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CARDIORESPIRATORY FITNESS, VO2max, AND EXERCISE CAPACITY AS PREDICTORS OF CARDIOVASCULAR RISK AND MORTALITY: A NARRATIVE REVIEW

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ABSTRACT

Background. Cardiovascular disease is one of the leading causes of morbidity and mortality worldwide. Physical inactivity and sedentary behavior are important modifiable risk factors. Cardiorespiratory fitness (CRF), often expressed as VO2max, VO2peak, metabolic equivalents (METs), exercise capacity, or estimated CRF, has gained attention as a predictor of cardiovascular and overall health.

Aim. This review evaluated the prognostic significance of CRF in relation to cardiovascular risk, cardiovascular outcomes, cardiovascular mortality, all-cause mortality, and premature mortality in adults.

Materials and methods. This narrative review was based on English-language publications identified in PubMed and Google Scholar. Meta-analyses, systematic reviews, observational cohort studies, clinical reviews, expert statements, and interventional studies relevant to cardiorespiratory fitness, exercise capacity, cardiovascular prevention, mortality, and cardiac rehabilitation were included in the synthesis.

Results. The reviewed evidence consistently indicates that higher CRF is associated with a lower risk of all-cause mortality, cardiovascular mortality, and cardiovascular events. This relationship has been observed using various assessment methods, including directly measured VO2max or VO2peak, treadmill-derived peak METs, exercise capacity, and estimated CRF. CRF also appears to have prognostic value in populations with obesity, diabetes, hypertension, coronary artery disease, and heart failure. Changes in CRF over time may be associated with changes in mortality risk. These findings support the interpretation of CRF as a modifiable prognostic marker.

Conclusions. CRF should be regarded as a measure of physical performance as well as an indicator of cardiovascular, respiratory, metabolic, and functional health. Its assessment may support cardiovascular risk stratification, prevention, and rehabilitation strategies in adult populations.

KEYWORDS

Cardiorespiratory Fitness, VO2max, Exercise Capacity, Cardiovascular Risk, Mortality, Physical Activity

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1. Introduction

Cardiovascular disease is one of the major causes of morbidity and mortality worldwide. Its prevention is a central objective of public health and clinical medicine. Physical inactivity and sedentary behavior are recognized as important modifiable risk factors for cardiovascular disease, metabolic disorders, functional decline, and premature mortality [1,2]. Several mechanisms contribute to cardiovascular protection from regular physical activity and structured exercise, including improvements in blood pressure, lipid profile, insulin sensitivity, vascular function, body composition, and cardiorespiratory fitness [2,3]. Public health analyses suggest that even modest increases in physical activity can have a positive impact on health, while meeting recommended levels of physical activity significantly reduces the risk of mortality and cardiovascular outcomes [4]. However, physical activity level alone does not fully capture the functional capacity of the cardiovascular, respiratory, and muscular systems.

Therefore, cardiorespiratory fitness (CRF) has gained increasing attention as a clinically relevant marker of cardiovascular and overall health. CRF reflects the ability of the cardiovascular, respiratory, and skeletal muscle systems to deliver and utilize oxygen during sustained physical activity. CRF provides a functional measure of physiological reserve that may be more comprehensive. It can account for the cumulative effects of lifestyle, aging, genetic factors, comorbidities, and cardiovascular status [5,6,7]. A growing body of evidence suggests a strong association between CRF and all-cause mortality, cardiovascular mortality, and incident cardiovascular outcomes. According to some reviews and expert statements, CRF may offer prognostic information that extends beyond traditional cardiovascular risk factors such as obesity, hypertension, diabetes, smoking, and dyslipidemia [5,8,9,10].

CRF is most commonly expressed as maximal oxygen uptake (VO2max), peak oxygen uptake (VO2peak), metabolic equivalents (METs), exercise capacity, or estimated cardiorespiratory fitness (eCRF). Although cardiopulmonary exercise testing is considered the reference method for direct physiological assessment, treadmill or cycle ergometer protocols, field-based tests, six-minute walk tests, and non-exercise prediction equations are also used in research and clinical practice [5,6,11]. The use of different assessment methods is the reason why related but not identical terms are used in the literature when examining the prognostic value of fitness. Recent evidence comparing objectively measured and estimated CRF suggests that both approaches retain prognostic value, which may be especially relevant for large-scale population studies and settings where direct testing is not feasible [11,12,13].

Despite the substantial evidence connecting CRF to cardiovascular and mortality outcomes, its clinical significance is not always fully reflected in routine cardiovascular risk assessments. Functional capacity is included less frequently in traditional risk models, which primarily focus on demographic, biochemical, and clinical variables. At the same time, CRF can be modified through physical activity, structured exercise, and cardiac rehabilitation. This makes CRF not only a marker of risk but also a possible therapeutic target. The aim of this narrative review is to evaluate the prognostic significance of cardiorespiratory fitness, as measured by VO2max, VO2peak, METs, exercise capacity, and estimated CRF, in relation to cardiovascular risk, cardiovascular outcomes, cardiovascular mortality, all-cause mortality, and premature mortality in adults.

2. Materials and Methods

This narrative review was based on publications identified in the PubMed and Google Scholar databases. The literature search covered publications available online up to May 2026. No strict publication-date limit was applied. Priority was given to recent publications, with particular emphasis on data from the past five years, as well as to studies of particular relevance and significance. Only English-language publications were considered. The search results were based on the following keywords: "cardiorespiratory fitness," "VO2max," "VO2peak," "maximal oxygen uptake," "peak oxygen uptake," "exercise capacity," "metabolic equivalents (METs)," "cardiovascular risk," "cardiovascular disease," "cardiovascular mortality," "all-cause mortality," and "premature mortality."

The narrative synthesis drew on meta-analyses, systematic reviews, observational cohort studies, clinical reviews, expert statements, and interventional studies relevant to exercise capacity, cardiovascular prevention, or cardiac rehabilitation. Publications were selected according to relevance to the objective of the review. Particular attention was paid to cardiorespiratory fitness, VO2max or VO2peak, exercise capacity, cardiovascular outcomes, and mortality.

Given the narrative design of this review, no formal risk-of-bias assessment tool was applied.

3. Review Results

3.1. Assessment and Clinical Meaning of Cardiorespiratory Fitness

CRF is defined as the integrated ability of the cardiovascular, respiratory, and skeletal-muscle systems to deliver and utilize oxygen during sustained physical activity [7]. It is closely related to exercise capacity and is typically expressed as maximal oxygen uptake (VO2max), peak oxygen uptake (VO2peak), or metabolic equivalents (METs), where 1 MET corresponds to 3.5 mL O2/kg/min [5,6]. The gold standard for assessing CRF in cardiovascular fitness testing is cardiopulmonary exercise testing (CPET), which directly measures oxygen consumption during activity. In practice, other tools are also used to estimate CRF, such as results from treadmill or bicycle ergometer protocols, field tests, 6-minute walk tests, or non-exercise prediction equations [6]. This variety of assessment methods clarifies the tendency of prognostic studies to utilize related but not identical terms, such as VO2max, VO2peak, exercise capacity, peak METs, and estimated CRF [6,11].

The clinical significance of CRF extends beyond its role as a measure of physical performance. Low CRF has been identified as a significant cardiovascular risk indicator. It has been suggested as a clinical vital sign due to its notable associations with cardiovascular and all-cause outcomes [5,6]. Although direct CPET provides the most accurate physiological assessment, it is not always feasible in routine clinical practice or large epidemiological studies because it requires equipment, trained personnel, and patient effort [6,12]. eCRF has gained importance as a practical alternative, particularly in population-based research and risk stratification [12]. Recent studies indicate that, irrespective of the assessment method, the associations of CRF with mortality risk remain broadly consistent [11,12]. This approach has also been applied to large population cohorts and selected high-risk groups. These groups include adults with hypertension and middle-aged or older adults from population-based studies. In these studies, higher eCRF was associated with lower cardiovascular risk or mortality [13,14].

3.2. Cardiorespiratory Fitness and All-Cause Mortality

Numerous studies have found a strong inverse association between cardiorespiratory fitness and all-cause mortality. A meta-analysis of healthy adults by Kodama et al. found a significant association between higher maximal aerobic capacity and lower all-cause mortality risk. Specifically, the study showed that each 1-MET higher level of maximal aerobic capacity was associated with a 13% lower risk of all-cause mortality [15]. Laukkanen et al. conducted a more recent, broader study in which they confirmed this association: a 1-MET increase in objectively assessed CRF was associated with an 11% lower risk of all-cause mortality. Individuals in the highest CRF tertile had a mortality risk approximately 45% lower than those in the lowest tertile [16]. A review of meta-analyses by Lang et al. likewise demonstrated this association. A 1-MET higher CRF level was linked to an 11–17% decrease in all-cause mortality risk [8]. Furthermore, Singh et al. demonstrated that regardless of the method used to assess physical fitness — whether objectively measured or estimated — CRF had prognostic significance. Each 1-MET increase in CRF was associated with a 14% lower risk of all-cause mortality [11].

Large cohort studies based on treadmill exercise testing also support the clinical relevance of CRF as a predictor of mortality. The strongest predictor of all-cause mortality among Black and White male veterans, as found by Kokkinos et al., was exercise capacity, expressed in peak METs. Each 1-MET increase was associated with a 13% lower mortality risk [17]. Mandsager et al. also demonstrated an inverse relationship between cardiorespiratory fitness and long-term mortality. Their study included a cohort of over 122,000 adults who underwent exercise treadmill testing. The lowest risk was observed among individuals with the highest fitness levels [18]. This graded relationship was confirmed in a large veteran cohort that included different age, sex, and racial groups. In this cohort, being unfit was associated with a greater mortality risk. This mortality risk was greater than several traditional cardiovascular risk factors [9]. Similar results were observed in the Asian clinical cohort. Peak MET values were independently associated with cardiovascular mortality and all-cause mortality across clinical subgroups [19].

It is important to note that CRF should not be perceived as a static baseline characteristic. Evidence from repeated fitness assessments shows that changes in CRF over time are also clinically relevant. For example, Blair et al. demonstrated that men who improved their physical fitness had a substantially lower risk of all-cause mortality than those who remained unfit [20]. More recently, Kokkinos et al. found that, in both individuals with cardiovascular disease and those without such conditions, changes of at least one metabolic equivalent (MET) were associated with inverse and proportional changes in mortality risk [21]. The CARDIA cohort data also indicate that higher fitness in early adulthood and better preservation of fitness through midlife are linked to a reduced risk of all-cause mortality later in life [22]. These findings collectively support the interpretation of CRF as a modifiable prognostic marker and highlight the significance of maintaining or enhancing fitness throughout life.

3.3. Cardiorespiratory Fitness and Cardiovascular Outcomes

Cardiorespiratory fitness is a significant prognostic factor for cardiovascular mortality and events. Meta-analytic evidence indicates a graded association between higher CRF and lower cardiovascular risk. For example, in a meta-analysis by Kodama et al., a 1-MET increase in maximal aerobic capacity was associated with a 15% lower risk of coronary heart disease or cardiovascular events [15]. More recent evidence confirms that this relationship is not limited to directly measured CRF. A systematic review and meta-analysis by Singh et al. found that each 1-MET increase in CRF was associated with a 16% lower risk of cardiovascular disease mortality, with similar associations observed for both objectively measured and estimated CRF [11]. Furthermore, a review of meta-analyses conducted by Lang et al. showed that higher levels of CRF were associated with a lower risk of several cardiovascular events, including an 18% lower risk of heart failure for every 1-MET increase in CRF [8]. These results suggest that CRF is an indicator not only of overall survival but also of cardiovascular disease burden.

The value of CRF is particularly evident in studies that use treadmill exercise testing and peak METs as practical measures of exercise capacity. Research consistently shows that lower fitness levels are associated with higher cardiovascular risk, even after accounting for traditional risk factors. In middle-aged adults without a history of cardiovascular disease, lower fitness was associated with an increased risk of major adverse cardiovascular events, defined as myocardial infarction, stroke, or all-cause death. Compared with high fitness levels, moderate and low fitness levels were associated with adjusted hazard ratios of 1.65 and 2.17, respectively. A 1-MET decrease in peak exercise capacity was associated with an 18% higher risk of major adverse cardiovascular events [23]. Similar findings from treadmill-based cohorts support the interpretation of exercise capacity as a practical cardiovascular risk marker, especially since peak METs can be obtained during widely available exercise stress tests [9,17,18,19].

CRF is also relevant to specific cardiovascular outcomes, such as heart failure, sudden cardiac death, and atherosclerotic cardiovascular disease. Among men without baseline cardiovascular disease, low CRF was strongly associated with heart failure mortality, with an adjusted hazard ratio of 3.97 for low fitness compared with high fitness [24]. Among middle-aged men who were overweight or obese, higher fitness was associated with a 39% lower risk of sudden cardiac death. The same study showed no notable elevated risk of sudden cardiac death among fit overweight or obese men when compared to their fit, normal-weight counterparts [25]. Recent studies also indicate that higher CRF is linked to a reduced risk of atherosclerotic cardiovascular disease (ASCVD), independent of genetic factors. In the UK Biobank cohort, each 1 standard deviation (SD) higher CRF level was associated with an 8% lower ASCVD hazard [26]. In summary, CRF is a comprehensive indicator of cardiovascular risk that reflects functional, metabolic, and circulatory capacity beyond traditional risk factors.

3.4. Cardiorespiratory Fitness in Populations with Obesity, Diabetes, and Cardiovascular Disease

CRF has a particularly significant prognostic value in populations with obesity, diabetes, hypertension, and cardiovascular disease because traditional risk factors often co-occur in these populations. In overweight or obese individuals, CRF appears to modify the risk attributed to adiposity. A recent systematic review and meta-analysis revealed that overweight/obese individuals who are fit do not have a greater risk of all-cause mortality than normal-weight, fit individuals. However, individuals with a body mass index (BMI) in the normal, overweight, or obese range who are unfit had a significantly higher mortality risk [27]. The findings indicate that fitness status may provide more useful information about risk than BMI alone. Similar observations have been reported in women. Higher CRF was associated with lower mortality across BMI categories. Different measures of body fat were less informative when CRF was not considered [28,29]. Obesity remains an important cardiovascular risk factor. However, low CRF may identify a particularly vulnerable subgroup. This relationship is observed within normal-weight, overweight, and obese groups [25,27,30].

Reduced CRF is also strongly associated with an adverse prognosis in patients with diabetes. Men with diabetes and low fitness are at a higher risk for cardiovascular mortality in all BMI categories, with hazard ratios of approximately 2.7–2.8 compared to normal-weight men with high fitness [31]. A similar association was observed in another group of men with diabetes. Those in the lowest fitness quartile had a significantly higher risk of all-cause mortality compared to those in the highest quartile [32]. These findings are clinically relevant because diabetes is often accompanied by obesity, hypertension, endothelial dysfunction, inflammation, microvascular impairment, and skeletal muscle abnormalities, all of which may contribute to reduced exercise capacity [33]. Thus, in diabetic populations, CRF may reflect not only lifestyle-related physical activity, but also the cumulative burden of metabolic and cardiovascular dysfunction.

Among patients diagnosed with coronary artery disease (CAD) and heart failure (HF), CRF is recognized as a prognostic indicator and a therapeutic objective. Among patients with CAD undergoing cardiac rehabilitation, an independent and cumulative association between low CRF and central obesity has been demonstrated, with both factors independently predicting elevated all-cause mortality. These observations indicate that body composition should be considered alongside exercise capacity; it should not be considered in isolation [34]. Risk-profile improvement may be achieved through exercise-based cardiac rehabilitation, which increases functional capacity. High-intensity interval training (HIIT) has been shown to improve peak VO2 more than moderate-intensity continuous training (MICT) in patients with CAD [35]. Exercise interventions in patients with CAD and HF have improved exercise capacity and selected prognostic markers, according to meta-analytic evidence [36]. In HF, exercise intolerance indicates central and peripheral pathophysiological limitations [7]. Exercise training is recommended for clinically stable patients because it improves exercise capacity, quality of life, and clinical outcomes [37].

eCRF may be useful for high-risk clinical groups for whom direct exercise testing is not feasible. In adults with hypertension, a 1-MET increase in estimated CRF was associated with decreased all-cause and cardiovascular mortality, with adjusted hazard ratios of 0.78 and 0.79, respectively [14]. The practical value of eCRF for risk stratification in large populations and routine clinical settings supports these observations. However, estimated CRF is recommended to complement, rather than replace, direct physiological assessments when cardiopulmonary exercise testing (CPET) or exercise stress testing (EST) is clinically indicated [5,11,14]. Evidence gathered from high-risk populations indicates that CRF functions as an integrative indicator of cardiometabolic health, functional reserve, and cardiovascular prognosis, instead of simply serving as a marker of athletic performance.

3.5. Clinical Implications

Available evidence supports including cardiorespiratory fitness in clinical risk assessments. CRF provides prognostic information beyond traditional cardiovascular risk factors and has been proposed as a clinical vital sign in preventive cardiology. Its assessment may be performed using cardiopulmonary exercise testing, treadmill or cycle ergometer protocols, field-based tests, or the 6-minute walk test. Validated non-exercise equations may also be used when direct testing is not feasible [5,6,10]. This is clinically significant because higher CRF is consistently associated with lower all-cause and cardiovascular mortality. Comparative evidence indicates that objectively measured, exercise-estimated, and non-exercise-estimated CRF all retain prognostic value [11]. Therefore, CRF should be interpreted not only as a marker of physical performance. It should also be interpreted as an integrated indicator of cardiovascular, respiratory, metabolic, and muscular health.

From a therapeutic perspective, CRF is a modifiable target. Exercise prescription should be personalized based on factors such as age, initial fitness level, the presence of other health conditions, symptoms, medication use, and overall clinical stability. Patients with established cardiovascular disease can improve their exercise capacity and selected prognostic markers through cardiac rehabilitation and structured exercise training [2,36,37]. For patients with stable coronary artery disease, high-intensity interval training has been shown to improve peak VO2 more effectively than moderate-intensity steady-state training, with an adjusted between-group difference of approximately 1.04 mL/kg/min after eight weeks [35]. In cases of heart failure, the inability to tolerate exercise is indicative of both central and peripheral pathophysiological limitations. For patients who are clinically stable, exercise training is recommended, as it has been shown to enhance exercise capacity, quality of life, and clinical outcomes [37]. These findings suggest that improving CRF is an important goal not only for prevention but also for secondary prevention and rehabilitation.

At the population level, the clinical relevance of CRF supports early and sustained promotion of physical activity. This promotion should occur across the life course. Public health evidence indicates that even modest amounts of moderate-to-vigorous physical activity are associated with health benefits. Meeting guideline-recommended activity levels provides a substantial proportion of the maximal mortality and cardiovascular risk reduction achievable through physical activity alone [4]. Higher fitness in early adulthood and better preservation of fitness through midlife are associated with lower later risk of all-cause mortality and cardiovascular outcomes, while repeated fitness assessments show that changes in CRF over time are linked to proportional changes in mortality risk [21,22]. This practical message for clinicians and public health professionals is supported by the evidence: CRF should be assessed when possible, improved when low, and maintained throughout adulthood and older age as part of cardiovascular prevention [3,38,39].

4. Discussion

The findings of this review indicate that CRF is a strong and consistent marker for predicting cardiovascular health and survival. Higher CRF, assessed by VO2max, VO2peak, peak metabolic equivalents (METs), exercise capacity, or estimated CRF, was associated with a lower risk of mortality and cardiovascular events. This association has been observed across various studies [8,9,11,15,16]. This relationship has also been observed using various CRF assessment methods and in different populations, including healthy adults, patients with cardiovascular disease, obese individuals, patients with diabetes, and adults with hypertension [11,14,27,31,32,34]. Additionally, evidence from repeated fitness assessments suggests that CRF is not solely a fixed baseline characteristic. Changes in CRF over time are clinically relevant, and improvements or declines in fitness appear to correspond with changes in mortality risk [21,22]. Therefore, CRF can be interpreted as both a prognostic marker and a modifiable target.

The importance of CRF in predicting outcomes may be explained by its role in integrating physiological processes. CRF represents the combined function of the cardiovascular, respiratory, skeletal muscle, and metabolic systems during physical exertion [7]. Low CRF may therefore indicate impaired cardiac reserve, vascular dysfunction, reduced skeletal-muscle oxidative capacity, physical inactivity, or the cumulative burden of chronic diseases. This is particularly relevant in populations with obesity and type 2 diabetes, where low exercise capacity may reflect not only reduced physical activity but also insulin resistance, endothelial dysfunction, inflammation, microvascular impairment, and skeletal-muscle abnormalities [1,3,33]. Similarly, exercise intolerance in heart failure results from central and peripheral limitations, explaining why CRF and exercise capacity are closely linked to symptoms, functional status, and prognosis [7,37]. Therefore, CRF is valuable because it summarizes several biological and clinical pathways that are not fully captured by traditional cardiovascular risk factors.

From a clinical perspective, the evidence supports the broader use of CRF in cardiovascular risk stratification and prevention. CRF has been proposed as a vital sign, and assessing it may improve risk classification beyond conventional factors, such as blood pressure, lipid profile, obesity, smoking, and diabetes [5,6,10]. Cardiopulmonary exercise testing provides the most accurate physiological evaluation when available. However, treadmill testing, peak metabolic equivalents (METs), field-based tests, six-minute walk tests, and non-exercise equations can also provide clinically useful information, especially in settings where direct measurement is not feasible [6,11,12]. This is important because CRF is measurable and modifiable. Exercise prescription, cardiac rehabilitation, and structured physical activity interventions can improve functional capacity and prognosis-related markers, particularly in patients with coronary artery disease and heart failure [2,36,37]. Consequently, recognizing low CRF should result in not only risk identification but also targeted preventive or rehabilitative measures.

5. Limitation of the Review

Several limitations are present in this review. First, it is a narrative review and did not include a formal systematic-review protocol, PRISMA-based screening process, or risk-of-bias assessment. Second, the included evidence is heterogeneous in terms of populations, CRF assessment methods, follow-up duration, and clinical endpoints. Studies used different measures, including directly measured VO2max or VO2peak, treadmill-derived peak METs, symptom-limited exercise capacity, and estimated CRF. This limits direct comparison between findings [6,11,12]. Third, observational cohort studies, which provide most of the available evidence, should not be interpreted as definitive proof of causality because they are subject to certain limitations. Finally, although estimated CRF is useful for large-scale and routine risk assessment, it should not be regarded as a full substitute for direct physiological testing when CPET or exercise stress testing is clinically indicated [6,12,13,14]. Despite these limitations, the consistency of the findings across different study designs and populations supports the clinical relevance of CRF as an important marker of cardiovascular and mortality risk and functional health.

6. Conclusions

CRF is a strong and consistent indicator of cardiovascular risk and mortality in adults. Higher CRF, assessed by VO2max, VO2peak, metabolic equivalents (METs), exercise capacity, or estimated CRF, is associated with lower all-cause mortality, cardiovascular mortality, and cardiovascular event risk [8,9,11,15,16,23]. Evidence indicates that this relationship is observed across different CRF assessment methods and in both general and clinical populations. Therefore, CRF should be regarded as both a measure of physical performance and an important indicator of cardiovascular, respiratory, metabolic, and functional health.

The findings of this review support the inclusion of CRF in cardiovascular risk assessment when feasible. While direct measurement by cardiopulmonary exercise testing is the most accurate approach, treadmill testing, peak METs, field-based tests, and estimated CRF may also provide clinically useful prognostic information [5,6,11]. Importantly, CRF is a modifiable factor. Evidence indicates that improvements in fitness over time may be associated with better survival, which supports the role of physical activity, structured exercise, and cardiac rehabilitation in cardiovascular prevention and long-term health promotion [2,21,37]. Future research should focus on standardizing CRF assessment methods and determining whether longitudinal improvements in CRF translate into consistent reductions in cardiovascular risk across different clinical populations.

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