ELECTROCARDIOGRAPHIC T WAVE CHANGES WITH HEAVY EXERCISE

D. E. Kennedy and J. L. Mayhew
Department of Physical Education, Appalachian State University,
Boone, North California.

Introduction

Positive changes in the electrocardiographic T wave accompanying exercise are well established (Tuttle and Korns 1941 and Beckner and Winsor 1954). Reduction in T wave amplitude or its inversion are considered pathological signs of coronary insufficiency (Seneback 1946). However, little information exists on the normal deviations of the T wave and their association with athletic performance, especially in endurance events.

In many cases the training programme of long distance runners is an academic procedure and bears little relation to the immediate physical state of the individual. As a consequence the programme very often suits but a few runners and overtrains the others in an effort to reach the greater states of performance. However, there is no scientific evaluation of the overtrained state nor the cardiovascular reaction to it.

Purpose

The purpose of this study was to observe the effect of a season (ten weeks) of cross-country training and racing on the T wave of the ECG. Any abnormal deviations were to be noted in frequency and intensity.

Procedure.

Test. The electrocardiogram was recorded in the precordial position (Lead V_4) under the following conditions:

1. supine rest.
2. 30 seconds post-exercise (bench stepping on a 17-inch bench at 30 steps/min. for five mins.),
3. five minutes post-exercise, and
4. ten minutes post-exercise.

All recordings were taken with the subject in the supine position. Recordings were made with the standard ten millimeters pen deflection per one millivolt. Each subject was tested before the season (T-1), following five weeks of training

TABLE 1

T Wave Amplitude Changes with Cross-County Training

(N = 6)*	Supine rest	30 secs post-ex.	5 mins post-ex.	10 mins post-ex.
T-1 mean	6.58*	11.44	6.58	6.10
S.D.	3.45	3.58	2.68	2.69
T-2 mean	7.56	13.13	7.82	7.56
S.D.	3.87	5.17	3.79	3.52
T-3 mean	7.46	13.32	7.93	7.94
S.D.	3.03	3.63	2.48	3.06
Mean change from T-1 to T-2	0.98	1.69	1.24	1.46
Mean change from T-2 to T-3	0.10	0.19	0.11	0.38
Mean change from T-2 to T-3	0.88	1.88	1.35	1.84

* Measured in millimeters.

** One subject was removed because of bifid T wave.

at mid-season (T-2), and following ten weeks of training at the end of the season (T-3). All testing was done in the early morning hours with the subject in a fasting state. Each subject rested in the supine position for 15 minutes prior to the initial ECG recording.

Subjects

Seven members of a university cross-country team were used as subjects for the study (mean height = 69.16 ± 1.29 ins.; mean weight = 137.66 ± 12.23 lbs.; mean age = 19.08 ± 1.13 yrs.).

Training programme

The training programme employed was a combination of interval training and long continuous runs. The Subjects ran four to seven miles each morning at an 8:00/mile pace. The afternoon training sessions alternated daily between long runs of six to 12 miles and interval training using 440's, 550's and 660's as the basic distances repeated for a total of five to eight miles per session. All runners trained six days per week and raced approximately once weekly.

Results

Positive change. Six of the athletes made positive changes in the amplitude of the T wave in 11 of 12 conditions. The resting T wave showed an increase from T-1 to T-2 and a decrease from T-2 to T-3. This agreed with Cureton (1958) who indicated that severe training was needed to amplify the T wave but that if the training was too severe and/or prolonged it could cause depression of the T wave.

Immediate post-exercise amplitudes were greater after training and elevated above the resting T wave amplitude. Five minutes post-exercise recordings showed amplitudes were generally higher than in the resting state but lower than the immediate post-exercise recordings. Ten minutes post-exercise amplitudes returned to approximately the same as in the resting recordings. These results agreed with the findings of Wolf (1953), Cureton (1958), Carlile and Carlile (1961) Rose and Dunn (1964), and Pioletman and Miller (1968). See Table 1 for T wave data.

Abnormal changes. One subject exhibited abnormal T wave configurations. The subject was a senior member of the team, producing the best times the previous cross-country season. He was a relatively large individual for a distance runner (height = 73.0 ins.; weight = 173.0 lbs.; age = 21.58 yrs.). During the months prior to the competitive season (June, July and August), he had been engaged in farm labour and had done very little running.

TABLE 2

T Wave Amplitude Changes in an Overtained Subject

	Supine rest	30 secs. post-ex.	5 mins. post-ex.	10 mins. post-ex.
T-1	3.51*	8.66	2.60	3.67
T-2	2.58	10.22	3.23	3.29
T-3	5.64	10.05	4.53	4.93
Change from T-1 to T-2	-0.93	1.56	0.63	-0.38
Change from T-2 to T-3	3.06	-0.17	1.30	1.64
Change from T-1 to T-3	2.13	1.39	1.93	1.26

*Measured in millimeters.

The T - 1 ECG recording was normal in all conditions. The only observable consequence was a elevated S-T segment in the supine rest and ten minute post exercise recordings. However, this was within normal bounds and agreed with the findings of Bramwell and Ellis (1931), Lloyd-Thomas (1961), and Marriott (1967). The 30 seconds post-exercise and five minutes post-exercise recordings showed a return of the S-T segment to the isoelectric line which coincided with the work of Chelton and Burchell (1955).

The T-2 ECG recording manifested abnormal T wave configurations in supine rest, five minutes post-exercise, and ten minutes post-exercise. The T wave was bifid in all of the above conditions. (See Fig. 1 for illustration of the bifid T wave). The bifid condition was most marked in supine rest. Following the bench stepping exercise the bifid condition disappeared as indicated by the 30 seconds post-exercise recordings. However, it returned in both the five and ten minutes post-exercise recordings. These results in the ECG recordings agreed with those found by Plas (1963) and Kiessling, et al. (1964).

The recording at 30 seconds post-exercise was apparently normal. There was noted elevation of the T wave amplitude in this condition but no evidence of a bifid tendency. This data coincided with most studies in which effort tests Had been employed (Beckner and Winsor 1954, Strandell 1963, Rose, et al. 1966).

When questioned on his physical well-being, the runner indicated a feeling of "fatigue," "nervousness," "strain in hitting interval training paces," and "undue strain in racing". Observations by the coaches gave credence to his report, viz., inefficiency in motion in the late stages of training sessions, marked deterioration in five-mile cross-country races, and inability to repeat interval training runs at a racing pace.

Following the T-2 testing period, the subject was removed from the strenuous training programme and placed on a self-directed training routine. Morning running was reduced to three days per week of four to six miles at 8:00/mile. Afternoon training sessions involved more long easy running over varying terrain and less interval training. Only occasionally was interval training employed and then not at the previous volume or intensity.

The T-3 ECG recording showed marked improvement over both the T-1 and T-2 recordings in seven of eight conditions. The 30 seconds post-exercise recording registered a slight decrease (-0.17 mm) from the T-2 measure. There were no signs of a bifid tendency in any of the T-3 recordings.

When asked about his physical well-being, the subject indicated "nervousness" still prevailed; however, he was "less fatigued after workouts," "more relaxed in races," and generally "strained less to turn in a good time." In the last four races (five miles cross-country) the subject averaged 20 seconds faster than in his first five races. Physical performance as well as psychological well-being were enhanced. See Table 2 for this subject's T wave data.

Discussion

The increase in the amplitude of the T wave resulting from ten weeks of strenuous cross-country training agreed with previous findings (Tuttle and Korns 1941, Wolf 1953, Beckner and Winsor 1954, Cureton 1958, Rose and Dunn 1964, and Pioletman and Miller 1968). The slight reduction in the T wave amplitude from T-2 to T-3 in supine rest and the very slight position gains in the remaining conditions are supported by the findings of Cureton (1958). These may have been indicative of the strenuousness of the interval training programme or the total work load.

The bifid T wave exhibited in one subject at T-2 paralleled an overtrained or fatigued state. The nature and configuration of the bifid wave stimulated those reported elsewhere (Plas 1963 and Kiessling, et al. 1964). While little research has been advanced to explain the bifid T wave, it is possible that the heart ceases to use lactate as its primary fuel source (Bing, et al. 1960) and begins to use more glycogen (Plas 1963). Whatever the metabolic process, the bifid T wave was associated with a general state of fatigue and was not pathologically abnormal. Sufficient rest and reduction in training intensity resulted in complete disappearance of any abnormal T wave configurations.

References:

Beckner, G.L. & T. Winsor. "Cardiovascular Adaptations to Prolonged Physical Effort."Cir. 9:835-846,1954.

Bing, R.J., et al."Physiology of the Myocardium." JAMA 172:438-444,1960.

Bramwell, C. & R. Ellis. "Some Observations on the Circulatory Mechanism in Marathon Runners." Quart. J. Med.. 24: 329-346, 1931.

Carlisle, F. & U. Carlile. "Physiological Studies of Australian Olympic Swimmers in Hard Training." Aust. J. P. E. 23:5-34, 1961.

Chelton, L. G. & H. B. Burchell. "Unusual RT Segment Deviations in Electrocardiograms of Normal Persons." Am. J. Med. Sci. 230:54-60, 1955.

Cureton, T. K. "Effects of Longitudinal Physical Training on the Amplitude of the Highest Precordial T-Wave of the ECG". Med. Sp. 12:259-281,1958.

Kiessling, C. E., et al. "A Study of T Wave Changes in the Electrocardiogram of Norman Individuals." Am J. Card. 13:598-602,1964.

Lloyd-Thomas, H.G. "The Effect of Exercise on the Electrocardiogram in Healthy Subjects." Bri. Heart J. 23:260-270, 1961.

Marriott, H. J. L. "Normal Electrocardiographic Variants Simulating Ischemic Heart Disease," JAMA 199:325, 1967.

Plas, F.R. "Electrocardiographic Changes During Work and Prolonged Effort." J. Sp. Med. Phy. Fit. 3:131-136, 1963.

Poiletman, R.M. & H. A. Miller. "The Influences of Wheat Germ Oil on the Electrocardiographic T Waves of the Highly Trained Athlete." J.Sp. Med. Phy. Fit. 8:26-33, 1968.

Rose, K. D. & F. L. Dunn. "Physiology of Running Studied by Use of Radio Telemetry." J. Sp. Med. Phy. Fit. 14: 3-15, 1964.

Rose, K. D., et al. "Serum Electrolyte Relationship to Electrocardiographic Changes in Exercising Athletes." JAMA 195:111-114, 1966.

Seneback, W. "Some Common Conditions Not Due to Primary Heart Disease, That May be Associated with Changes in the ECG." Ann.Int. Med. 25:632-647, 1946.

Strandell, T. "ECG Findings at Rest, During, and After Exercise in Healthy Old Men Compared with Young Men." Acta Med. Scand. 174:479-499,1963.

Tuttle, W. W. & M. Korns. "Electrocardiographic Observations on Athletes Before and After a Season of Physical Training." Am. Heart J. 21:104-107,1941.

Wolf, J. G. "Effects of Posture and Muscular Exercise on the Electrocardiogram." Res. Quart. 24:475-490,1953.

BOOK REVIEW

BIBLIOGRAPHY OF SPORTS MEDICINE

Edited by: Jack C. Hughston.
Kenneth S. Clarke.

Published by: American Academy of Orthopaedic Surgeons.

Price: $2.50

This is a short bibliography of references (in number 1,314) of works published up until 1970.

It provides a satisfactory list of first line works relating to clinical sports medicine and associated disciplines and as such is a useful handbook for any clinician following up literature in the field. It is however very far from being inclusive - a point which the Editors acknowledge.

It is to be recommended as a useful little handbook.

J. G. P. Williams, F.R.C.S.Ed., D. Phys.Med.