British Heart Journal, 1973, 35, 1055-1061.

Exercise electrocardiogram patterns in normal women[1]

Gordon R. Cumming, Cecile Dufresne, Larry Kich, and John Samm
From the Clinical Investigation Unit, Children's Hospital of Winnipeg, and the University of Manitoba, Canada

Exercise tests were obtained in 357 women aged 20 to 83 years without cardiac disease. The bicycle exercise was submaximal to 86 per cent of predicted maximal heart rate, or maximal to the point of voluntary fatigue. Up to 25 per cent of women 20 to 39 years, 50 per cent of women 40 to 59 years, and 66 per cent of women over 60 years, had electrocardiographic abnormalities consistent with ischaemia depending on the criteria used. Until different criteria are established, exercise electrocardiography is of limited value in women.

Exercise stress testing with electrocardiographic monitoring is used clinically to confirm or exclude a diagnosis of angina pectoris, and has been used in epidemiological surveys as an indicator of coronary risk. As early as 1950, Scherlis *et al.* noted that, compared to men, normal women were more likely to have electrocardiographic abnormalities after exercise, and these observations were confirmed by Lepeschkin and Surawicz (1958), and by Åstrand (1965). Little attention has been directed to this paradox of more women showing electrocardiographic evidence of 'ischaemia' on exercise, but less clinical coronary heart disease, and separate criteria for interpreting exercise electrocardiograms have not been established for women. The purpose of this report is to document the frequency of the various types of ST segment changes observed in normal women during and after exercise.

Subjects and methods

Three groups of volunteers were recruited: 136 were women hospital workers, 116 were women attending fitness classes at the YMCA, and 105 were tested at farm fairs in rural communities of less than 3,000 inhabitants. Subjects with known coronary or valvular heart disease were eliminated, as were the few who developed angina during the exercise test. The ages of the subjects ranged from 20 to 83 years.

The hospital women exercised in a laboratory on an Elema electric bicycle ergometer for 6 minutes at 300, 450, or 600 kpm/minute, depending on age and estimated fitness. After a 10-minute test, they then walked on a treadmill at 3·3 mph starting at 5 per cent slope. The subjects walked until the point of voluntary exhaustion while the slope was increased by 1 per cent every minute.

The YMCA and rural women exercised on a mechanically braked Monark ergometer at a YMCA or in an air-conditioned van located at farm fairs. These subjects performed one 6-minute work load of 300 to 750 kpm/minute selected to produce a heart rate of about 85 per cent of age predicted maximum (Åstrand, 1960). If this target heart rate was not reached, a second 6-minute load was immediately added. The YMCA women under age 41 years continued exercising until voluntary exhaustion, while the load was increased 150 kpm/minute each minute.

A bipolar electrocardiogram lead CM5 from the manubrium to the V5 position was recorded on a direct writing recorder with specifications exceeding the 1967 American Heart Association standards. Recordings of 10 seconds' duration were made at rest, every 1 to 2 minutes during exercise, during the first 20 seconds of recovery, and at 2 and 5 minutes of recovery. The feet were raised with the subject sitting in a comfortable chair during recovery to minimize postural effects.

The Finnish system for classification of ST segment changes was used (Punsar, Pyorala, and Siltanen, 1968). This classification is summarized in Table 1. Group A changes are those with sagging or horizontal ST segment depression and are accepted as being highly suggestive of myocardial ischaemia by most authorities. Electrocardiograms with depression of the J point below the isoelectric level, but with ascending ST segments, were placed in B or C groups depending on whether or not the ST segment reached the isoelectric level before the onset of the T wave.

A major problem in exercise electrocardiography is the separation of junctional depressions with ascending ST segments into those that may signify an abnormality and those that are benign. The 5-year follow-up study of

Received 26 February 1973.
1 Supported by a Dominion-Provincial Public Health Grant.

TABLE 1 *Finnish classification of exercise ST segment changes**

Horizontal or downsloping ST segment (A)	*Slowly ascending† (B)*	*Rapidly ascending (C)*	*No ST change (O)*
A1 J↓ ≥2·0 mm	B1 J↓ ≥2·0 mm	C1 J↓ ≥2·0 mm	J isoelectric
A2 J↓ 1–1·9 mm	B2 J↓ 1–1·9 mm	C2 J↓ 1–1·9 mm	No ST sag
A3 J↓ 0·5–0·9 mm	B3 J↓ 0·5–1·0 mm	C3 J↓ 0·5–1·0 mm	
A4 J zero, 0·6 mm or greater sag	B4 J↓ 0·1–0·4 mm		
A5 J zero, <0·5 mm sag			

* From Punsar *et al.* (1968).
† Slowly ascending defined as failing to reach the isoelectric level before the onset of the T wave.
J = junction point where ascending limb of the S wave abruptly changed into the ST segment.

TABLE 2 *Percentage of subjects classified by exercise electrocardiographic abnormalities*

Age group	*Total no.*	*Per cent by category – Finnish classification*					
		A1, A2, A4	*A3, A5*	*B1, B2*	*B3, B4*	*C1–3*	*O*
20–29	71	13	1	13	11	49	13
30–39	72	10	1	13	15	47	14
40–49	91	26	12	19	11	22	10
50–59	80	24	9	21	6	28	13
60–69	34	27	12	21	12	15	15
Over 70	9	44	11	11	11	0	22

TABLE 3 *Maximum heart rates of women*

	Hospital treadmill walk	*YMCA bicycle*	*Åstrand (1960)*
20–29	197±7	183±8	187±3
30–39	192±10	183±8	185±2
40–49	179±8	167±17	178±3
50–59	167±10	—	170±2
60–69	158±15	—	
70–79	145±20	—	

Punsar *et al.* (1968) justified their separation of these changes into the slowly ascending ST segment that does not reach the isoelectric point before the onset of the T wave, and the rapidly ascending ST segment that does reach the isoelectric level before the onset of the T wave. The two types may be distinguished quite rapidly in most exercise electrocardiograms by scanning 6 to 10 beats. If any question arose as to whether the isoelectric level was actually reached because of difficulty in deciding the onset of the T wave, or the exact isoelectric level, the electrocardiogram was arbitrarily put in the C category.

TABLE 4 *Incidence of smoking, hypertension, low fitness, and low vital capacity by exercise electrocardiographic category*

Age group	*No. of subjects*		*Per cent smokers*		*Per cent resting hypertension*		*Per cent exercise hypertension*		*Per cent low fitness*		*Per cent low vital capacity*	
	A	*N*	*A*	*N*	*A*	*N*	*A*	*N*	*A*	*N*	*A*	*N*
20–29	19	52	5	23	0	0	11	8	32	15	21	12
30–39	17	55	20	22	6	0	12	13	6	11	0	6
40–49	52	39	24	19	15	10	25	31	10	13	22	23
50–59	43	37	12	27	14	22	35	38	9	5	21	15
60–69	20	14	10	8	38	31	62	39	10	—	25	31
70+	6	3	—	—	83	67	80	67	—	—	50	67

A = 'Abnormal' exercise electrocardiogram.
N = 'Normal' exercise electrocardiogram.
Smokers – more than 5 daily.
Resting hypertension – BP > 150/100 mmHg.
Exercise hypertension – BP > 200/100 mmHg.
Low fitness – > 1 SD below mean for predicted $\dot{V}o_2$ max.
Low vital capacity – < 90 per cent of predicted based on age, height.

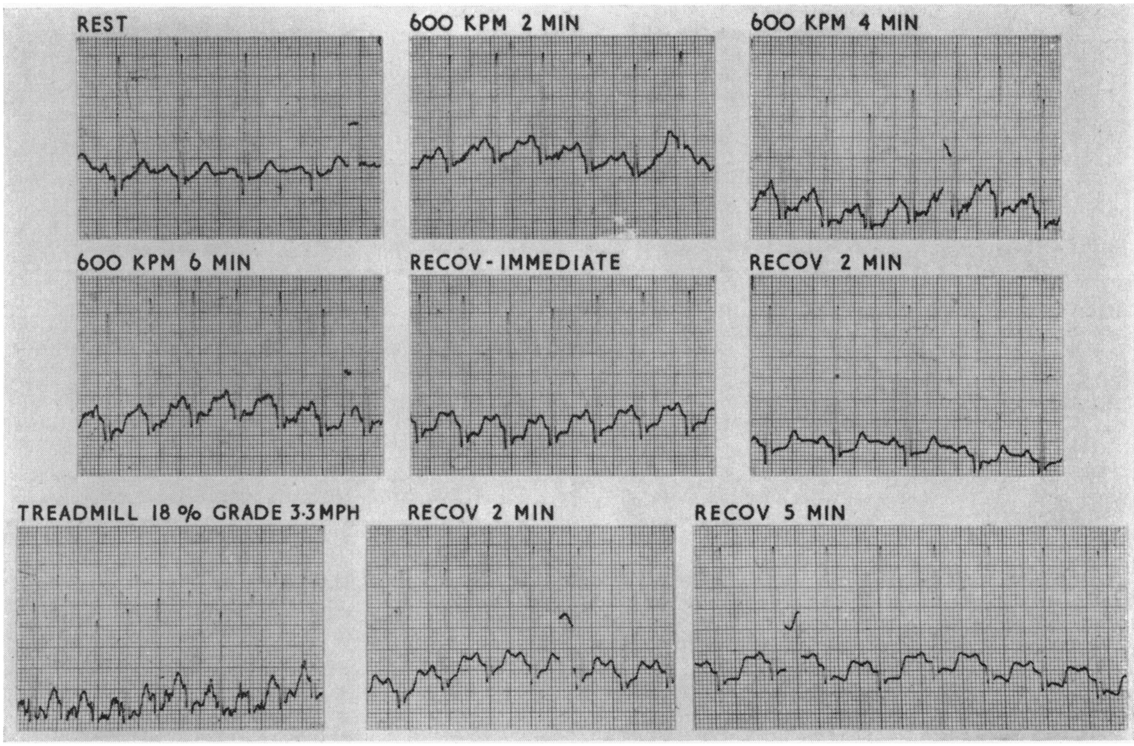

FIG. 1 *Normal young woman – normal electrocardiogram resting on ergometer. 'Ischaemic' type ST changes after 4 minutes at 600 kpm/minute work, and during recovery. 'Ischaemic' change during treadmill work, and after 5 minutes of recovery.*

Results

The frequency of the various ST segment changes by age group, combining all three groups of subjects, is summarized in Table 2. Only the most severe change present in the series of exercise and recovery electrocardiograms was recorded for each subject. In several subjects there was progression from a type C change through various degrees of type B to the more 'ischaemic' type A. In the subjects given submaximal exercise only, the mean exercise heart rate of all subjects was 86 ± 8 per cent of the age-predicted maximum heart rate. In the subjects exercised maximally, the mean heart rates are shown in Table 3.

The most conspicuous changes (A1, A2, A4) occurred in just over 10 per cent of women of 20 to 39 years of age. An example of a young woman showing these changes, which would be labelled ischaemic by all available criteria, is shown in Fig. 1.

Changes of type A1, A2, and A4 occurred in about 25 per cent of women aged 40 to 70 years, and in about 50 per cent of women over 70 years of age. Fig. 2 shows such a change in a 48-year-old asymptomatic subject. Changes labelled A3 and A5 are labelled 'ischaemic' in several classification systems. Only a few of the younger women in this series showed these patterns, and about 10 per cent of the older subjects had one of these patterns.

The most pronounced of the slowly ascending type change (B1 and B2) occurred in 13 per cent of the subjects under 40, and in 20 per cent of the subjects over 40, not a striking difference. The less severe changes of the slowly ascending type (B3 and B4) occurred in about 10 per cent of subjects without much age trend. Junctional depression with rapidly ascending ST segments (type C) were present in about 50 per cent of the young subjects, and in 25 per cent of the 40- to 60-year-olds. Absence of any ST segment change occurred in 1 of every 8 women tested, with no major difference between age groups.

If types A1 to 5 and B1 and 2 were arbitrarily called abnormal, then 25 per cent of women 20 to 39 years of age, 50 per cent of the women 40 to 59 years of age, and 66 per cent of the women over 60 years

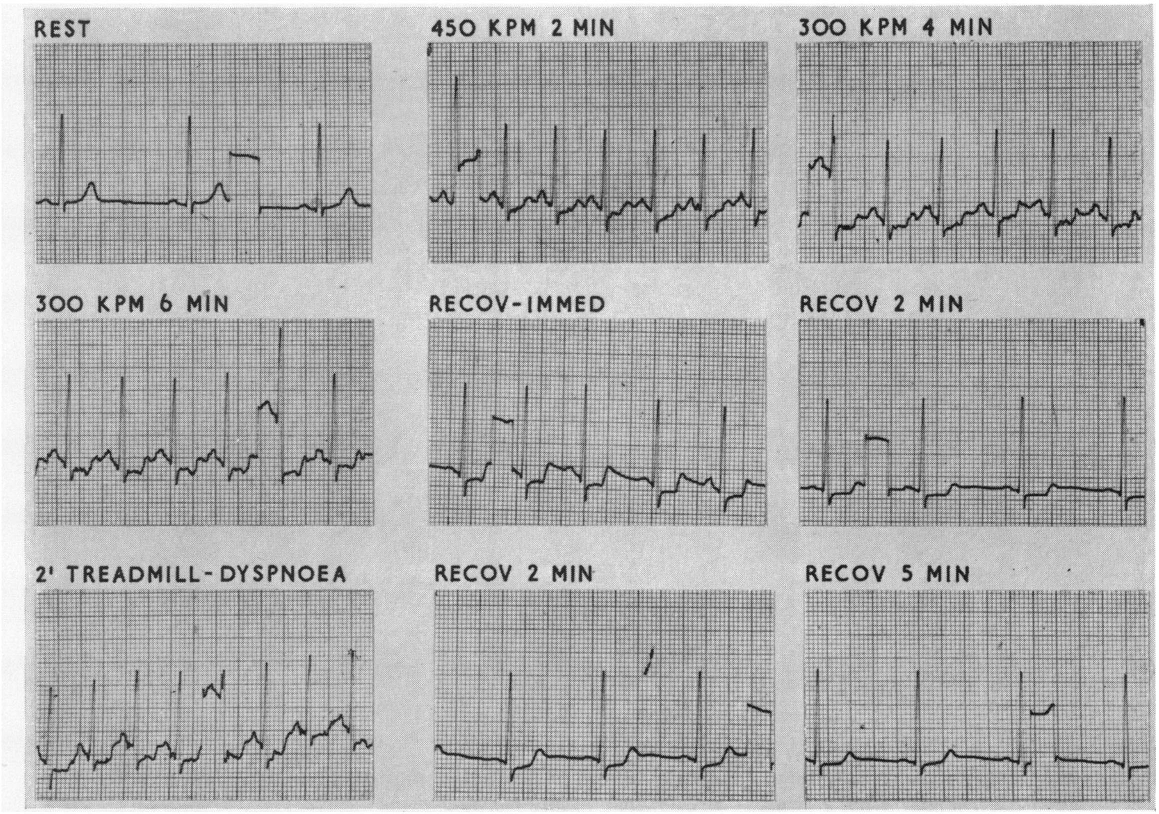

FIG. 2 *Asymptomatic 49-year-old woman. Normal resting electrocardiogram sitting on ergometer. 450 kpm found to be too difficult and load reduced to 300 kpm. At 4 minutes change of type B1, after 6 minutes change of type A1. 2 mm ST depression during treadmill exercise, and slowly ascending ST types B2 at 2 minutes recovery, and type A3 or B3 at 5 minutes recovery.*

of age, would fall into this category. This frequency is similar to that reported by Åstrand (1965) in 117 women and Profant *et al.* (1972) in 144 women.

The frequency of various risk factors that might be related to coronary heart disease and abnormal exercise electrocardiograms is compared in subjects with normal and abnormal exercise electrocardiograms in Table 4. For this purpose, electrocardiograms belonging in Group A or B1 and 2 were classified as 'abnormal', and the others as normal. Based on the χ^2 test, there were no statistically significant differences in the number of smokers, the number of women with resting or exercise hypertension, or the number with low fitness or low vital capacity in the two electrocardiographic groups. While the women under 40 with abnormal exercise electrocardiograms tended to be less fit, to have a lower vital capacity, and to be non-smokers, none of the differences was significant. For comparison, it is to be noted that normal men with ischaemic exercise electrocardiographic abnormalities are more likely to have hypertension, low fitness, and high cholesterol (Cumming, Borysyk, and Dufresne, 1972).

Discussion

If we had demanded strict criteria of abnormality in our subjects (greater than 0·1 mV ST depression that was either downsloping or perfectly horizontal for 0·08 sec), 10 per cent of subjects under 40, and 25 per cent of subjects over 40 would have been considered to show ischaemia. However, if all exercise electrocardiograms in which there is junctional depression with slowly ascending ST segments are considered normal, many patients with proven ischaemic heart disease will be considered to have a negative exercise test. The prognostic import of slowly ascending ST changes in the study of Punsar

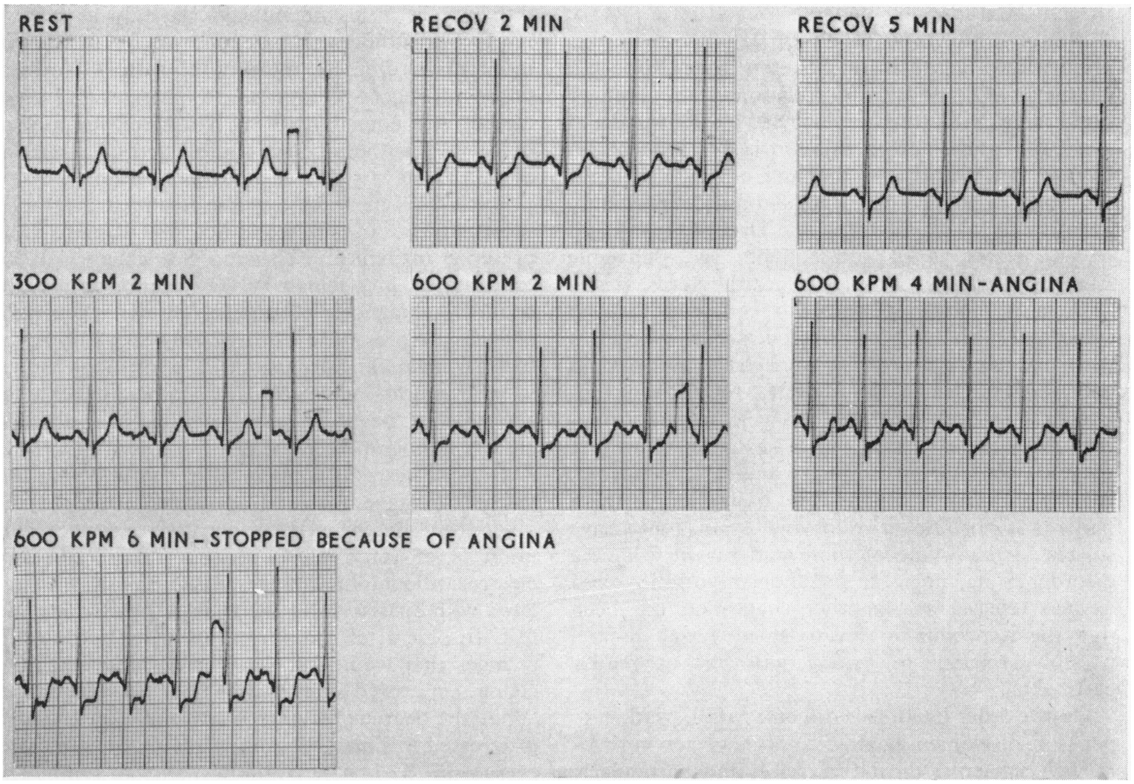

FIG. 3 *Man with proven coronary heart disease demonstrating need for slope criteria. Angina after 4 minutes exercise 600 kpm/minute, electrocardiogram shows over 3 mm J depression with ascending ST segment. Exercise continued for 2 minutes and horizontal ST segment was observed. Classification was 300 kpm C3; 600 kpm 2 minutes C2, 600 kpm 4 minutes B1; 600 kpm 6 minutes A1; recovery 2 minutes B2, recovery 5 minutes C2.*

et al. (1968) was previously mentioned. Fig. 3 shows an example of the progression of ST segment changes in a male subject with proven severe coronary heart disease with angina. The exercise test could well have been stopped when the patient first complained of angina, and at this point there was junctional depression with an ascending ST segment change. Only when the exercise was continued to the point of intolerable angina was the more acceptable horizontal or downsloping ST segment change observed. Criteria for abnormality should include ST segments with positive slopes.

There is a problem in defining a slowly ascending ST segment. To Punsar *et al.* it was one not reaching the isoelectric point before the onset of the T wave, to Lester, Sheffield, and Reeves (1967), it was an ST segment with a slope of less than 1 mV/sec, while Profant *et al.* (1972) defined as abnormal any ST segment that was 0·10 mV below the isoelectric point 0·06 sec after the nadir of the S wave. Slowly ascending ST changes, as defined by Punsar *et al.* (1968), were present in about 20 per cent of our normal women, slightly less often than the horizontal or downsloping ST changes that are generally considered to be more definite criteria of ischaemia. As yet there is no clinical or epidemiological evidence that any one of the above criteria to define 'slowly' ascending is better than another.

The whole field of exercise electrocardiography is further complicated by observer error, use of computer averaging, and interpretation (which may yield a higher percentage of positives as shown by Profant *et al.*, 1972), and the use of multiple leads which may increase even further the yield of positive responders in a series such as the current one (Rautaharju and Wolf, 1971).

In men, the validity of the criteria for positive electrocardiogram stress tests has been established in clinical studies on patients (Wood *et al.*, 1950; Mattingly, 1962), by follow-up studies in normal populations (Rumball and Acheson, 1963; Robb and Marks, 1967), and by correlation with coronary arteriography, as recently reviewed by Redwood and Epstein (1972). Such validation is not available in women. In women complaining of chest pain resembling angina, coronary angiography is frequently negative (Waxler, Kimbiris, and Dreifus, 1971), and in one series 36 of 100 patients had ischaemic changes in their exercise electrocardiograms.

It is no longer possible to conclude that an ischaemic basis for pain is ruled out by a negative coronary angiogram. Infarctions have occurred in such patients (Eliot and Bratt, 1969), and biochemical evidence of ischaemia with lactate formation in coronary sinus blood has been shown in patients with normal coronary angiograms (Kemp, Elliott, and Gorlin, 1967). The basic fault in these patients is not known. Eliot and Bratt (1969) have suggested that some of these patients may have a disorder of haemoglobin metabolism with impaired oxygen release, and another suggestion has been that the ischaemia is due to small vessel disease, possibly related to endogenous or exogenous oestrogens.

On the other hand, it is difficult to believe that 50 per cent of women aged 40 to 60 have actual myocardial ischaemia during exercise, and particularly that 25 per cent of women aged 20 to 39 years suffer from inadequate myocardial blood flow during exercise. While false positive exercise tests are known to occur with hyperventilation, anxiety, electrolyte disturbance, postural change, and sympathotonia, there was no gross evidence of any of these factors in the large majority of women in this series. Lepeshkin (1969) has suggested that myocardial hypokalaemia may be present in women, but documentation of this in normal women is lacking.

The only follow-up information available for women with exercise ST changes was recorded by Åstrand (1965) who followed 117 women, aged 40 to 60 years, for 8 years. Initially, 44 per cent had a positive exercise test in 1954, and in 1962 55 per cent were considered to have a positive test, but there were no instances of infarction or death. Thus, exercise ST changes in women seem to be relatively benign compared to the same changes in men (Kattus *et al.*, 1971).

In the Framingham study (Kannel and Feinleib, 1972), myocardial infarctions were about 25 per cent as common in women aged 40 to 60 compared to men. In women with angina, the rate of infarction was only 2 per cent per annum with a 10-year mortality rate of only 15 per cent. This relatively good prognosis for women with angina adds to the difficulty of any epidemiological study as a large number of subjects must be followed for 10 years or more to accumulate meaningful data. Of special note with regard to exercise ST changes and myocardial ischaemia is that the Framingham women (without prior infarction) complained of angina as often as men (7·5% over a 16-year period).

At the present time, exercise electrocardiography seems to be of limited value in women. The presence of typical ischaemic ST changes in an exercise test in a female subject cannot be used to confirm a diagnosis of angina pectoris when such changes are present in 25 to 50 per cent of asymptomatic women. The prognostic value of such changes is also questionable. Clearly, other criteria of abnormality need to be established for exercise electrocardiography in women.

Exercise tests in women with suspected cardiac disease do have some value; exercise capacity is objectively determined, a negative electrocardiogram is of some diagnostic assistance, and any electrocardiographic changes observed can be correlated with symptoms at the time of performing the test. In several of the normal women showing ST changes that would be classified as ischaemia, the changes appeared shortly after the start of exercise. While the degree of change increased as the exercise progressed in time or intensity, an abnormality was present in the first few minutes, and no symptoms of angina developed. It may be possible to redefine the criteria for abnormality for the exercise electrocardiogram for women, but until such a time as new criteria are available, exercise electrocardiographic changes in women can contribute only a limited amount of information either for patient care or in population surveys.

References

Åstrand, I. (1960). Aerobic work capacity in men and women with special reference to age. *Acta Physiologica Scandinavica*, **49**, Suppl. 169.

Åstrand, I. (1965). Exercise electrocardiograms recorded twice with an 8-year interval in a group of 204 women and men 48–63 years old. *Acta Medica Scandinavica*, **178**, 27.

Cumming, G. R., Borysyk, L., and Dufresne, C. (1972). The maximal exercise ECG in asymptomatic men. *Canadian Medical Association Journal*, **106**, 649.

Eliot, R. S., and Bratt, G. (1969). The paradox of myocardial ischemia and necrosis in young women with normal coronary arteriograms. *American Journal of Cardiology*, **23**, 633.

Kannel, W. B., and Feinleib, M. (1972). Natural history of angina pectoris in the Framingham Study. *American Journal of Cardiology*, **29**, 154.

Kattus, A. A., Jorgensen, C. R., Worden, R. E., and Alvaro, A. B. (1971). S-T segment depression with near-maximal exercise in detection of preclinical coronary heart disease. *Circulation*, **44**, 585.

Kemp, H. G., Elliott, W. C., and Gorlin, R. (1967). The anginal syndrome with normal coronary arteriography. *Transactions of the Association of American Physicians*, **80**, 59.

Lepeschkin, E. (1969). In Discussion following Irma Åstrand's chapter on 'Electrocardiographic changes in relation to the type of exercise, the work load, age and sex' on pp. 309–322. In *Measurement in Exercise Electrocardiography*, p. 321. Ed. by H. Blackburn. Thomas, Springfield, Illinois.

Lepeschkin, E., and Surawicz, B. (1958). Characteristics of true-positive and false-positive results of electrocardiographic Master two-step exercise tests. *New England Journal of Medicine*, **258**, 511.

Lester, F. M., Sheffield, L. J., and Reeves, T. J. (1967). Electrocardiographic changes in clinically normal older men following near maximal and maximal exercise. *Circulation*, **36**, 5.

Mattingly, T. W. (1962). The postexercise electrocardiogram. Its value in the diagnosis and prognosis of coronary arterial disease. *American Journal of Cardiology*, **9**, 395.

Profant, G. R., Early, R. G., Nilson, K. L., Kusumi, F., Hofer, V., and Bruce, R. A. (1972). Responses to maximal exercise in healthy middle-aged women. *Journal of Applied Physiology*, **33**, 595.

Punsar, S., Pyorala, K., and Siltanen, P. (1968). Classification of electrocardiographic S-T segment changes in epidemiological studies of coronary heart disease. *Annales Medicinae Internae Fenniae*, **57**, 53.

Rautaharju, P. M., and Wolf, H. K. (1971). Computer interpretation and classification of exercise electrocardiograms; vectorcardiographic aspects. In *Vectorcardiography 2. Proceedings of the XIth International Symposium on Vectorcardiography, New York City, 1970*, p. 223. Ed. by I. Hoffman. North Holland, Amsterdam.

Redwood, D. R., and Epstein, S. E. (1972). Uses and limitations of stress testing in the evaluation of ischemic heart disease. *Circulation*, **46**, 1115.

Robb, G. P., and Marks, H. H. (1967). Postexercise electrocardiogram in arteriosclerotic heart disease. *Journal of the American Medical Association*, **200**, 918.

Rumball, A. and Acheson, E. D. (1963). Latent coronary heart disease detected by electrocardiogram before and after exercise. *British Medical Journal*, **1**, 423.

Scherlis, L., Sandberg, A. A., Wener, J., Dvorkin, J., and Master, A. M. (1950). Effects of single and double '2 step' exercise tests upon electrocardiograms of 200 normal persons. *Journal of the Mount Sinai Hospital*, **17**, 242.

Waxler, E. B., Kimbiris, D., and Dreifus, L. S. (1971). The fate of women with normal coronary arteriograms and chest pain resembling angina pectoris. *American Journal of Cardiology*, **28**, 25.

Wood, P., McGregor, M., Magidson, O., and Whittaker, W. (1950). The effort test in angina pectoris. *British Heart Journal*, **12**, 363.

Requests for reprints to Dr. Gordon R. Cumming, The Children's Hospital of Winnipeg, 685 Bannatyne Avenue, Winnipeg, Manitoba R3E OW1, Canada.