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Low Cardiorespiratory Fitness in African Americans: A Health Disparity Risk Factor?

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Abstract

Low cardiorespiratory fitness (CRF) is a well-established risk factor for all-cause and cardiovascular disease mortality. African Americans have higher rates of cardiovascular disease compared to their Caucasian counterparts. However, the extent to which lower CRF levels contribute to the excess risk in African Americans has not been fully explored. The purpose of this review is to: 1) explore the literature evaluating the relationship between CRF and mortality specifically in African American populations; and 2) critically evaluate the studies which have compared CRF between African American and Caucasians in epidemiological studies and clinical trials. We have further discussed several potential mechanisms that may contribute to the observation of lower CRF levels in African American compared to Caucasian adults including potential racial differences in physical activity levels, muscle fiber type distribution, and hemoglobin levels. If lower CRF is generally present in African Americans compared to Caucasians, and is of a clinically meaningful difference, this may represent an important public health concern.

1. Introduction

African Americans have a significantly higher risk of cardiovascular disease (CVD) and the associated mortality compared to their Caucasian counterparts. The American Heart Association (AHA) 2008 statistics report that the prevalence of CVD is 44.8% and 47.3% in African American men and women, respectively, compared with 37.4% and 33.8%,

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respectively, in Caucasians [1]. Clearly, African Americans have significantly higher rates of the major CVD risk factors, including obesity and type 2 diabetes mellitus (T2DM) and have among the highest rates of hypertension in the world (44%) [2]. Therefore, the prevention and treatment of CVD and its risk factors is particularly imperative in the African American population.

The AHA has identified a sedentary lifestyle as a major modifiable risk factor for CVD, especially for coronary heart disease (CHD) [3]. Nevertheless, a sizable proportion of the United States (US) population is sedentary or at least relatively inactive, and a greater percentage of African Americans do not meet current recommendations for physical activity [4]. Substantial evidence has accumulated from epidemiological studies that has led many major health care organizations to recommend physical activity and exercise training [4–6] as a means to increase levels of cardiorespiratory fitness (CRF), which is a critical factor in the prevention of CVD and subsequent survival [7, 8]. Evidence has accumulated to suggest that African Americans may have lower levels of CRF [9–11] compared to Caucasians, which may contribute to their increased CVD burden.

In this manuscript, we will review data evaluating the association of CRF with subsequent mortality by race, and the research studies comparing CRF levels between African Americans and Caucasians. In addition, we will review the data comparing the response in CRF following aerobic training in African Americans and Caucasians. Recommendations are provided to improve the study of efforts to improve CRF levels and subsequently lower the CVD risk in the African American population.

2. Measurement of CRF

In clinical settings and epidemiological studies, CRF is generally evaluated through a maximal exercise test. Individuals exercise at a progressively higher intensity until volitional exhaustion, 85% of age-predicted maximum heart rate, or until clinical symptoms develop that prompt the ending of the test [12]. The CRF level is defined as the maximum metabolic equivalents (METs) achieved during the exercise test, which is estimated from the speed and the grade of the treadmill or the power output of a cycle ergometer using standardized equations [12]. One MET describes the resting metabolic rate ($3.5 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$). Thus, higher MET levels achieved during an exercise test represent higher CRF levels.

In exercise science research settings, CRF can also be measured by the highest rate of oxygen (O_2) consumption ($\text{VO}_2 \text{ max}$) during a maximal exercise test (e.g. treadmill or cycle ergometer), which is considered the gold standard [12]. Several criteria are generally used to determine if a maximal effort was elicited. More established criteria include achieving a plateau in O_2 consumption rate (VO_2) with an increase in exercise intensity, a maximum respiratory exchange ratio (RER) > 1.1 or 1.15 , and/or a maximum heart rate within 10 beats per minute of age predicted levels [13]. Peak VO_2 is used to describe the highest rate of oxygen consumption achieved when all of the criteria for a maximal test described above may not have been met. The Borg rating of perceived exertion (RPE) [14] is a subjective rating of exercise intensity of exercise on a 6–20 scale at each stage of the exercise test. Maximal RPE level may also be used during exercise testing to further evaluate if a maximal effort was achieved [14]. Researchers need to pay careful attention to these criteria and to relevant confounders (e.g. age, sex, weight differences) when comparing CRF levels between African Americans and Caucasians.

In recent waves of the National Health and Nutrition Examination Survey (NHANES), CRF has been estimated based on heart rate responses from two stages of a submaximal treadmill test extrapolated to an age-predicted maximal heart rate level [11, 15, 16]. However,

estimating CRF from submaximal testing has a much greater error compared to measuring CRF with maximal testing [11].

3. CRF as a major risk factor for mortality and CVD

CRF is inversely associated with all-cause and cardiovascular mortality in healthy populations [17–19] and among people with elevated CVD risk including adults with the metabolic syndrome [20] and T2DM [21]. Blair et al. [19], using Aerobic Center Longitudinal Study (ACLS) data, found that low CRF (lowest 20th percentile of sample) was associated with 58% and 94% higher risk of all-cause mortality in men and women, respectively, after adjustment for age and other CVD risk factors compared with the other four quintiles. Additionally, the greatest reduction in age-adjusted all-cause mortality risk was observed between the least fit compared to the next CRF quintile (men: 3.4 vs. 1.4; women: 4.7 vs. 2.4). Thus, improving CRF levels specifically in individuals with low CRF has high public health importance. Conversely, high CRF levels have been associated with reduced prevalence of several CVD risk factors such as hypertension [22, 23] and obesity [24, 25], as well as lower incidence of the metabolic syndrome [26–28] and T2DM [29–31]. A recent meta-analysis by Kodama et al. [32] observed that a one MET higher CRF was associated with a 13% and 15% reduction in all-cause mortality and CVD/CHD risk, respectively. Thus, maintaining high levels of CRF is protective of future cardiovascular disease and all-cause mortality. However, much of the data evaluating the relationship between CRF and mortality outcomes were derived from primarily Caucasian samples.

4. Mortality Risk Reduction by CRF in African American and Caucasian Populations

Similar to Caucasian populations, African Americans with lower CRF levels tend to have a worsened CVD risk profile (hypertension, obesity, insulin resistance, and elevated inflammation) [9, 10, 33–35]. Further, the few data evaluating CRF and mortality by race suggest that CRF is an important risk factor for mortality in both African American and Caucasian adults. Kokkinos et al. [36], based on data obtained from exercise tests from two Veterans Affairs Medical Centers (African American: n=6,749; Caucasian: n=8,911), observed that a one MET increment in CRF was associated with a similar reduction in mortality risk in African American (14%) and Caucasian (12%) men. In addition, a similar reduction in all-cause mortality risk was observed between the lowest quartile (<5 METs) and the next quartile (7.1 to 10.0 METs) in both African Americans (19%) and Caucasians (21%) as shown in Figure 1 [36]. However, in a different study in men with T2DM, Kokkinos et al. [37] observed a greater risk reduction in all-cause mortality per one MET of CRF in Caucasians (19%) compared to African Americans (14%) using Veterans Affairs Medical Centers data (African American: n=1,703; Caucasian: n=1,445). In addition, the authors observed a smaller reduction in all-cause mortality risk between low (< 5 METs) and the next quartile (5.1–7.9 METs) CRF categories in African Americans (35%) compared to Caucasians (43%) [37]. Thus, maintaining adequate CRF levels may be especially important for African American men with T2DM.

To our knowledge, only one study evaluated the effect of CRF on CVD events in African Americans and Caucasians in patients with heart failure. In this study performed by Arena et al. [38], higher levels of peak VO₂ was associated with fewer CVD events in African Americans (hazard ratio [HR]: 0.83) and Caucasians (HR: 0.92) in univariate analysis. However, peak VO₂ was only significant in multivariate regression models in Caucasian participants with left ventricular ejection fraction, age, body mass index (BMI) and heart failure etiology in the model. The authors reported that the lack of a significant relationship

for peak VO_2 and CVD events in African Americans was due to lower predictive value of CRF in African American women.

Thus, the available data suggest that CRF is an important risk factor for mortality in both African American and Caucasians, especially in populations without heart failure. However, replication of these results is needed in other datasets. Additionally, more studies are necessary in African American and Caucasian women.

5. Inclusion criteria for studies evaluating race and CRF levels

In the present review, we included published studies from peer review journals that directly compare CRF levels from exercise testing (estimated CRF levels from submaximal testing, maximal METs, maximal oxygen consumption) in African American and Caucasian adults as a primary or secondary measure. We did not include studies conducted in children or adolescents. We utilized academic search engines to identify articles (Web of Science, Pub Med, Google Scholar), and we reviewed the bibliographies of all articles meeting our selection criteria for additional articles. A total of 29 studies were identified based on these criteria. We excluded 4 studies due to low sample size (<15 participants total in each racial group) [39–42]. Thus, 25 studies were appropriate for the purposes of this review.

6. Estimated CRF in African Americans compared to Caucasians in the National Health and Nutrition Examination Survey (NHANES)

NHANES does not collect CRF data obtained from maximal exercise testing but instead estimates CRF levels from a submaximal cycle ergometer test [11, 15, 16, 43]. Despite this limitation, at this time, NHANES is the only study with data evaluating differences in CRF between African Americans and Caucasians in a sample designed to be representative of the United States. Evidence from studies using NHANES data generally report lower CRF in African Americans overall [11, 16] and especially in African American women compared to Caucasian women [11, 15, 16].

Duncan et al. [16] observed lower estimated CRF in African Americans ($33.0 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) compared to Caucasian adults ($34.9 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) in NHANES (examination years: 1999–2002). In sub-group analyses, the authors observed lower mean CRF in African American ($33.1 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) compared to Caucasian women ($36.4 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) but not men. Ceaser et al. [11] ($n = 3115$, NHANES 1999–2004) observed lower mean estimated CRF levels in African Americans ($37.9 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) compared to Caucasian ($40.2 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) adults aged 18–49 years. Lower CRF in African Americans in the full sample persisted after adjustment for sex, education level, marital status, smoking status, and waist circumference, as well as vigorous physical activity and physical activity volume measured by questionnaire. Similar results were found in sub-group analyses stratified by sex, with the exception that in men racial differences in CRF were no longer present after adjustment for physical activity levels. Wang et al. [44], also using NHANES 1999–2004 data, evaluated racial differences in estimated CRF in different age groups and BMI categories in a larger sample ($n = 4860$, age 20–49 years). African American men were reported to have lower mean CRF compared to Caucasians in men 30–39 years old only. Conversely, in women, the authors observed lower CRF levels in African American compared to Caucasians in all age groups except 20–29 year olds. Importantly, the race disparity in mean CRF in African American compared to Caucasian women was especially apparent in overweight (32.2 vs. $35.1 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) and obese women (31.5 vs. $34.2 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$).

Thus, the available data from NHANES suggest lower CRF in African Americans, and especially African American women. However, important limitations of these studies are that CRF values were estimated from submaximal exercise testing and a subset of NHANES participants were excluded from performing exercise testing due to safety concerns (e.g. symptoms of CVD) or because of conditions that affected the estimation of CRF levels.

7. Maximal CRF (Maximal METs or VO_2)

7.1 Apparently healthy populations

Several epidemiological studies and clinical trials have evaluated racial differences in maximal CRF between African Americans and Caucasians in apparently healthy populations. The vast majority of the available data indicate lower CRF levels in African American compared to Caucasian adults. A summary of these studies and their findings are listed in Table 1.

Wilbur et al. [45] observed lower mean CRF measured by a Bruce protocol treadmill test in apparently healthy overweight African American ($n=64$, $24.6 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) compared to Caucasian ($n=109$, $27.23 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) midlife women (46–65 years of age) without differences in age or maximum heart rate from exercise testing. Arena et al. [46] observed lower mean CRF values (measured using a modified Balke protocol) in age- and sex-matched healthy African American ($n=33$, $27.9 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) compared to Caucasian ($n=33$, $38. \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) adults along with greater aortic stiffness in African Americans. Using data from the Cooper Center Longitudinal Study, Howard et al. [47] observed lower mean CRF levels in African American compared to Caucasians in both men (10.9 METs vs. 11.7 METs) and women (8.8 METs vs. 9.8 METs). In the Coronary Artery Risk Development in Young Adults (CARDIA) study, Sidney et al. [48] observed lower mean CRF levels measured with a graded treadmill exercise test in young (18–30 years) African American compared to Caucasian men (13.0 METs vs. 13.8 METs) and women (9.4 METs vs. 11.1 METs). The authors suggested that the observed racial differences in CRF could be attributed in large part to the lower rating of perceived exertion in African American compared to Caucasian participants (i.e. African Americans may not have provided a maximal effort to the same extent as Caucasians during exercise testing). However, other investigations have observed similar results where criteria for a maximal test were achieved. For example, LaMonte et al. [34], in an examination of women from the Cross-Cultural Activity Participation Survey, observed lower mean maximal METs levels in African American ($n=44$, 7.2 METs) compared to Caucasian women ($n=46$, 10.0 METs) where all participants reached 85% of age-predicted maximal heart rate and an RPE 17, indicating similar levels of effort in both races.

Racial differences in CRF have been replicated in studies that use maximal oxygen consumption and a rigorous criteria to define an acceptable maximal test (e.g. $\text{RER}>1.1$, plateau in VO_2 , and no lower than 10 beats/min below the age predicted maximum heart rate). Thus, the mean CRF levels reported in the following studies are less likely to be influenced by potential bias of African Americans not providing a maximal effort. For example, Hunter et al. [49] observed significantly lower mean CRF levels in African American ($n=94$, $\text{VO}_2 \text{ max: } 27.5 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) compared to Caucasian ($n=93$, $\text{VO}_2 \text{ max: } 29.0 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) pre-menopausal women with specific criteria for an acceptable $\text{VO}_2 \text{ max}$ test met by all participants. In a different study, Hunter et al. [50] observed lower mean CRF levels in African American ($n=17$, 1.9 L/min) compared to Caucasian ($n=18$, 2.17 L/min) pre-menopausal women with a similar criteria met for all maximal exercise testing. Furthermore, these results did not change when analyses were adjusted for weight, fat-free mass (FFM), or activity-related energy expenditure. Hunter and colleagues have replicated these results in two other studies in pre-menopausal women [51, 52]. Zeno et al. [33] found

lower mean CRF levels in African American men (42.0 vs. 46.5 mL•kg⁻¹•min⁻¹) and women (32.3 vs. 38.0 mL•kg⁻¹•min⁻¹) compared to Caucasians. In addition, African Americans had higher fasting insulin values and a greater prevalence of the metabolic syndrome compared to Caucasians. All participants included in this analysis also met established criteria for VO₂ max, with no significant differences in age [33].

The largest trial evaluating racial differences in CRF by VO₂ in apparently healthy participants was conducted by Skinner et al. [53] in the Health, Risk Factors, Exercise Training And Genetics (HERITAGE) study. The authors observed lower mean CRF levels in African American (n=198) compared to Caucasian (n= 435) men (33.3 vs. 37.3 mL•kg⁻¹•min⁻¹) and women (24.7 vs. 29. mL•kg⁻¹•min⁻¹) over a wide age range (17–65 years) of adults. All participants included in the analyses completed two exercise tests and met criteria for a maximal exercise test. Racial differences in CRF were still present after adjusting CRF values for FFM instead of body weight.

To our knowledge, the only major study in apparently healthy adults that did not report significant racial differences in mean CRF was conducted by Carpenter et al. [54] in older (>55 years) men (African American [n=28]: 1.9 L/min, Caucasian [n=37]: 2.1 L/min) and women (African American [n=37]: 1.4L/min, Caucasian [n=52]: 1.4 L/min). Similar results were obtained when mean absolute CRF was adjusted for FFM. An important limitation of this study, however, was the African American participants were younger, which was especially notable for the men in the study (64 vs. 70 years). Similar mean CRF between African Americans and Caucasians were reported in other smaller clinical trials in apparently healthy participants [39, 40, 42]; however, the study samples are likely too small (n = 15) to be representative of the African American population to fairly evaluate racial differences.

7.2 Populations with CVD risk

Racial differences in CRF have also been observed in populations with elevated CVD risk and individuals with documented CVD or T2DM. A summary of these studies and their findings are listed in Table 2.

Brown et al. [55] observed lower mean CRF (modified Bruce protocol) in obese African American (n= 498, 6.3 METs) and Caucasian (n= 556, 7.3 METs) participants who were siblings of patients with documented CHD. African Americans were older and had a greater percentage of female participants, both factors which may over-estimate racial differences in mean CRF. However, Brown et al. [55] also reported that African American race was a significant predictor for CRF in multivariate analysis with age, sex, and other clinical (BMI, systolic blood pressure, waist circumference) and social (employment status, education level) variables included in the model. In obese postmenopausal women with elevated blood pressure, Swift et al. [56] observed lower mean CRF levels measured by peak VO₂ from 2 cycle ergometer tests in African American (n=122, 15.0 mL•kg⁻¹•min⁻¹) versus Caucasian (n=264, 15.8 mL•kg⁻¹•min⁻¹) after adjustments for age and maximum RER values. Additionally, African Americans had similar physical activity levels (measured through pedometry over the course of 7 days) compared to Caucasians.

7.3 Patients referred for stress testing, T2DM, and heart failure

Lower CRF in African Americans has been observed in patients referred for stress testing and in adults with T2DM. Lavie et al. [9] observed lower mean exercise capacity among male African American (10.7 METs) versus Caucasian (11.4 METs) patients but no differences between female patients (African American: 8.5 METs, Caucasian: 8.7 METs). African American men had a greater prevalence of obesity. In addition, in multiple linear

regression analyses, the Caucasian race was significantly associated with higher CRF, but the variance explained was low ($r^2 = 0.004$, $p < 0.001$). Kokkinos et al. [36], using Veterans Affairs Medical Centers data, observed lower mean CRF levels in older African American (6.9 METs) compared to Caucasian men (7.6 METs) with and without CVD. African Americans in this study had a higher prevalence of hypertension, T2DM and obesity compared to Caucasians.

Three studies have evaluated racial differences in CRF levels between African American and Caucasian adults with T2DM. Kokkinos et al. [37] observed a small but significantly lower mean CRF level in African American ($n=1703$, 6.3 METs) compared to Caucasian men ($n=1445$, 6.5 METs) with T2DM from the Veterans Affairs Medical Centers data. Estacio et al. [57] observed lower mean CRF in African Americans ($20.9 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) compared to Caucasians ($23.8 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) in the Appropriate Blood Pressure Control in Diabetes (ABCD) trial with no significant differences in maximum heart rate, RER or RPE from exercise testing. However, this study had a small sample of African American ($n=52$) participants compared with Caucasian ($n=322$). Ribisl et al. [58] in the Action for Health in Diabetes (Look AHEAD, $n=5,145$) study observed that mean CRF was lower in African American (6.7 METs) compared to Caucasian (7.3 METs) overweight and obese adults with T2DM [58] who performed a graded exercise treadmill test. Using multiple linear regression, African American race was found to be a significant predictor of CRF in both men and women with BMI, waist circumference, history of CVD, and hemoglobin A_{1c} and other variables within the model.

Two studies in higher risk populations did not find significant differences in CRF between African American and Caucasian adults. Arena et al. [38] found similar mean CRF levels in African American (men: $16.2 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$, women: $12.2 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) and Caucasian (men: $15.9 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$, women: $14.2 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) patients with heart failure referred for stress testing. However, the African American men were on average 10 years younger than their Caucasian counterparts (47.3 vs. 57.3 yrs.); therefore, it is unclear if racial differences in CRF would be present if analyses were adjusted for age (the main focus of the investigation was cardiovascular events). In addition, Hinson et al. [59] observed similar mean CRF levels in older African American ($n=66$, $13.7 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) and Caucasian ($n=52$, $14.0 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) stroke survivors.

8. The Prevalence of Categorically Defined Low CRF in African Americans compared to Caucasians

In addition to evaluating the magnitude of racial differences in CRF, several studies have specifically evaluated the prevalence of categorically defined low CRF in African Americans compared to Caucasians. As stated earlier in this review (section 3), low CRF is associated with the greatest all-cause and CVD mortality risk, which is substantially reduced when moving from low to moderate CRF categories [5, 19]. Duncan et al. [16], using data from NHANES (1999–2002), observed a greater proportion of African Americans (22.9%) had low estimated CRF defined by ACLS cut-points (lowest 20th percentile based on age and sex) compared to Caucasians (11.3%), which was especially notable in women (30.9% of African Americans vs. 13.5% of Caucasians). Since the ACLS CRF cut-points were derived from a mostly Caucasian and affluent sample, Sanders et al. [43] evaluated the prevalence of low estimated CRF (lowest 20% percentile based on age and sex) in African Americans compared to Caucasians in cut-points derived from NHANES. Both African American men (29%) and women (35%) had a greater prevalence of low estimated CRF compared to Caucasians (<20%). Howard et al. [47] observed that African American men had a 2 fold greater risk of low fitness in their fully adjusted model compared to Caucasians. African American women had 2.7 times greater risk of low CRF in the age-adjusted model,

but the difference was no longer significant in the fully adjusted model (including BMI, education, hypertension, hemoglobin, smoking and physical activity levels).

Other studies using maximal exercise testing have found a greater prevalence of categorically defined low CRF in African Americans compared to Caucasians. Lavie et al. [9] observed that a greater percentage of African Americans had low CRF (defined as <6 METs) compared to Caucasian adults in a large population of adults referred to stress testing. Zeno et al. [10] in apparently healthy adults observed that a greater percentage of African Americans (57.1%) had low to fair CRF levels compared to Caucasian (31.4%), based on American College of Sports Medicine (ACSM) criteria.

9. Low CRF and the presence of other CVD risk factors in African Americans

Along with lower CRF levels in African Americans, many of the reviewed studies observed indications of a worsened CVD profile such as a higher BMI [9, 46, 55], blood pressure (systolic [45, 46, 58]/diastolic [37, 55, 58]), glucose [55], waist circumference [60], C-reactive protein [34], and greater aortic stiffness [46] compared to Caucasians. Several studies have also observed a greater prevalence of the metabolic syndrome [33], low high density lipoprotein cholesterol levels [33], T2DM [36, 55], and CVD [36, 37] in African American populations with lower CRF compared to Caucasians. It is not possible to directly determine if the increased prevalence of CVD risk factors in African Americans are related to lower CRF levels in most of these studies. However, evidence from 3 studies in this review have observed that both African American race and other cardiometabolic risk factors (e.g. BMI, hemoglobin A_{1c}, fasting glucose, systolic blood pressure) are independent predictors of low CRF levels [9, 55, 58] in multiple linear regression models. This suggests that increased prevalence of risk factors may partially mediate racial differences in CRF, but there also may be an independent contribution from the African American race itself (which may be behavioral or physiological in origin). Future research is needed to clarify this distinction. It is important to emphasize that even in the case of lower CRF in African Americans with similar clinical characteristics, CRF is an independent risk factor for all-cause and cardiovascular mortality [7, 19].

10. Is low CRF a health disparity risk factor for African Americans?

In order for CRF to represent a health disparity risk factor, the difference in CRF between Caucasians and African Americans must be of a sufficient magnitude to be associated with a clinically relevant increase in all-cause or CVD mortality risk. Risk estimation is complicated by the differences in study population (e.g. age or disease state) and the methodology used to evaluate CRF (e.g. maximal estimated METs vs. METs converted from peak VO₂, treadmill vs. cycle ergometer). However, based on the studies described in this review, the difference in maximal METs between African American and Caucasian participants ranged from 0.8 to 2.8 METs in participants apparently free of CVD and from 0.2 to 2.9 METs for those with elevated cardiovascular disease or T2DM. In NHANES (calculated from estimated CRF levels), the lower CRF in African Americans compared to Caucasians ranged from 0.54 to 0.67 METs [11], with greater differences observed in overweight (0.82 METs) and obese (0.77 METs) women [15]. Based on data from Kodama et al. [32] and others [17–19], it is plausible that these racial differences in CRF could represent a clinically important increase in all-cause and CVD mortality in African Americans. However, future studies should investigate racial differences in CRF in African Americans compared to Caucasians with careful consideration of relevant covariates, adequate sample size, high quality maximal CRF data, and the overall effects of these differences in CRF on mortality. Thus, it may be too early to conclude definitively that low

CRF represents a health disparity risk factor for African Americans, but sufficient evidence exists to warrant further study in this area.

11. Limitations of previous studies investigating racial differences in CRF

Although the available data in this area generally suggest lower CRF levels in African American compared to Caucasian adults, several important limitations should be noted. The NHANES studies [11, 15, 16, 43] used estimated CRF values instead of measured maximal CRF levels such as maximal METs or peak VO_2 . Estimated CRF values have approximately a 0.79 correlation with maximal CRF levels [15] and therefore are less accurate compared to measuring CRF with a maximal test. Another limitation is that some studies have not controlled or accounted for potential racial differences in maximum exercise testing variables (e.g. maximum heart rate or RPE, etc.) or age, which has the potential to over- or under-report the magnitude of the racial differences in CRF. In some cases, statistical adjustments were not performed because CRF was not the primary outcome measure of the investigation.

An important limitation of many of the studies within this review is that CRF is corrected for body weight ($\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) and not lean mass. Since the fat mass contributes very little to the O_2 uptake with exercise, correction of CRF by lean mass may be more appropriate [61, 62], especially if differences in lean mass exist between the African Americans and Caucasians within a study. In our review of the literature, two studies observed lower mean CRF in African Americans after adjustment for FFM [51, 53]. Additionally, CRF measured by estimated METs and VO_2 (without correction for weight) are independent predictors of mortality and CVD [19]. Lastly, several studies utilized convenience samples, such as participants referred to exercise testing or within a hospital database, where it is possible that the demographic and clinical characteristics are not representative of African Americans or Caucasians in their region or in the U.S. It is also plausible that cultural differences specific to Caucasians or African Americans may affect the characteristics of participants who volunteer for research studies.

12. Potential Mechanisms

Potential mechanisms for the reported lower CRF levels in African American adults may have behavioral/cultural influences as well as physiological. Since CRF levels are determined in large part by physical activity levels, an obvious potential mechanism for the racial differences in CRF could be lower levels of physical activity in African Americans compared to Caucasians, a racial difference that has been previously reported [4, 63]. Haskell et al. [4] reported that a lower percentage of African Americans (41.8%) compared to Caucasians (51.1%) obtained recommended levels of physical activity based on the current Centers of Disease Control/ACSM recommendations. Tucker et al. [64] reported a higher percentage of African Americans (58.9%) participated in no moderate to vigorous activity (MVPA) compared to Caucasians (52.5%) determined through accelerometry. Troiano et al. [65] only observed lower MVPA in African Americans compared to Caucasians when requiring MVPA to be performed in 10 minute bouts in adults ≥ 60 years of age.

However, the studies within this review which collected both CRF and physical activity data provide only limited evidence to support the notion that lower physical activity levels in African Americans are primarily responsible for lower CRF levels. Ceaser et al. [11] observed that racial differences in mean CRF were no longer present in African American men after adjustment for physical activity levels, but persisted for women. Sidney et al. [48] observed lower mean CRF levels in African Americans compared to Caucasians despite similar questionnaire-determined physical activity scores in both men and women. Swift et

al. [56] observed lower mean CRF levels in African American compared to Caucasian postmenopausal women despite similar pedometer-determined physical activity levels (African American: 5,087 steps/day; Caucasian: 4,930 steps/day). Hunter et al. [50] observed lower mean CRF levels in African Americans compared to Caucasian premenopausal women despite similar levels of energy expenditure measured through doubly-labeled water. This limited evidence does not exclude the possibility that physical activity levels are involved in the reported racial differences in CRF. However, more studies with both objective physical activity measures and CRF data are needed to determine the extent to which physical activity levels are the primary etiology of racial differences in CRF.

Potential physiological mechanisms explaining racial differences in CRF include the oxidative capacity of the muscle tissue and hemoglobin levels. Several studies have suggested that African Americans have a lower percentage of type 1 muscle fibers (the more oxidative muscle fibers) compared to Caucasians [66–68], which could affect both CRF levels and overall physical activity preferences (i.e. endurance versus anaerobic). The presence of fewer type 1 muscle fibers has been associated with obesity, lower glucose tolerance and reduced aerobic capabilities during exercise [66]. Hunter et al. [51] evaluated the muscle oxidative capacity (the recovery rate of adenosine diphosphate) through magnetic resonance spectroscopy and hemoglobin levels in African American and Caucasian premenopausal women. African Americans had both lower muscle oxidative capacity expressed as adenosine diphosphate time constant (24.3 vs. 21.3 sec.) and hemoglobin levels (11.8 vs. 12.9 g•dL⁻¹) compared to Caucasians. Adjusting CRF by these variables, and lean mass attenuated but did not eliminate the racial differences in CRF between African Americans and Caucasians women. Swift et al. [56] observed higher mean hemoglobin levels in Caucasian (13.2 g•dL⁻¹) compared to African American (12.6 g•dL⁻¹) postmenopausal women; however, racial differences in CRF at baseline and following exercise training were still observed after adjustments for hemoglobin levels.

Thus, the available data suggest that differences in muscle fiber type and perhaps hemoglobin levels are contributing to, but do not entirely explain the differences in CRF observed between African Americans and Caucasians. Racial differences in physical activity levels may be involved, but the limited available data at the present time do not support this.

13. Response in CRF Following Exercise Training in African Americans and Caucasians

Increasing CRF is associated with a reduction in all-cause [69–71] and CVD mortality risk [69, 71]. It is well established that aerobic training is effective in increasing CRF in sedentary adults [5] and specifically in African Americans [53, 72, 73]. To our knowledge, two studies have evaluated whether the change in CRF differs between African Americans and Caucasian following participation in the same standardized aerobic exercise training program. The HERITAGE study observed an attenuated improvement in mean CRF in African American (n=198, 4.9 mL•kg⁻¹•min⁻¹) compared to Caucasian (n=435, 5.5 mL•kg⁻¹•min⁻¹) individuals following 20 weeks of aerobic training. However, when change in CRF was expressed in absolute (African American: 0.366 L/min, Caucasian: 0.399 L/min) terms or corrected for FFM (African American: 6.7 mL•kg FFM⁻¹•min⁻¹; Caucasian: 6.9 mL•kg FFM⁻¹•min⁻¹), no significant racial differences were observed. Thus, the investigators concluded that race explained only a small fraction of the variability in response of CRF (~1%) [74]. In the Dose Response to Exercise in Women (DREW) study, Swift et al. [56] observed an attenuated increase in mean CRF in African American compared to Caucasian women exercising at 100% (0.041 vs. 0.105 L/min) and 150% (0.039 vs. 0.128 L/min) of public health recommendations. Although racial differences were observed in the overall magnitude of the change in mean CRF following aerobic exercise

training, both African American and Caucasian women had similar response rates for categorically ($\text{CRF} > 0 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) improving CRF in all of the exercise groups.

More prospective training studies are needed in various age groups and disease states to determine if racial differences exist in the improvement of CRF following a standardized amount of aerobic exercise training and if these differences are clinically meaningful. If an attenuated response does exist in African Americans, it is likely small in magnitude. Aerobic training is especially important in sedentary African Americans with low CRF levels.

14. Future Directions

Future directions for research in this area should investigate the physiological and behavioral etiologies for low CRF in African Americans. In addition, normative data for the United States for maximal CRF levels in African Americans and other racial/ethnic groups are necessary, which is an objective of the proposed national registry for CRF [8]. Exercise training studies should evaluate how to maximize the response in CRF in African American populations through different training programs (modalities/intensity of exercise, dose-response relationships).

Another important factor that warrants study is to determine whether the lower CRF in African Americans persists across the lifespan or is due to a greater rate of decline in CRF with aging. The available evidence in this review generally shows lower CRF in African Americans compared to Caucasians in adult populations of various age groups, which is somewhat supported by NHANES in women [15]. The only epidemiological data in this area are from the CARDIA study, which showed a greater mean decline over 7 years in CRF (maximal METs) in young African Americans men compared to Caucasian men but no significant differences were observed for women [75]. However, it would be informative to evaluate the decline in CRF by race in older individuals and over a longer time period.

15. Conclusion

In the present review, we have summarized the literature evaluating racial differences in CRF between African Americans and Caucasians. Although these studies have important limitations, the vast majority of the data indicate that African Americans have lower CRF levels (measured via estimated CRF, maximal VO_2 , or maximal METs) and a greater prevalence of categorically defined low CRF (< 6 METs [9], ACSM definition [10], ACLS [16, 43] and NHANES [43] derived cut-points) compared to Caucasian adults. Additionally, these lower CRF levels were accompanied by a greater severity of CVD risk factors. Along with standard care, clinicians should evaluate the exercise and physical activity habits (particularly aerobic exercise) in African Americans due to the strong inverse relationship between CRF and all-cause/CVD mortality [17–19, 32]. The promotion of aerobic exercise training and maintaining high physical activity levels may be especially important in the preventive care of sedentary African Americans. Future research should address the cultural, behavioral and physiological etiologies for lower CRF in African Americans and determine the most effective exercise training programs to maximize the improvement in CRF.

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Figure 1.

Relative risk of all-cause mortality among African American and Caucasian men who achieved an exercise capacity of 5 to 7, 7.1 to 10, or >10 METs vs. those who achieved an exercise capacity <5 METs. (adapted with permission from Kokkinos et al. *Circulation*. 2008). METs: Metabolic equivalents

Table 1
Published studies evaluating differences in CRF between African American and Caucasian participants in apparently healthy adults.

Author	Participants	CRF measure	Lower CRF in AA?	CRF values	AA vs. CA (METs)	Maximal effort criteria
Arena et al. (2007) [46]	Healthy middle aged adults	Maximal oxygen consumption (TM)	Yes	AA adults (n=33): 27.9 mL•kg ⁻¹ •min ⁻¹ CA adults (n=33): 38.3 mL•kg ⁻¹ •min ⁻¹ a (age/sex matched)	3.0	VE
Carpenter et al. (1998) [54]	Older men and women (>55 years)	Maximal oxygen consumption (TM)	No	AA men (n=28): 1.9 L/min CA men (n=47): 2.1 L/min AA women (n=37): 1.4 L/min CA women (n=52): 1.4 L/min	-	VE, HR, RER
Howard et al. [47]	Adult men and women	Maximal METs (TM)	Yes	AA men (n=309): 10.9 CA men (n= 19,399): 11.7METs AA women (n=203): 8.8 METs CA women (n= 8,753): 9.8 METs	Men: 0.8 Women: 1.0	
Hunter et al. (2000) [50]	Premenopausal women	Maximal oxygen consumption (TM)	Yes	AA women (n=18): 1.90 L/min CA women (n= 17): 2.17 L/min	0.95	VE, HR, RER, O ₂
Hunter et al. (2001) [51]	Premenopausal women	Maximal oxygen consumption (TM)	Yes	AA women (n=43): 29.3 mL•kg ⁻¹ •min ⁻¹ CA women (n=33): 33.6 mL•kg ⁻¹ •min ⁻¹	1.2	VE, HR, RER, O ₂
Hunter et al. (2004) [52]	Premenopausal women	Maximal oxygen consumption (TM)	Yes	AA women (n=35): 28.2 mL•kg ⁻¹ •min ⁻¹ CA women (n=39): 31.5 mL•kg ⁻¹ •min ⁻¹	0.95	VE, HR, RER, O ₂
Hunter et al. (2010) [49]	Premenopausal women	Maximal oxygen consumption (TM)	Yes	AA women (n=94): 27.5 mL•kg ⁻¹ •min ⁻¹ CA women (n=93): 29.0 mL•kg ⁻¹ •min ⁻¹	0.43	VE, HR, RER, O ₂
LaMonte et al. (2002) [34]	Middle aged women	Maximal METs (TM)	Yes	AA women (n=44): 7.2 METs CA women (n=46): 10.0 METs	2.8	HR, RPE
Skinner et al. (2001) [53]	Healthy sedentary adults	Maximal oxygen consumption (C)	Yes	AA men (n= 78): 33.3 mL•kg ⁻¹ •min ⁻¹ CA men (n=209): 37.3 mL•kg ⁻¹ •min ⁻¹ AA women (n=120):24.7mL•kg ⁻¹ •min ⁻¹ CA women (n=226): 29.8 mL•kg ⁻¹ •min ⁻¹	Men: 1.1 Women: 1.4	VE, HR, RER, O ₂
Sidney et al. (1991) [48]	Young men and women (18–30 years)	Maximal METs (TM)	Yes	AA men (n= 1123): 13.0 METs CA men (n= 1147): 13.8 METs AA women (n= 1428): 9.4 METs CA women (n=1270): 11.1 METs	Men: 0.8 Women: 1.7 s	SYM
Wilbur et al. (2001) [45]	Mid-life (45 to 65 years) women	Maximal oxygen consumption (TM)	Yes	AA women (n=64): 24.7 mL•kg ⁻¹ •min ⁻¹ CA women (n=109): 27.2 mL•kg ⁻¹ •min ⁻¹	0.74	VE
Zeno et al. (2010) [10]	Young and middle aged adults	Maximal oxygen consumption (TM)	Yes	AA men (n= 41): 42.0 mL•kg ⁻¹ •min ⁻¹ CA men (n=27): 46.5 mL•kg ⁻¹ •min ⁻¹ AA women (n=50): 32.3 mL•kg ⁻¹ •min ⁻¹ CA women (n=24): 38.0 mL•kg ⁻¹ •min ⁻¹	Men: 1.3 Women: 1.6	O ₂ , BL, RER, HR, RPE

AA: African American, BL: blood lactate above a critical value, C: cycle ergometer, CA: Caucasian, CRF: cardiorespiratory fitness, HR: above a threshold for predicted maximum heart rate, METs: metabolic equivalents, O₂: Plateau in oxygen consumption, RER: respiratory exchange ratio above critical level, RPE: rating of perceived exertion above a critical value, TM: Treadmill, SYM: Symptom limited., VE: Volitional exhaustion. aCRF values not reported stratified by sex

Table 2

Published studies evaluating differences in CRF between African American and Caucasian adults with high risk for cardiovascular disease, known cardiovascular diseases, or type 2 diabetes.

Participants	CRF measure	Lower CRF in AA?	CRF values	AA vs CA (METs)	Maximal effort criteria
Arena et al. (2008) [38]	Adults with heart failure	No	AA men (n=123): 16.2 mL•kg ⁻¹ •min ⁻¹ CA men (n=356): 15.9 mL•kg ⁻¹ •min ⁻¹ AA women (n=84): 12.2 mL•kg ⁻¹ •min ⁻¹ CA women (n=99): 14.2 mL•kg ⁻¹ •min ⁻¹	-	SYM
Brown et al. (2011) [55]	Adults with high risk for CVD*	Yes	AA (n=498): 6.3 METs CA (n=556): 7.3 METs	1	SYM
Estacio et al. (1996) [57]	Adults with T2DM	Yes (in men only)	AA men (n=29): 20.9 mL•kg ⁻¹ •min ⁻¹ CA men (n=215): 23.8 mL•kg ⁻¹ •min ⁻¹ AA women (n=23): 16.59 mL•kg ⁻¹ •min ⁻¹ CA women (n=107): 18.89 mL•kg ⁻¹ •min ⁻¹	Men: 2.9	RER
Hinson et al. (2007) [59]	Stroke survivors	No	AA men (n=41): 13.7 mL•kg ⁻¹ •min ⁻¹ CA men (n=33): 14.0 mL•kg ⁻¹ •min ⁻¹ AA women (n=25): 11.5 mL•kg ⁻¹ •min ⁻¹ CA women (n=19): 15.1 mL•kg ⁻¹ •min ⁻¹	-	No criteria stated
Kokkinos et al. (2008) [36]	Men referred for stress testing	Yes	AA men (n=6,749): 7.6 METs CA men (n=8,911): 6.9 METs	0.7	VE, SYM
Kokkinos et al. (2009) [37]	Men with T2DM	Yes	AA men (n=1,703): 6.9 METs CA men (n=1,445): 7.6 METs	0.4	VE, SYM
Lavie et al. (2004) [9]	Adults referred for stress testing	Yes (in men only)	AA men (n=333): 10.7 METs CA men (n=3,217): 11.4 METs AA women (n=308): 8.5 METs CA women (n=1,211): 8.7 METs	Men: 0.7	SYM
Ribisl et al. (2007) [58]	Adults with T2DM ^b	Yes	AA (n=2,082): 6.7 METs CA (n=3,063): 7.3 METs	0.6	HR, > 4 METs
Swift et al. (2013) [66]	Postmenopausal women with elevated blood pressure	Yes	AA women (n=122): 15.0 mL•kg ⁻¹ •min ⁻¹ CA women (n=264): 15.8 mL•kg ⁻¹ •min ⁻¹	0.2	Analyses adjusted for RER and age

AA: African American, C: cycle ergometer, CA: Caucasian, CRF: cardiorespiratory fitness, CVD: Cardiovascular disease, HR: above a threshold for predicted maximum heart rate, METs: metabolic equivalents, RER: respiratory exchange ratio above critical level, SYM: Symptom limited, T2DM: type 2 diabetes mellitus, TM: Treadmill, VE: Volitional exhaustion.

^a 80% of tests were conducted on TM; 20% of tests were conducted on C,

^b Analyses not stratified by sex.