Examining the link between exercise and cardiac injury

Regular exercise is the cornerstone of prevention and treatment of many cardiac and non-cardiac diseases, and has been robustly validated across the medical literature. Recognizing the benefits of a healthy and active lifestyle, the American Heart Association suggests at least 150 minutes per week of moderate intensity aerobic activity or 75 minutes per week of vigorous aerobic activity – or a combination of both, preferably spread throughout the week.

Many people leading hectic lives, and seeking to exercise primarily for the purpose of general fitness, struggle to find the time necessary to attain these goals. On the other hand, most endurance athletes train for substantially more time than this. Many cyclists – including those at the recreational level – may exceed these recommendations, and even in a single workout.

The notion that too much exercise may be harmful has recently been embraced and disseminated by some parts of the media. Exercise at the Extremes, a detailed evidenced-based review published by the American College of Cardiology (ACC), addressed the controversies and available scientific data surrounding excessive training volumes, citing a number of adverse findings which have caused some to view exercise as a “drug” which may be beneficial in moderation, but also potentially harmful when abused. Furthermore, observational studies such as the **Copenhagen City Heart Study** have suggested that the benefits of exercise demonstrate a “U-shaped” distribution whereby the benefits of training reach a plateau, and where exceeding that plateau may actually be detrimental to an athlete’s health.

Horrifying individual reports of professional cyclists who develop serious heart problems, or even suffer sudden cardiac death (SCD), have garnered tremendous media scrutiny – diverting attention from the true benefits of exercise in managing heart problems and reducing long-term mortality risk. In turn, this has produced anxiety for both professionals and amateurs regarding their own risk.

But of course non-athletes also experience heart problems and SCD, so the question should be: Is it really the exercise that is causing the problem? A recent comprehensive and widely-discussed study by physicians at the Cleveland Clinic Foundation, conversely suggests that the benefits of cardiorespiratory fitness (CRF) are “linear” with respect to longevity, concluding that the highest levels of CRF are associated with the lowest risk of premature death – even among “elite” performers.

In other words, there is no such thing as too much exercise. So, where is the truth?

As we have discussed before, consistent endurance training induces “physiologic remodeling,” or normal adaptations to the heart resulting in improved efficiency of an athlete’s engine. Sports like cycling, marathon running, and triathlon require habitual training to perform well, even at the lowest competitive levels.

Cyclists are unique because they typically perform the most prolonged exercise pattern – more hours per day and more days per year than nearly any other athletes – often functioning at a very high percentage of their VO2 max. (Both objective and accurate, VO2 max measures the maximum amount of oxygen an athlete can consume and use for energy during intense exercise, and is felt to be the best indicator of an athlete’s CRF.) During a typical high-octane workout, cyclists often sustain heart rates exceeding 80 percent of maximum predicted for age (maximum predicted heart rate = 220 – age) for extended periods of time in order to produce the needed cardiac output.

When high intensity aerobic workouts, performed near peak efficiency, are coupled with sustained elevations in heart rate, this creates dynamic stress, or a “volume load” on the heart. Long tempo efforts, routinely punctuated by intense anaerobic dashes, creates static stress, exposing the heart to a “pressure load” because of sustained increases in blood pressure.

Most sports require some combination of both types of effort, although when both dynamic and static components are high, as in cycling, the degree of cardiac remodeling is most prominent. With consistent high volume training, elite cyclists are therefore expected to have generally increased cardiac mass with mild to moderately enlarged hearts from dynamic stress, combined with mildly increased thickness of the heart muscle in response to the static stress component. (In contrast, a body builder training at a lower percentage of VO2 max, and completing high static/ low dynamic stress workouts, would adapt by thickening the heart muscle but without the same degree of heart enlargement as a cyclist.) These examples highlight the importance of understanding the demands of the specific sport when assessing normal changes related to training versus abnormal pathology.

Several studies have reported unexpected abnormalities in endurance athletes, suggesting transient or sometimes even permanent heart damage – supporting the notion that excessive training may be harmful. For example, marathon runners exhibit increased post-race blood levels of troponin, a protein released from injured heart muscle. The degree of elevation of troponin is related to both the intensity and duration of exercise; more critically, in over 50 percent of runners it exceeds the cutoff values typically used by doctors to diagnosis a heart attack. Echocardiograms (cardiac ultrasound) have also hinted at transient cardiac injury following intense efforts, demonstrating post-exercise reductions in heart pumping function which sometimes last up to 48 hours.

Finally, and even more concerning, MRI scans have shown that between 12-50 percent of marathon runners develop varying degrees of permanent scarring of the heart muscle, called myocardial fibrosis, sometimes resulting in Phidippides Cardiomyopathy. [Note: Phidippides, a Greek messenger who died in 490 B.C. after running 26.2 miles from Marathon to Athens, was the first reported case of SCD in a distance runner].

The degree of fibrosis is directly linked to the number of years of training and the number of marathons (or other extreme events) completed, and it occurs in a pattern which is different than typically seen with heart attacks. This suggests that mechanical stress from prolonged, intense exertion may be the causative agent. During intense exercise, pulmonary arterial pressure (pressure in the lung blood vessels) significantly increases, causing the right ventricle (which pumps blood to the lungs) to preferentially show abnormal remodeling. Interestingly, the high altitude training that many pro cyclists employ can also aggravate the process.

This type of program can cause an exercise-induced arrhythmogenic RV cardiomyopathy that substantially increases the risk of a variety of abnormal heart rhythms – some manageable and others potentially lethal. Statistically, about 80 percent of athletes who develop this specific syndrome are high-level, competitive cyclists and triathletes. (The Haywire Heart outlines the broad spectrum of heart rhythm abnormalities endurance athletes may experience, and notably presents data to support a 5-fold increased risk of developing atrial fibrillation.)

Lastly, in addition to these pump and electrical problems, elite athletes also more commonly develop plumbing issues. Coronary artery calcium deposits, indicating underlying coronary artery disease (CAD), are paradoxically identified even though exercise generally reduces the chances of developing CAD in the first place. Although many of the long-term clinical implications remain unclear, all of these findings have nonetheless fueled the earlier-mentioned concerns regarding the potential risks of training beyond a certain level, leading some experts to support a “U-shaped” benefit as suggested by the Copenhagen authors.

The Cleveland Clinic Foundation study zeroed in on this relationship – with perhaps the largest and most comprehensive study – between cardiorespiratory fitness and all causes of mortality. This study reviewed data on 122,007 consecutive patients who underwent exercise stress testing (ETT) at their facility from 1991-2014, objectively grouping them into fitness levels based on their relative performance.

ETT is most commonly done using a standard Bruce protocol (or similar variation). In this procedure, exercise time directly correlates with energy expenditure expressed as metabolic equivalents or METS, where one MET is defined as the amount of energy required to sleep. (METs are essentially a “poor man’s” method to indirectly estimate VO2 max without all the fancy equipment required for a formal metabolic stress test.)

By quantifying fitness in this manner, the study demonstrated that the risk of death was inversely proportional to the level of CRF. And contrary to some of these recent concerns about the potential dangers of vigorous exercise, the extreme fitness category was actually associated with the lowest risk of dying prematurely. Elite performers in this cohort showed a staggering 80 percent risk reduction versus low level performers, and there was no evidence of a plateau or upper limit of aerobic fitness beyond which a survival benefit was no longer observed. This was true for both men and women of all age groups – even those above age 70.

So do these results represent a breakthrough or false hope for cyclists and other endurance athletes? The Cleveland Clinic results perhaps deserve greater attention because of the vastly larger number of subjects (122,007) studied compared to the Copenhagen data (5,048), but more importantly, because each person’s CRF was measured objectively based on ETT performance rather than subjectively based on responses obtained from a fitness questionnaire regarding reported running pace, frequency and distance as in the Copenhagen study. In fact, the Copenhagen authors themselves admitted that based on the small size of their sample and other methodological limitations, it may be premature to conclude that high exercise volumes increase cardiovascular risk.

On the other hand, although the Cleveland Clinic results provide affirmation for exercise addicts, they should also be viewed with cautious optimism for several reasons. The patients included in this study were referred to ETT for good reason: the average age of the cohort was 53 years; they often had multiple other health issues; and they were being evaluated for either known CAD or other concerning symptoms. Some would therefore question whether this cohort truly represents the typical, healthy elite athlete. And does a person’s fitness level based on a single ETT truly reflect their long term exercise habits and potential risk related to habitual training?

Recognizing these potential criticisms, and after statistically correcting for these confounding variables, they still observed the same trends. Their findings were concordant with an often-referenced observational study showing 41% lower mortality among the 786 French cyclists who participated in at least one Tour de France from 1947 – 2012, when compared with the general male population. Despite the two main causes of death in this study being cancer and heart disease, the cyclists still had a “substantially and significantly” lower risk of death. This observation is important and complements the Cleveland Clinic results since the average Tour de France participant is much more fit (VO2 max 70-80; average male 45) than even the best athlete assessed in their study (VO2 max 58), supporting a linear trend even in well-trained and truly gifted individuals.

How then, do we explain tragedies involving truly elite performers likes Michael Goolaerts during last year’s Paris-Roubaix, or Robbert de Greef during this spring’s Omloop van de Braakman? Media attention plays a definite role in sensitizing all of us to these events, even when in fact objective data has thankfully shown a low incidence of SCD in professional cycling.

Nonetheless, these tragedies do occur, and when they do, training volume is often called into question. But there is probably more at play than training habits alone; otherwise we would expect to see a much higher incidence. Some hypothesize an underlying genetic predisposition may sensitize some athletes to develop heart problems induced by heavy training loads. Others point to an increased risk of heart attack and SCD related to high adrenaline levels produced by the excitement of competition coupled with the heavy workload. This is particularly true of middle-aged marathon runners whose short term cardiac risk

during competition is increased, even though their long term risk remains low.

Unfortunately, as we have pointed out before, identifying susceptible athletes can sometimes be elusive despite our best efforts.

Lifelong, committed exercise has clear benefits, and the studies mentioned above all show that athletes of any fitness level tend to live longer than sedentary individuals. Athletes who die during competition are far more likely to make the evening news than the infinitely larger number of people who may die as a result of exercising too little. In fact, the Cleveland Clinic group found the risk of mortality associated with low levels of CRF to be comparable, or in some cases greater, than associated with traditional risk factors such as CAD, diabetes and smoking, thus identifying CRF as a modifiable risk factor to improve longevity.

The ACC Sports and Exercise Cardiology Leadership Council contends that although worthy of further investigation, the current available data shows that even for the very active, life-long endurance athletes, the benefits of training outweigh the risks. Although elite athletes do exhibit a higher incidence of things like atrial fibrillation, coronary artery calcification, and cardiac fibrosis, the long-term implications of these abnormalities still remain unclear, and the Cleveland Clinic Study suggests that they do not negatively impact longevity. In fact, these associations may turn out, in some instances, to represent benign adaptations to exercise instead of true pathologic findings.

For example, although coronary calcium volume is often a “red flag” correlating directly to the amount of underlying CAD, research has suggested that increased coronary calcium density actually occurs in athletes because of beneficial stabilization of soft, vulnerable cholesterol plaques – explaining why they have a lower incidence of cardiovascular events than sedentary individuals. On the other hand, some abnormalities, such as atrial fibrillation are a bit harder to rationalize as a “benign adaptation” to training. However, vastly more sedentary individuals develop this problem on the basis of traditional cardiac risk factors rather than exercising too much.

In summary, and despite the slightly differing conclusions from the various different studies above, it is manifestly clear that exercise is critical for good health, and that more exercise is better for you. Notwithstanding that, athletes of any level should discuss appropriate risk screening with their physician, even in light of the encouraging results of the Cleveland Clinic Study. Equally as important, athletes should never ignore suspicious symptoms or an unexplained decline in performance, because either could be an important clue to serious underlying conditions and in some instances may involve reducing training volumes.

By Dr. William Apollo and Steve Maxwell, June 13th, 2019.