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HEART RATE RESPONSE TO EXERCISE DURING ATRIAL FIBRILLATION COMPARED TO SINUS RHYTHM: IMPLICATIONS FOR DETECTING OCCULT AF AND FOR REDUCING AF BURDEN

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Abstract

Elite athletes who have maintained competitive fitness for many years appear to have abnormally high risk of atrial fibrillation (AF), a risk that may apply also to recreational runners who have competed for years in long distance races. Because asymptomatic AF episodes may be far more frequent than symptomatic AF, I propose an approach to both detection and nonmedical treatment of occult paroxysmal AF through heart-rate controlled exercise. Detection is based on studies showing that heart rate response to light exercise is exaggerated during AF episodes compared to response in sinus rhythm. This differential response can be detected by the athlete with the help of a Polar monitor, and hence it can signal the need for a medical diagnosis, or it can serve as a method of screening in the context of a clinical trial to measure the prevalence of occult AF. A runner or other athlete diagnosed with AF is faced with a dilemma. Exercise, even if it does increase the risk of AF, also has indisputable health benefits. It is worth exploring therefore whether altering and controlling the intensity of exercise might maintain health benefits while reducing the added risk of arrhythmia. This paper proposes an approach based on keeping heart rate below an individually adjusted threshold, and suggests that this criterion may be of use in striking a balance between maximum competitive fitness and optimal cardiac health.

Key words: *atrial fibrillation; heart rate; exercise; running; overtraining*

Introduction

The nature and scope of the problem

Athletes who have maintained competitive fitness for many years are reported to have a much higher risk of atrial fibrillation than a general sedentary population of the same age (1,2). Furlanello et al have recently reported successful use of catheter ablation to treat athletes afflicted with disabling symptoms of drug-refractory lone AF (3). Because so few treatment procedures for AF in athletes have been described, the Furlanello study and accompanying editorial by Lampert (4), merit attention. However, there is some evidence that asymptomatic AF may be far more prevalent than clinically identified PAF. In one small sample of patients with paroxsysmal AF, asymptomatic episodes were 12 times more common than were symptomatic episodes (5). The magnitude of the problem depends on the number of exercisers as well as the prevalence of occult AF within that population. Most reports of high AF risk in athletes have focused on elite athletes, but the excessive sustained exercise thought to be responsible for the risk can plausibly apply also to long-term recreational athletes, for whom exercise may be excessive with respect to their own age and fitness. A large number of older runners have competed, within their age category, in marathons or other long distance races, for many years. The 2008 Chicago marathon age-category results show that, of 17,100 male finishers, 4750 (27%) were over age 45, and 500 (3%) were over age 60. Moreover, there were about 300 hundred other long-distance road races registered with the Chicago Area Runners Association during 2008, making it plausible that the number of runners over age 60 in the Chicago area may be well over 10,000. Moreover, many of these older runners may have been running for decades. The magnitude of the occult AF problem, although unknown, is clearly worth serious attention. It seems clear also, from the viewpoint of cost-effectiveness, that no reasonable amount of ECG screening in a generally healthy athletic population can substitute for enlisting the cooperation of the athletes themselves. This paper describes a practical screening program for subsequent ECG diagnosis that, if implemented, may help estimate the prevalence of occult AF in a healthy population of older recreational competitive runners. From the viewpoint of the individual runner, the problem of detecting asymptomatic and low burden AF will be addressed (6), as well as issues of designing an exercise regimen that takes into account cardiac health in addition to competitive fitness.

AF: Atrial or Auricular fibrillation.
PAF: Paroxysmal, episodic, self-terminating AF
occult AF: asymptomatic, undetected AF
ECG: Electrocardiogram

Competitive fitness vs. cardiac health

For most U.S. long-distance road races, results are posted in 5-year age groups, and competition may be as keen within the 60-65 year age group, as among olympic athletes. The legendary Pheidippides was not the only runner to give his life in the cause of getting to the finish line fast.

Runners who have already been diagnosed with AF face the problem of how to maintain and improve fitness and health through exercise and yet reduce, or at least avoid any increase, in AF burden. Many more who may have occult AF unknowingly face the same dilemma. I suggest that individual self-monitoring based on the sensitivity of heart-rate response to exercise (HRRX) during episodes of AF is relatively simple, requires a minimum of instrumentation (a Polar monitor), is supported by empirical research (7-9), and it can call attention to the possible need for an ECG-based diagnosis.

The technique for detecting high HRRX can be applied also to designing a practical exercise regimen that may prevent new onset of AF or may reduce AF burden, a design that requires individually adjusting the three basic variables of exercise - intensity, frequency, and duration. Endurance training usually entails a progressive increase of one or more of these three, the goal in general being to improve fitness for competition. Our goal here is, first, to reduce AF burden, and in that context, reconsider how to achieve fitness for competition.

Early, apparently neglected, research on HRRX

The HRRX story began 84 years ago with a paper by Hermann Blumgart of Boston, who conducted research at the University College Hospital Medical School in London (7). In 9 AF patients who had little or no cardiac enlargement and no signs of heart failure, he measured the response of heart-rate to a brief stair-stepping exercise.

The pre-exercise resting average heart rate (avHR) for the patients with AF was 101. 6 healthy subjects in normal sinus rhythm (NSR) were used as controls, with avHR 78.5. No HR measurements were made during the (3 min or so) exercise. The avHR values as a function of time after exercise termination were then shown graphically, with three data points especially noted, as follows, where AF designates the 9 patients, and C the 6 controls:

10 sec: AF 156 C 103
05 min: AF 112 C 79
12 min: AF 109 C 78

Blumgart calls attention to the finding that the increased HRRX in AF patients contrasts sharply with the relatively small rise observed in the normal subjects.

A new series of 5 patients was next tested before and after cardioversion (with quinidine) in order more specifically to identify the differences between AF and sinus rhythm within the same person.

The pre-exercise resting avHR for the 5 new AF patients was 88.3 pre-CV, and 65.3 post-CV. Of crucial importance here is the fact that the 5 new patients served as their own controls. Under conditions otherwise the same as outlined above, the avHR values pre- CV (AF) and post-CV (NSR) were, respectively:

10 sec: AF 150 NSR 107
05 min: AF 100 NSR 76
12 min: AF 99 NSR 71

It is notable that heart rates before and after exercise were higher in the 9 AF patients than in the 6 controls in NSR. Of potential importance also, the return of heart rate to the pre- exercise values in (the 5 new) AF patients was prolonged to 12 minutes or more irrespective of cardioversion, in contrast to the original 6 controls for whom heart rate had returned to normal by 4 or 5 minutes post-exercise (7).

Post-1924 articles relevant to Blumgart study

Ernst Boas, at the Montefiore Hospital for Chronic Diseases in NY noted in 1929 that many authors have commented on an increased ventricular rate after exercise in AF patients, and he states that the most careful study has been that by Blumgart. Boas reports his own observations of AF patients, based on 24h monitoring with a cardiotachometer, showing that relatively slight activity as well as just walking will increase the ventricular rate by a large amount (8).

A study similar to Blumgart-1924, 79 years later

In 2003, Zerrin Yigit et al., conducted a study of 27 patients with nonvalvular PAF in which they measured HRRX, comparing sinus rhythm with AF in the same person, independently reconstructing the problem investigated 79 years earlier by Blumgart (7,9). However, Yigit et al reported heart rates during exercise and did not report data for the post-exercise period, unlike Blumgart who focused only on the post-exercise period. Thus the two studies are complementary.

Yigit et al. went beyond the scope of Blumgart's work in a number of respects, but our focus here will be on the results for all stages of the treadmill exercise

HRRX: Heart Rate Response to Exercise
AF-burden: percentage of time in AF
avHR: average HR
NSR: Normal sinus rhythm
HR: Heart Rate
CV: Cardioversion (conversion AF to NSR)

(modified Bruce protocol; 3 min. stages) in the 11 AF subjects without other heart diseases.

The pre-CV resting average heart rate (avHR) of these 11 subjects was 96.1, and 81.3 in post-CV NSR. Thus, resting avHR during AF is 18% greater than resting avHR during NSR.

As was the case for the „5 new patients" of Blumgart, these subjects also served as their own controls. AvHR in response to each of the 4 stages of exercise, respectively, before and after cardioversion (marked as AF and NSR), is shown as follows, with a third line added to show the percentage by which the AF HRRX is greater than the HRRX during NSR (9).

AF: 150.8 159.6 170.8 185.0
NSR: 107.3 117.9 134.1 157.6
41% 35% 27% 17%

For an athlete with PAF who begins an exercise routine when in normal sinus rhythm, the last line shown represents the average increase in %HR seen at any subsequent onset of AF. The greatest proportionate increase is 41% in Stage 1. Stages 2,3,4 show progressively less increase. That is, the earliest stages of exercise are the most sensitive indicators of HR response, and so of the possible onset of PAF. The stage 4 increase of 17% does not differ from the similar increase for the heart rate at rest (18%, noted above). All of above results are subject to high inter-person variability, which is reflected in the high standard deviations reported by Yigit et al. However, the fluctuations the individual athlete sees when using the Polar monitor are because of his own intra-person variability which can best be assessed by the apparent clarity of the distinction between his own sinus rhythm and his own heart rhythm when in AF. The sensitivity and specificity of HRRX to detect AF episodes can then be determined only by an ECG.

Heart Rate as a signal of PAF: comments and conclusions

To detect episodes of undiagnosed AF that occur only infrequently and without symptoms - i.e. occult PAF - requires an ECG, but raises the prior question of whom to select for the procedure. The population of interest is healthy and has no symptoms suggesting the need for an ECG. This paper proposes that athletes who are made aware of a potential heart arrhythmia by observing HRRX on the display of a Polar monitor then select themselves for ECG monitoring. In effect, the Polar monitor output becomes a substitute for symptoms. The problem of detecting low AF-burden is shifted to the athlete who can choose how often to observe the monitor - and who may also be able to identify times of day or other circumstances that suggest when and for how long to conduct ECG monitoring.

Further investigation is necessary to determine the average of all individual values of sensitivity and specificity of HRRX. When this is determined, a systematic pre-screening program for subsequent ECG monitoring can be designed, a program that becomes practical because it enlists the participation of many individual athletes.

The possibility of detraining as therapy for AF

A recent case study of a 53-year old male endurance runner reported that detraining and lighter exercise for a 3-month period ameliorated symptoms of AF and decreased the frequency of atrial ectopic beats, changes that were sustained at a 6-month followup (10).

Although no mention was made of heart rate, it is of course clear that such reduction in exercise levels must have entailed large reductions in average heart rate. Moreover, heart-rate control is a widely accepted component of AF pharmacotherapy.

A study of 13 young olympic-class athletes with PAF showed that an episode of PAF could be triggered by trans-esophageal atrial pacing and that the PAF would disappear if athletic activity is stopped for long enough periods of time (an average of 20 months in the group studied) (11). The authors also cite animal experiments showing that rapid atrial pacing can induce AF. It is plausible that intensive exercise might have a similar effect, and that rest and rehabilitation itself may be effective therapy.

A suggested model for an exercise regimen

The individual athlete, with the aid of a Polar monitor (12) or equivalent, can keep HR low by appropriately limiting exercise intensity. Normally, in sinus rhythm, as exercise is initiated, HR will be seen to increase gradually, with small fluctuations, until a steady state is reached which will persist until the intensity levelof the exercise is changed. If HR jumps suddenly by an unusual amount and becomes visibly irregular for more than a few minutes, it is possible that AF was triggered. One should then test whether such aberrant rhythms can be avoided by keeping HR at some target threshold below which NSR can consistently be maintained. Such a target may be related to a „critical heart rate" discussed in an earlier article (1).

The recovery period from exercise is normally a time of high risk for an AF episode, and perhaps especially so if a heavy workout is abruptly terminated (e.g. as at the finish of a race). During a recovery period, vagal control of heart rate is dominant, as it is while sleeping or just after meals (13), these latter also being times of high risk for the spontaneous onset of PAF.

In sum, the individual athlete is urged to take an exploratory approach to designing an exercise regimen that minimizes the risk of inducing AF, a regimen based on frequency, duration, intensity, rate of warmup and cooldown, while maintaining HR (as displayed by a Polar monitor) below an estimated threshold or critical heart rate. An exercise regimen for maintaining or improving fitness can then be explored subject to the constraint that heart rate is kept in NSR.

A personal test of the proposed regimen

The purpose of describing this test is not to present a case report, but rather to elucidate the proposed exercise regimen and the relationship between the Polar monitor results and ECG Holter results. The regimen is intended as a set of guidelines rather than a prescription, for it must in any event be adapted to the age and level of fitness of the individual user.

I was diagnosed with PAF in September, 2005. At the time of diagnosis I was age 81 and had been running about 3 mi per day for thirty years at a moderate training pace, but more intensively before and during long distance races (mostly 10km to 20km). Prior to the diagnosis, I had become concerned about frequent episodes of high wrist-pulse variability; an ECG then showed PAF, and, on September 14, 2005, a 48h Holter session (at the University of Chicago Hospitals Electrophysiology Lab) indicated 60% of time in AF/AFL; Rory Childers was the reading MD. Ten months later, a 48h Holter on July 10, 2006, indicated 100% of time in AF/AFL. Matthew Sorrentino was the reading MD. At no time had I experienced any symptoms, but the apparent progression of AF-burden from 60% to 100% seemed to support what I took to be a prevailing opinion that AF was expected to be progressive and that average AF-burden was unlikely to diminish.

Following the second diagnosis, I initiated a detraining approach (1,10). Because I was asymptomatic, I did not consider other forms of treatment. After several weeks rest, I began a HR-limited exercise regimen. Throughout the ensuing 18-month period, the Polar Monitor clearly revealed many sudden transitions from a relatively low and stable HR rhythm to high HR and high HR variability. These seemed to be two distinct modes of heart rhythm.

In 2007 I participated in a series of clinical tests of a new instrument (Decipher Holter, Medicomp, Inc.) and software designed to detect and measure AF automatically. A software algorithm that captures a complete arrhythmia profile based on rate, rhythm and p-wave abnormalities, yields data for calculating AF burden, irrespective of the presence or absence of symptoms (14). This novel instrument is small, lightweight, and suitable for use while running and wearing a Polar monitor.

The following data are based on a report from the Medicomp Cardiac Monitoring Center, Holter ECG Tabular Summary, covering the 8-day (193h) period of continuous monitoring from 5pm Dec 6, 2007 to 6pm Dec 14, 2007. Ignoring days in which the total time in AF was less than 4 minutes, only day 2 and day 5 had appreciable one-day burdens (58% and 14%, respectively). The average burden over the 8-day period was therefore 9%, a value that is encouragingly low but chance effects cannot be ruled out.

I recorded also an exercise and heart rate log based on a Polar monitor worn simultaneously with the Holter throughout the entire period. The Polar monitor identified the same two major periods of AF, on days 2 and 5, and no false positives. (Brief episodes of PAF may be missed by a Polar monitor because there are practical limits to how often the monitor display is observed.)

The exercise regimen I followed was accompanied by other interventions intended to reduce AF burden that included antiinflammatory agents and proton pump inhibitors, a rationale for which can be found in (1,13). Controlled trials are needed to determine which, if any, of these variables are significant and clinically important.

Summary and Conclusions

Published empirical research long ago showed that heart rate response to even brief or light exercise is exaggerated during episodes of atrial fibrillation compared to normal sinus rhythm in the same person. This paper proposes an approach to aerobic exercise-based on heart rate control without pharmaceutical or surgical intervention, and focused on self-monitoring by the athlete who notices high HRRX with the help of a Polar monitor. The primary goal of this approach is to signal possible episodes of AF in order subsequently to obtain an ECG diagnosis and estimate of AF burden. A second goal is to reduce the risk of AF and AF-burden. The method is suitable for prescreening in a clinical trial designed to measure AF burden in a healthy population of regular exercisers, particularly runners, but needs further research to determine the average sensitivity and specificity of HRRX for detecting episodes of PAF.

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AFL: Atrial Flutter

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A – Study Design
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