Epidemiology and Demographics of Coronary Artery Disease

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1 A Brief History of Coronary Artery Disease

Coronary artery disease (CAD) has plagued mankind for thousands of years. In fact, recent computed tomography imaging studies of mummies over 4000 years old identified vascular atherosclerosis in a large number who had an average age of death of 43 years [1]. However, the description of coronary atherosclerosis is much more recent and dates back just centuries. Leonardo da Vinci was one of the first to describe vascular atherosclerosis in the late fifteenth century stating "vessels in the elderly, through thickenings of the tunics, restrict the transit of the blood [2]." Over 200 years later, in 1772 William Heberden is credited with the first description of angina [2, 3]:

> Those who are afflicted with it are seized, while they are walking, and more particularly when they walk soon after eating, with a painful and most disagreeable sensation in the breast which seems as if it would take their life away if it were to increase or to continue. The moment they stand still, all this uneasiness vanishes.

The connection between angina and CAD was made by Edward Jenner in the late eighteenth century, after a patient of his who described angina was found to have ossified coronary arteries on autopsy [2]. It was not until the nineteenth century that Rudolph Virchow described his famous triad of thrombosis and provided the early theories of the development of atheroma which remain relevant today [2] (see Fig. 1 for current understanding of the development of coronary atherosclerosis and myocardial infarction). In 1910, Obrastzow and Straschesko, two Russian clinicians described clinical acute myocardial infarction (MI) in a living patient confirmed

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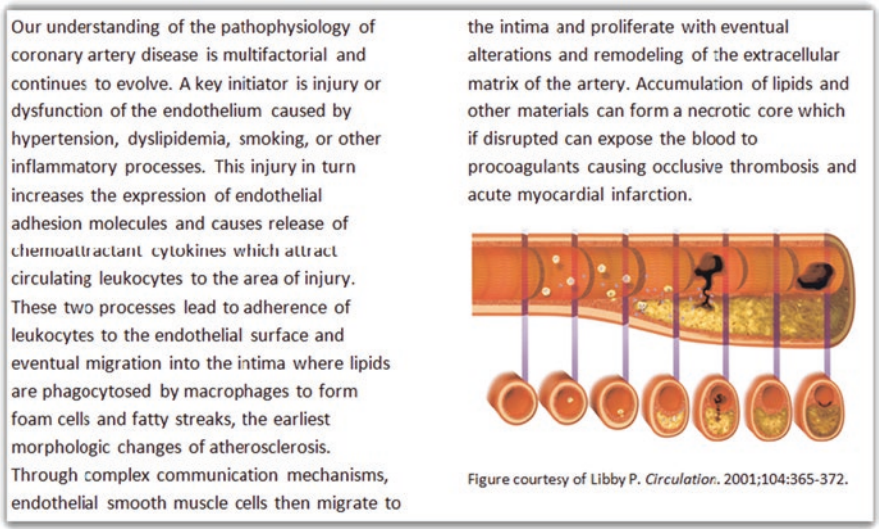

Fig. 1 Brief pathophysiology of coronary artery disease

later on autopsy [2, 3]. Just 2 years later, James Herrick established the use of electrocardiography to diagnose MI and the role of bed rest for management [2–4].

The twentieth century saw a boom in the understanding and diagnosis of CAD with the discovery of lipoproteins, the advent of cardiac catheterization by Werner Forssmann in 1929, selective coronary angiography by Mason Sones in 1958, and identification of risk factors associated with CAD through the Framingham Heart Study [2, 5]. Additionally, the treatment of CAD with medical therapy through clinical trials and the development of coronary artery stents were paramount in the late twentieth century.

Despite the advances in our understanding of CAD in regard to diagnosis, management, and prevention, cardiovascular diseases (CVD), and specifically coronary heart disease (CHD), remain the leading causes of death in the twenty-first century.

2 History of Coronary Artery Disease Epidemiology

The study of epidemiology is vital in identifying the connections which exist between lifestyle, environment, and disease, thus providing knowledge of the factors, distribution, and pathology of the particular disease. A notable shift in the study of epidemiology occurred in the mid-twentieth century when epidemiological studies began to include chronic noncommunicable diseases such as lung cancer and CAD [6]. Prior to that, epidemiology studies largely focused on infectious diseases as they were easier to diagnose. On the other hand, noncommunicable diseases like CAD were much more difficult to diagnose and understand as they had

long latency periods [6, 7]. In order to understand CAD, a paradigm shift in the approach to disease was warranted, one that required the understanding of disease as the outcome of numerous compounding factors, often habitual in nature, and that were chronic rather than acute [6].

Coronary artery disease was the consequence of multiple "risk" factors with unpredictable onset and disease progression resulting in atherosclerotic lesions which could not be observed in the living patient. In fact, a diagnosis of CAD in the beginning of the twentieth century could only be made postmortem. Therefore, it was difficult to truly assess the prevalence and mortality of CAD, although even at that time it was estimated that approximately one in five deaths in the United Kingdom were due to atherosclerotic heart disease [6]. Additionally, such factors of risk or "risk factors" (which was a term that was not well established until the early 1960s) were not always present in patients with disease [6]. Thus, the implementation of prospective cohort studies by the Framingham Study sought to better understand CAD epidemiology.

The Framingham study, which investigated heart disease epidemiology, was designed in 1947 as a longitudinal study intended to perform long-term follow-up of a population of individuals without known heart disease and assess the progression of CAD in order to study the natural history of coronary heart disease (CHD) [6]. Risk factor epidemiology emerged from the CAD methodology of epidemiology which, unlike prior noncommunicable disease epidemiology studies, identified multiple risk factors for a single disease [6]. Coronary artery disease epidemiologists incorporated the multiple risk factor concept that the insurance industry had used for years previously [6]. Over the ensuing years, factors including hypercholesterolemia, hypertension, use of tobacco, and physical activity were identified to impact risk of CAD although a causal link was not established due to study design until the 1980s [6].

Since then, numerous studies have been performed that have evaluated the natural history and epidemiology of CAD providing clinicians with the tools to better diagnose, treat, and even prevent CVD and CAD.

3 Total Cardiovascular Disease Statistics

3.1 Prevalence

According to the most updated 2020 America Heart Association (AHA) heart disease and stroke statistics, the prevalence of CVD (including CHD, heart failure, stroke, and hypertension) in the United States (US) is approximately 121.5 million or 48% of adults ≥20 years of age (Fig. 2), which accounts for almost one out of every two adults ≥20 years of age [8, 9]. The prevalence of CVD is lower in women, those with a bachelor's degree or higher, and those who are employed [9].

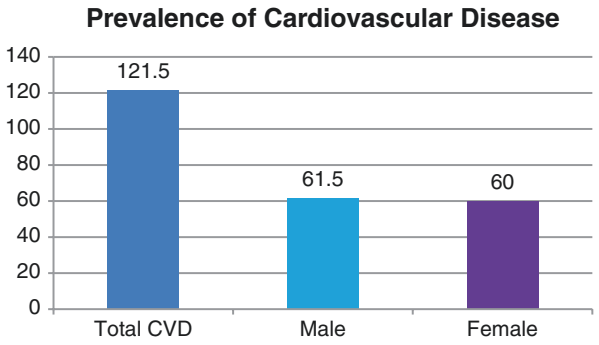

Fig. 2 Prevalence of cardiovascular disease by sex in the US in adults ≥20 years of age (data presented in millions). *CVD* = cardiovascular disease, *US* = United States. Data extracted from the American Heart Association heart disease and stroke statistics—2020 update [9]

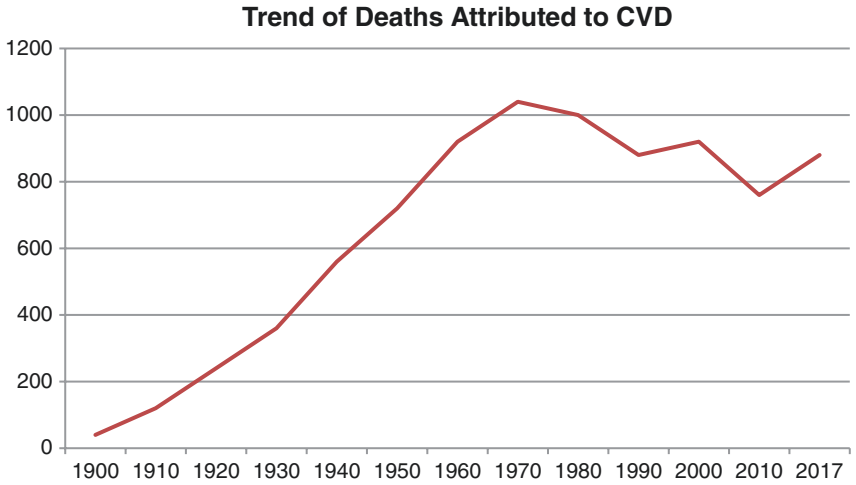

Fig. 3 General trend of deaths attributed to CVD in the US between 1900–2017. Deaths are presented in the thousands. *CVD* = cardiovascular disease. Data extracted from the American Heart Association heart disease and stroke statistics—2020 update [9]

3.2 Mortality

Globally, CVD is the leading cause of death, and in 2017, approximately 17.8 million deaths were attributed worldwide to CVD, which is a 21% increase compared to a decade prior [9].

According to the Centers for Disease Control and Prevention, CVD remains the leading cause of death in the US accounting for one in four deaths [8]. Deaths attributable to CVD increased from the 1900s to the 1980s where it declined in 2010; however, recently there has been an increase (Fig. 3) [9]. Although the absolute number of CVD deaths continues to increase, the age standardized death rate has decreased by approximately 15% from 2007 to 2017 [9]. In 2016, over 1000 CVD-related deaths occurred daily with the highest mortality rates in non-Hispanic blacks (Fig. 4) [9].

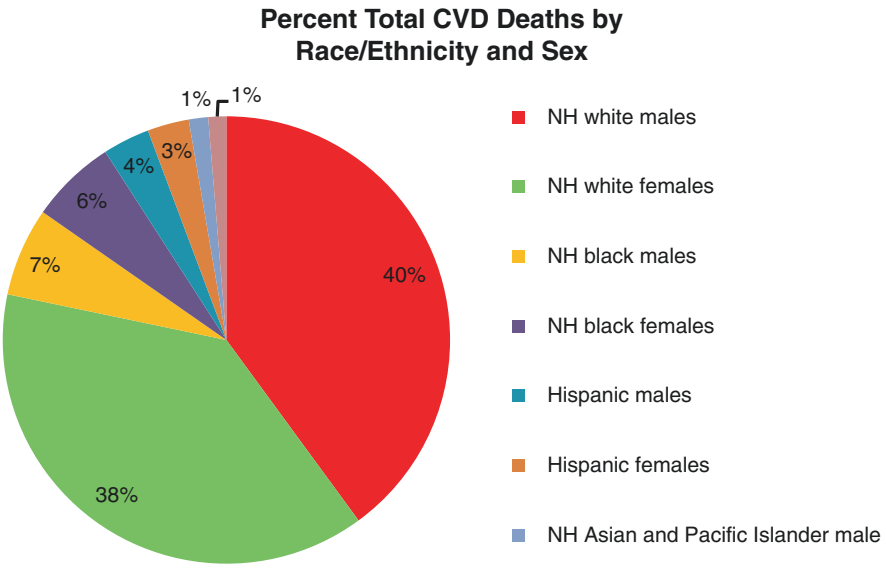

Fig. 4 Percent total CVD death by race/ethnicity and sex in the US. *CVD* cardiovascular disease, *NH* = non-Hispanic. Data extracted from the American Heart Association heart disease and stroke statistics—2020 update [9]

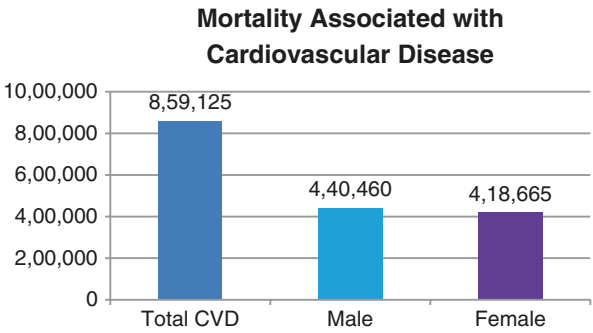

Fig. 5 Mortality associated with cardiovascular disease by sex in the US. *CVD* = cardiovascular disease, *US* = United States. Data extracted from the American Heart Association heart disease and stroke statistics—2020 update [9]

A common misconception is that cardiovascular diseases do not affect females as it does males. This could not be further from the truth (Fig. 5). Cardiovascular diseases claimed the lives of approximately 420,000 American females in 2017; by comparison, breast cancer took the lives of just over 42,000 American females. For comparison, Fig. 6 illustrates the other top causes of death in the US. Of note, the data presented in Fig. 6 is based on 2017 data and does not take into account deaths caused by the 2020 Coronavirus disease 19 (COVID-19) pandemic, which at the time of writing this chapter accounted for approximately 350,000 deaths (per report, it was the third leading cause of death at the current time) [8].

Regionally, the highest CVD-related mortality rates are in Louisiana, Mississippi, Alabama, and Oklahoma, and the lowest rates are in Minnesota, Colorado,

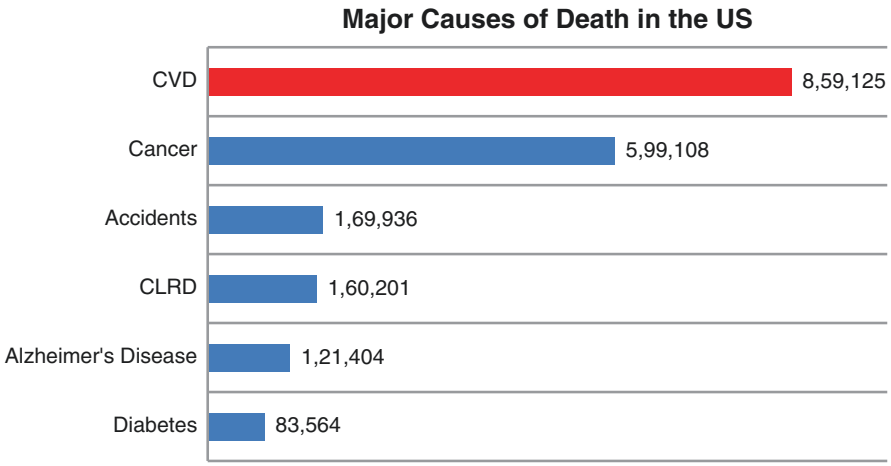

Fig. 6 Major causes of death in the US (total number) per 2017 data. *CLRD* = chronic lower respiratory disease, *CVD* = cardiovascular disease. Data extracted from the American Heart Association heart disease and stroke statistics—2020 update [9]

Massachusetts, and Hawaii [9]. CVD mortality is higher with lack of insurance and lower socioeconomic status.

The estimated direct and indirect cost of CVD is approximately $220 billion.

4 Coronary Artery Disease Statistics

4.1 Prevalence

Heart disease caused by CAD or CHD accounts for almost half of all causes of heart disease and remains the leading cause of death in the US in those over age 35 years (Fig. 7) [9]. Approximately 18.2 million Americans ≥20 years old have CHD (9.4 million males and 8.8 million females). For comparison, the population of the four most populated cities in the US combined is approximately 18 million (New York City, Los Angeles, Chicago, and Houston). The prevalence of CHD is 6.7% of US adults ≥20 years of age (7.4% for males and 6.2% for females) with the highest prevalence among blacks (Fig. 8).

The prevalence of CHD has decreased over time based on autopsy studies in US military personnel. Autopsy confirmed that CHD in soldiers in the Korean War in the 1950s was approximately 77%, while it was 8.5% in soldiers who died from 2001 to 2011, although the majority of the soldiers were male [10, 11].

Globally, it is estimated that 126.5 million people have CHD, which is almost a 75% increase between 1990 and 2017, with highest prevalence in North Africa, the Middle East, and Eastern Europe.

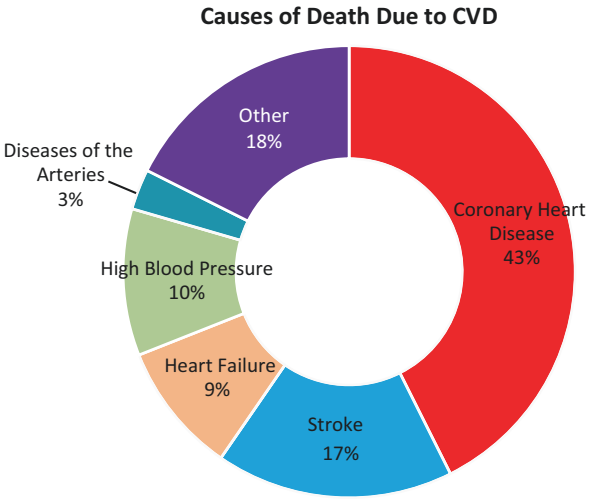

Fig. 7 Causes of death attributed to CVD by percent. *CVD* = cardiovascular disease. Data extracted from the American Heart Association heart disease and stroke statistics—2020 update [9]

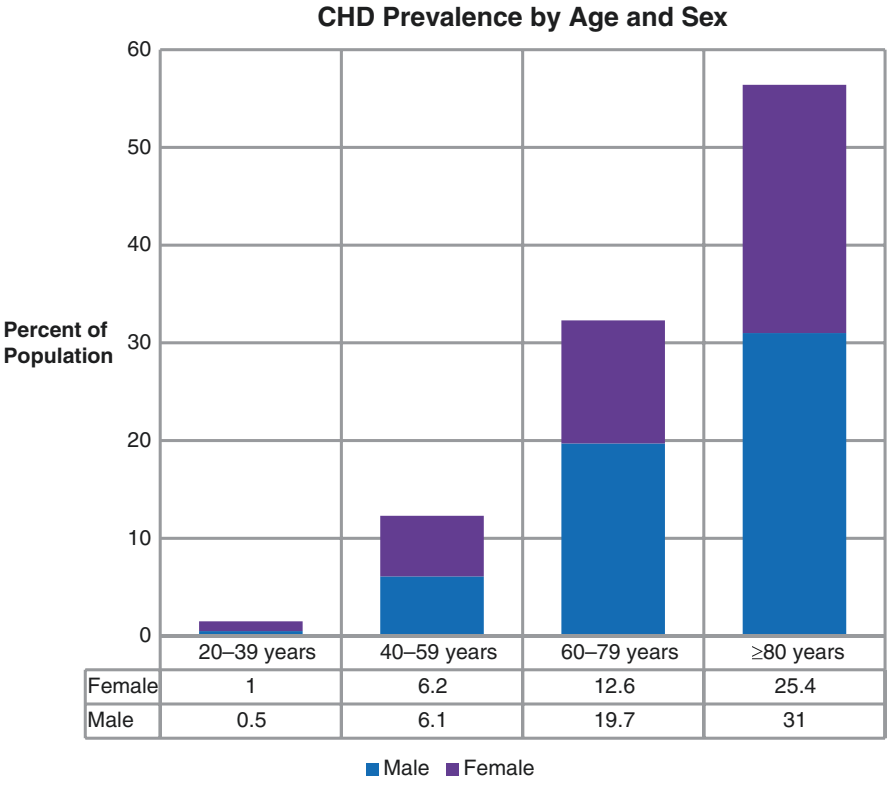

Fig. 8 Coronary heart disease prevalence (in percent) by age and sex in the United States. *CHD* = coronary heart disease. Data extracted from the American Heart Association heart disease and stroke statistics—2020 update [9]

In regard to MI, the overall prevalence is 3.0% in US adults ≥20 years of age (4.0% in males and 2.3% in females). Interestingly, males have a higher prevalence than females in all age groups except the 20–39 year age group [9].

4.2 Incidence

Annually, it is estimated that 805,000 Americans will have an MI. Of these, approximately 605,000 are first time MIs, and approximately 200,000 are recurrent MI's [9]. It is also estimated that 170,000 of these MIs will be silent. The average age at first MI for males is 65.6 and for females is 72.0. The incidence of MI increases with lower income and lower education level. However, there is suggestion that the rate of MI has declined significantly over time [9].

According to the ARIC study, clinically recognized MI was higher in whites than in blacks (5.04 versus 3.24 per 100 person-years) [12].

Interestingly, the rate of MI as a primary diagnosis decreased, while the rate of MI as a secondary diagnosis increased (this may be due to increased type 2 events or acute myocardial injury in response to acute illness rather than type 1 events or acute myocardial injury) [9].

4.3 Mortality

Mortality associated with CHD was 541,008, and MI mortality was 149,028 [9]. Although CVD and CHD remain leading causes of death, mortality from MI has decreased significantly [13] (by over 50% over the last 25 years). Fortunately, there is also a downward trend in CHD mortality, and this trend is predicted to continue. For example, between 2007 and 2017, there was a 10% decline in the number of deaths due to CHD [9]. Reasons for this trend largely are due to therapy (both primary and secondary prevention).

CHD age-adjusted death rates were highest in non-Hispanic black males followed by non-Hispanic white males, Hispanic males, non-Hispanic black females, non-Hispanic white females, and Hispanic females [9]. Additionally, survival and life expectancy after an MI is higher in whites than in blacks (7.4% vs. 5.7%) and improved with higher socioeconomic area [9]. Unfortunately, approximately 35% of people with CHD will suffer a coronary event and approximately 14% will die because of the coronary event. Interestingly, over 75% of CHD deaths occurred out of hospital [9].

The estimated direct and indirect cost of CHD and MI combined is approximately $21 billion and accounts for two of the top ten most expensive conditions treated in the US.

Mortality from CAD is expected to increase in developing countries due to economic and societal changes that occur with advanced development [14, 15]. The

risk of development of CAD is said to increase with the transition of rural, agrarian, economically underdeveloped to urbanized, industrialized modern societies [14, 15]. Modernization leads to a more sedentary lifestyle, diets higher in calories, and psychosocial stresses [15]. It was found that a population of Japanese people (Japan being a low risk CAD location) who immigrated to the US acquired an incidence of CAD that was similar to those native to the US [14]. Higher life expectancy, changes in diet, lifestyle, and environment may be to blame [15]. India, China, and the United States are among the countries with the highest deaths attributed to CAD [14].

See Fig. 9 for a quick overview of relevant statistics related to CVD and CAD.

5 Risk Factors Associated with CAD

Epidemiological studies have provided the medical community with determinants of CAD. Approximately 90% of patients with CAD have at least one major modifiable risk factor such as hypertension, physical inactivity, smoking, hyperlipidemia, obesity, dietary factors, and regular alcohol use [16]. See Fig. 10 for a brief list of

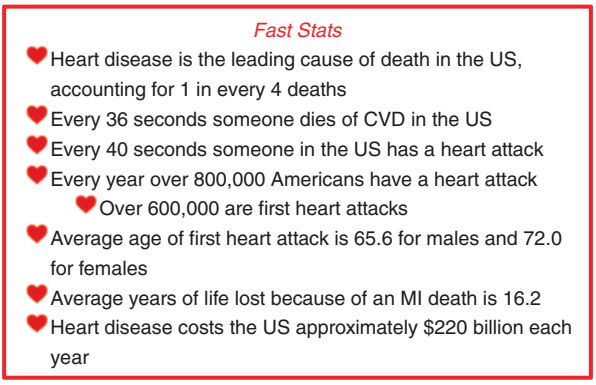

Fig. 9 Cardiovascular disease fast stats. *CVD* = cardiovascular disease, *MI* = myocardial infarction, *US* = United States

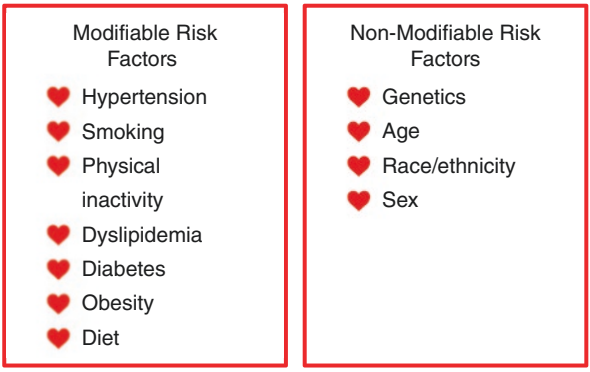

Fig. 10 Brief list of risk factors associated with CVD and CHD. *CHD* = coronary heart disease, *CVD* = cardiovascular disease

risk factors associated with CAD. The more risk factors a person has, the higher the risk of CVD and CAD [16]. The following section is a brief discussion regarding some common CAD risks factors.

5.1 Hypertension

The prevalence of hypertension (defined as a blood pressure greater than or equal to 130/90 mmHg) was 46% or 116.4 million adults (58.7 million males and 57.7 million females), which translates to roughly one in three Americans [9]. However, it is estimated that 35% of adults are unaware that they have hypertension [9]. There is a doubling of mortality from CHD and stroke for every 20/10 mmHg increase in blood pressure [17].

5.2 Physical Inactivity

Physical inactivity is another major risk factor of CAD. Physical inactivity increases risk of CAD by up to twofold [9]. Based on self-reporting, the prevalence of physical inactivity among adults has declined from 40.2% in 2005 to 25.9% in 2017 [9]. However, the prevalence of high school students meeting the recommended physical activity goal of ≥60 minutes of moderate to vigorous activity 7 days a week was 26.1% with girls meeting this goal half as likely as boys [9]. Additionally, 19.5% of girls and 11.0% of boys report that they do not participate in ≥60 min of any kind of physical activity in the prior week. Of note, these data are based on 2017 data, prior to implementation of the virtual learning environment due to the COVID-19 pandemic.

5.3 Smoking/Tobacco Use

Smokers are 2–3 times more likely to develop CHD than nonsmokers [18]. Smoking just one cigarette per day carries a greater than expected risk of developing CHD. In fact, smoking just one cigarette per day carries half the risk of smoking 20 cigarettes per day, thus there is no safe level of smoking in regard to CVD risk [18]. However, 27.1% of high school students and 7.2% of middle school students admit to using tobacco products with highest rates in non-Hispanic whites [9]. Although the rates of smoking have decreased by 50% since the 1960s, currently the prevalence for smoking in adults ≥18 years of age is 34.1 million or 14% of the adult population [8]. The highest rates of smoking are in males, those aged 45–64 years, non-Hispanic American Indians/Alaska Natives, lower education level, lower income, and those

who are divorced/separated/widowed [8]. Approximately 90% of people that use cigarettes daily begin before age 18 years [8].

The most commonly used tobacco product in adolescents is now electronic cigarettes which has increased from 1.5% to 20.8% from 2011 to 2018 (although the CVD risks associated with electronic cigarettes are not known at this time) [9]. Quitting smoking at any age does significantly lower mortality from diseases related to smoking including CVD [9, 18].

5.4 Overweight and Obesity

Obesity is an independent risk factor for CHD, and over 80% of patients with CHD are overweight or obese [19]. The hazard ratio for CHD in adults with obesity ranges between 2 and 3 [9]. The prevalence of obesity in adults increased significantly (30.5% in 1999) to 38.3% in 2018 (36% of males and 40.4% of females). The highest rates in males are in Hispanics and in females are in non-Hispanic blacks. Obesity correlates with CHD, diabetes mellitus (DM), hypertension, hyperlipidemia, and sleep-disordered breathing which can all worsen CVD.

In adolescents aged 12–19 years, the prevalence of obesity (defined as BMI ≥95th percentile for age) is 20.6% with lowest rates in non-Hispanic Asians. Longitudinal studies have identified that adolescents with obesity carry a significantly increased risk of CHD-related death as adults with a hazard ratio of 4.9 compared to adolescents at the lowest BMI quartile [9].

5.5 Hyperlipidemia

It is estimated that 92.8 million Americans have total blood cholesterol ≥200 mg/dL, which is about 38.2% of the adult population with an increasing trend [9]. Females had higher prevalence of total cholesterol ≥200 mg/dL (40.4% vs 35.4% in males) and the mean LDL-C for adults ≥20 years of age was 112.1 mg/dL and for HDL was 54.2 mg/dL [9].

5.6 Diabetes

Diabetes mellitus doubles the risk of CHD [8]. It is estimated that 26 million adults have diagnosed DM, 9.4 million have undiagnosed DM and 91.8 million have prediabetes [9]. Additionally, 1.5 million new cases of diabetes were diagnosed in adults in 2015 [9]. Worldwide, the trend of diabetes is increasing [9].

6 Conclusion

Despite the wealth of knowledge gained through epidemiological studies of CVD and CHD, there is still much work to do as CVD and CHD remain the leading causes of death. We must continue to push community education and awareness programs. In fact, the median time from cardiac symptom onset to hospital arrival has not improved significantly (45% presented within first 2 hours of symptoms between 2001 and 2003 compared to 48% between 2009 and 2011) [9]. Additionally, it is unknown what the consequences of the COVID-19 pandemic will have on CVD and CHD rates going forward. There is data suggesting that the delay in cardiac symptom to first medical contact has increased as a result of fears related to contracting COVID-19 [20, 21]. Additionally, there is concern that patients may be avoiding health care all together, suffering MIs at home. Only time will tell as to the longer term cardiovascular sequelae of COVID-19. As we continue to monitor the distribution of CAD in populations, epidemiology will provide us with even better insights into such devastating disease worldwide.

References

1. Thompson RC, Allam AH, Lombardi GP, et al. Atherosclerosis across 4000 years of human history: the Horus study of four ancient populations. Lancet. 2013;381(9873):1211–22.
2. Gotto AM. Some reflections on arteriosclerosis: past, present, and future: presidential address. Circulation. 1985;72(1):1–17.
3. Hajar R. Coronary heart disease: from mummies to the 21st century. Heart Views. 2017;18(2):68–74.
4. Herrick JB. Clinical features of sudden obstruction of the coronary arteries. JAMA. 1912;59(23):2015–20.
5. Nabel EG, Braunwald E. A tale of coronary artery disease and myocardial infarction. NEJM. 2012;366(1):54–63.
6. Oppenheimer GM. Profiling Risk: the emergency of coronary heart disease epidemiology in the United States (1947-70). Int J Epidemiol. 2006;35:720–30.
7. Lynch J, Smith GD. A life course approach to chronic disease epidemiology. Annu Rev Public Health. 2005;26:1–35.
8. CDC website. https://www.cdc.gov. Accessed 28 December 2020.
9. Benjamin EJ, Muntner P, Alonsoa A, et al. Heart disease and stroke statistics – 2019 update: a report from the American Heart Association. Circulation. 2019;139:56–8.
10. Joseph A, Ackerman D, Talley JD, et al. Manifestations of coronary atherosclerosis in young trauma victims—an autopsy study. JACC. 1993;22(2):459–67.
11. Webber BJ, Sequin PG, Burnett DG, et al. Prevalence of and risk factors for autopsy-determined atherosclerosis among US service members, 2001-2011. JAMA. 2012;308(24):2577–83.
12. Zhang ZM, Rautaharju P, Prineas RJ. Race and sex differences in the incidence and prognostic significance of silent myocardial infarction in the atherosclerosis risk in communities (ARIC) study. Circulation. 2016;133(22):2141–8.
13. Gerber Y, Weston SA, Jiang R, et al. The changing epidemiology of myocardial infarction in Olmsted County, Minnesota, 1995-2012. Am J Med. 2015;128:144–51.
14. Tyroler HA. Coronary heart disease epidemiology in the 21st century. Epidemiol Rev. 2000;22(1):7–13.

15. Sanchis-Gomar F, Perez-Quilis C, Leischik R, et al. Epidemiology of coronary heart disease and acute coronary syndrome. Ann Transl Med. 2016;4(13):256.
16. Yusuf S, Hawken W, Ounpuu S, et al. Effect of potentially modifiable risk factors associated with myocardial infarciton in 52 countries (the INTERHEART study): case-control study. Lancet. 2004;364:937–52.
17. Lewington S, Clarke R, Qizilbash N, et al. Age-specific relevance of unusual blood pressure to vascular mortality: a meta-analysis of individual data for one million adults in 61 prospective studies. Lancet. 2002;360:1903–13.
18. Hacksaw A, Morris JK, Boniface S, et al. Low cigarette consumption and risk of coronary heart disease and stroke: meta-analysis of 141 cohort studies in 55 study reports. BMJ. 2018;360:j5855.
19. Ades PA, Savage PD. Obesity in coronary heart disease: an unaddressed behavioral risk factor. Prev Med. 2017;104:117–9.
20. Abdelaziz H, Abdelrahman A, Nabi A, et al. Impact of COVID-19 pandemic on patients with ST-segment elevation myocardial infarction: insights form a Britich cardiac center. Am Heart J. 2020;226:45–8.
21. Tam CCF, Cheung KS, Lam S, et al. Impact of coronavirus disease 2019 (COVID-19) outbreak on ST-segment elevation myocardial infarction care in Hong Kong, China. Circ Cardiovasc Qual Outcomes. 2020;13:1–3.