. We recommend that USAF continues to use AC in combination with other body composition metrics, such as WHtR and BMI. Given CDC caveats, documented criticism, and evidence from our analyses, we recommend that *BMI should not be used alone as a diagnostic tool to indicate health risk or to report on the health of the force*. Using BMI alone, as the media and others commonly do, can lead to very different and potentially inaccurate conclusions about airman fitness. That is, BMI may systematically misclassify a large portion of USAF as overweight. Other USAF measures that assess cardiorespiratory and muscular fitness should also be used in conjunction with body composition measures to gain a more comprehensive understanding of the force's health and fitness.

Future analysis should explore which combination of fitness measures are most predictive of important health outcomes. As we demonstrated with body

FIGURE 8

Differences in the Percentage of Airmen Exceeding Body Composition Measure Cutoffs, by Standard



composition, different fitness measures may assess independent risk factors and should be considered together when evaluating the health and fitness of the force. However, even the best fitness measures are still imperfect markers of health and may require different interpretations of health risk for airmen from different demographic groups. Therefore, direct measures should be used to confirm the accuracy of inferences suggested by the results of a fitness assessment. As a final note, airmen are facing new challenges and limitations to their health and fitness because of the COVID-19 pandemic, such as reduced access to gyms and increased requirements to stay inside, so it remains to be seen what impact the pandemic may have on the positive trends observed over the past decade. The pandemic has only highlighted the fact that it is essential to have a better understanding of the health and fitness of airmen, and future analyses should explore which combination of fitness measures is most predictive of adverse health outcomes.

Notes

[1] This cost estimate includes treating current and former service members and their families (National Center for Chronic Disease Prevention and Health Promotion, 2021).

[2] Current USAF policy requires all airmen to complete a fitness assessment at least once a year.

[3] The Centers for Disease Control and Prevention (CDC) provides the definition of BMI as "a person's weight in kilograms divided by the square of height in meters. A high BMI can be an indicator of high body fatness." The CDC lists four categories based on BMI (CDC, 2021):

- underweight = < 18.5
- healthy weight = 18.5–24.9
- overweight = 25–29.9
- obesity = 30 or greater.

[4] USAF provides specific exemptions (e.g., 1.5-mile run exemption) or exemptions from the entire fitness assessment for medical reasons (e.g., injury), pregnancy, or deployment. Commanders also have the authority to grant exemptions, but the specific reasons for these exemptions must be documented in the Air Force Fitness Management System.

[5] Cox models were estimated using time-varying observations for an airman's fitness that were updated each time fitness was measured. The outcomes were measured as the first diagnosis after the airman's first fitness assessment. Models were estimated with control stratification variables of gender, race, rank type, ever deployed, and age.

[6] USAF AC cutoff is 35.5 inches (versus the CDC cutoff of 35 inches) to account for rounding, which is specified in policy and needed when we computed these groups. Our low and high groupings for each body composition metric are as follows:

- BMI categories of underweight and healthy weight (low) versus overweight and obese (high)
- AC of ≤ 35.5 inches for females and ≤ 39 inches for males (low) versus > 35.5 inches for females and > 39 inches for males (high)
- WHtR of ≤ 0.5 (low) versus > 0.5 (high).

References

Ashwell, Margaret, and Sigrid Gibson, "Waist-to-Height Ratio as an Indicator of 'Early Health Risk': Simpler and More Predictive Than Using a 'Matrix' Based on BMI and Waist Circumference," *BMJ Open*, Vol. 6, No. 3, March 14, 2016, pp. 1–7.

Ashwell, Margaret, Pippa Gunn, and Sigrid Gibson, "Waist-to-Height Ratio Is a Better Screening Tool Than Waist Circumference and BMI for Adult Cardiometabolic Risk Factors: Systematic Review and Meta-Analysis," *Obesity Reviews*, Vol. 13, No. 3, March 2012, pp. 275–286.

Benjamin, Emelia J., Salim S. Virani, Clifton W. Callaway, Alanna M. Chamberlain, Alexander R. Chang, Susan Cheng, Stephanie E. Chiuve, Mary Cushman, Francesca N. Delling, Rajat Deo, et al., "Heart Disease and Stroke Statistics—2018 Update: A Report from the American Heart Association," *Circulation,* Vol. 137, No. 12, March 20, 2018, pp. e67–e492.

CDC—*See* Centers for Disease Control and Prevention.

Centers for Disease Control and Prevention, "Assessing Your Weight," webpage, September 17, 2020. As of December 3, 2020: https://www.cdc.gov/healthyweight/assessing/index.html

———, "Defining Adult Overweight & Obesity," webpage, June 7, 2021. As of February 12, 2021: https://www.cdc.gov/obesity/adult/defining.html

Correll, Diana Stancy, "Can Digital Fitness Coaching Get Airmen in Shape? The Air Force Wants to Know," *Air Force Times*, February 24, 2020.

Department of Defense Directive 1308.1, *DoD Physical Fitness and Body Fat Program*, Washington, D.C.: U.S. Department of Defense, June 30, 2004.

Department of Defense Directive 1308.2, *Joint DoD Committee on Fitness*, Washington, D.C.: U.S. Department of Defense, February 4, 2005.

Fernandes M. de Sousa, Arilson, André R. Medeiros, Sebastián Del Rosso, Matthew Stults-Kolehmainen, and Daniel A. Boullosa, "The Influence of Exercise and Physical Fitness Status on Attention: A Systematic Review," *International Review of Sport and Exercise Psychology*, Vol. 12, No. 1, 2019, pp. 202–234.

Hales, Craig M., Margaret D. Carroll, Cheryl D. Fryar, and Cynthia L. Ogden, *Prevalence of Obesity and Severe Obesity Among Adults: United States, 2017–2018*, Washington, D.C.: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Health Statistics, NCHS Data Brief No. 360, February 2020.

Hall, Kimberly Curry, Kirsten M. Keller, David Schulker, Sarah Weilant, Katherine L. Kidder, and Nelson Lim, *Improving Gender Diversity in the U.S. Coast Guard: Identifying Barriers to Female Retention*, Homeland Security Operational Analysis Center operated by the RAND Corporation, RR-2770-DHS, 2019. As of July 31, 2021: https://www.rand.org/pubs/research_reports/RR2770.html

Janssen, Ian, Peter T. Katzmarzyk, and Robert Ross, "Body Mass Index, Waist Circumference, and Health Risk: Evidence in Support of Current National Institutes of Health Guidelines," *Archives of Internal Medicine*, Vol. 162, No. 18, October 2002, pp. 2074–2079.

Jayedi, A., A. Rashidy-Pour, M. Khorshidi, and S. Shab-Bidar, "Body Mass Index, Abdominal Adiposity, Weight Gain and Risk of Developing Hypertension: A Systematic Review and Dose-Response Meta-Analysis of More Than 2.3 Million Participants," *Obesity Reviews*, Vol. 19, No. 5, May 2018, pp. 654–667.

Kredlow, M. Alexandra, Michelle C. Capozzoli, Bridget A. Hearon, Amanda W. Calkins, and Michael W. Otto, "The Effects of Physical Activity on Sleep: A Meta-Analytic Review," *Journal of Behavioral Medicine*, Vol. 38, No. 3, June 2015, pp. 427–449.

Meadows, Sarah O., Charles C. Engel, Rebecca L. Collins, Robin Beckman, Matthew Cefalu, Jennifer Hawes-Dawson, Molly Doyle, Amii M. Kress, Lisa Sontag-Padilla, Rajeev Ramchand, and Kayla M. Williams, *2015 Department of Defense Health Related Behaviors Survey (HRBS)*, Santa Monica, Calif.: RAND Corporation, RR-1695-OSD, 2018. As of August 1, 2021: https://www.rand.org/pubs/research_reports/RR1695.html

Meadows, Sarah O., Charles C. Engel, Rebecca L. Collins, Robin L. Beckman, Joshua Breslau, Erika Litvin Bloom, Michael Stephen Dunbar, Mary Lou Gilbert, David Grant, Jennifer Hawes-Dawson, Stephanie Brooks Holliday, Sarah MacCarthy, Eric R. Pedersen, Michael W. Robbins, Adam J. Rose, Jamie Ryan, Terry L. Schell, and Molly M. Simmons, *2018 Department of Defense Health Related Behaviors Survey (HRBS): Results for the Active Component*, Santa Monica, Calif.: RAND Corporation, RR-4222-OSD, 2021. As of August 1, 2021: https://www.rand.org/pubs/research_reports/RR4222.html

National Center for Chronic Disease Prevention and Health Promotion, "Chronic Diseases and Military Readiness," webpage, November 8, 2021. As of August 11, 2021: https://www.cdc.gov/chronicdisease/resources/publications/factsheets/military-readiness.htm

Papasavvas, Theodoros, Robert O. Bonow, Mohammad Alhashemi, and Dominic Micklewright, "Depression Symptom Severity and Cardiorespiratory Fitness in Healthy and Depressed Adults: A Systematic Review and Meta-Analysis," *Sports Medicine*, Vol. 46, No. 2, February 2016, pp. 219–230.

Robson, Sean, Isabel Leamon, Maria C. Lytell, Miriam Matthews, and Margaret Chamberlin, *A Review of the Air Force Fitness Assessment*, Santa Monica, Calif.: RAND Corporation, RR-A762-1, 2021. As of July 27, 2021: https://www.rand.org/pubs/research_reports/RRA762-1.html

Rothman, K. J., "BMI-Related Errors in the Measurement of Obesity," *International Journal of Obesity*, Vol. 32, August 2008, pp. S56–S59.

Wagner, Dale R., and Vivian H. Heyward, "Measures of Body Composition in Blacks and Whites: A Comparative Review," *American Journal of Clinical Nutrition*, Vol. 71, No. 6, June 2000, pp. 1392–1402.

Acknowledgments

We are grateful for the support of Brig Gen Troy E. Dunn, Director, Military Force Management Policy, Deputy Chief of Staff for Manpower, Personnel and Services, Headquarters, U.S. Air Force (AF/A1P). Our primary contacts in AF/A1P were Col Jennifer Allee, Lt Col Matthew Huibregtse, and Emi Izawa. We very much appreciate their willingness to provide policy background and support related to this research. We also appreciate Neal Baumgartner for his subject-matter expertise on fitness and discussions on the evolution of fitness assessments within USAF. We appreciate those who helped organize and process the data for the fitness variables and health outcomes, including Teague Ruder, Linda Cottrell, David Schulker, Perry Firoz, and Anthony Lawrence. Finally, we thank Nelson Lim, director of RAND Project AIR FORCE's Workforce, Development, and Health Program, for his support throughout the project and our reviewers, Maria Lytell and Chuck Engel, for extremely helpful comments that improved the report.

About This Report

Gaining a more comprehensive understanding of how different fitness components influence health is critical to promoting a ready and deployable force. The objective of this project was to evaluate the validity and relevance of different fitness metrics by examining their potential impact on predicting airmen's future health risks, which could affect the readiness and deployability of the U.S. Air Force. To address this objective, we analyzed the empirical associations between Department of the Air Force fitness assessment scores, alternative body composition measures, and various health-related outcomes.

This research was commissioned by the Air Force's Force Management Policy Directorate (AF/A1P) and conducted within the Workforce, Development, and Health Program of RAND Project AIR FORCE as part of a fiscal year 2020 project, "Fitness Standards to Support Readiness and Deployability."

RAND Project AIR FORCE

RAND Project AIR FORCE (PAF), a division of the RAND Corporation, is the Department of the Air Force's (DAF's) federally funded research and development center for studies and analyses, supporting both the United States Air Force and the United States Space Force. PAF provides the DAF with independent analyses of policy alternatives affecting the development, employment, combat readiness, and support of current and future air, space, and cyber forces. Research is conducted in four programs: Strategy and Doctrine; Force Modernization and Employment; Resource Management; and Workforce, Development, and Health. The research reported here was prepared under contract FA7014-16-D-1000.

Additional information about PAF is available on our website: www.rand.org/paf/

This report documents work originally shared with the DAF on March 22, 2021. The draft report, issued on March 22, 2021, was reviewed by formal peer reviewers and DAF subject-matter experts.

www.rand.org