

# Effects of an 18 week walking programme on cardiac function in previously sedentary or relatively inactive adults

Kathryn Woolf-May, Steve Bird, Andrew Owen

## Abstract

**Objective**—To investigate the effects of an 18 week walking programme upon cardiac function.

**Methods**—29 sedentary or relatively inactive but otherwise healthy subjects (15 walkers and 14 controls, aged 40-68 years) completed the study. The walkers completed a progressive 18 week walking programme which required an estimated average energy expenditure of 900 kcal week<sup>-1</sup> for the total duration of the study and 1161 kcal week<sup>-1</sup> during the final six weeks. Walking was carried out at an intensity of 67.8(SD 4.99)% of maximum oxygen consumption and 73.8(6.99)% of maximum heart rate. Before and after the intervention all subjects underwent an M mode echocardiogram, graded treadmill walking test, and step test for the assessment of aerobic fitness.

**Results**—After 18 weeks the results of the control group showed no change in any of the variables measured while the walkers showed a statistically significant increase in the velocity of relaxation of the longitudinal myocardial fibres of the left ventricle and a decrease in heart rate measured during the step tests, indicating an improvement in aerobic capacity.

**Conclusions**—Walking promotes improvements in cardiovascular fitness. Moderate forms of exercise may improve cardiac function.

(*Br J Sports Med* 1997;31:48-53)

Keywords: walking; heart; fitness.

It is widely established that cardiac function declines with age. The causes of the decline may be both structural and physiological. Reported changes in cardiac structure include an increase in ventricle chamber stiffness, caused by a reduction in the passive viscoelastic properties of the myocardium.<sup>12</sup> Other structural changes may be linked to the age related increase in blood pressure, which requires the left ventricle to contract more forcefully, thereby resulting in a thickening of the ventricle wall.<sup>3,4</sup>

Changes in cardiac structure and physiology result in alterations in cardiac function. Those commonly observed include an increased refractory period, lengthened contraction time, increased time to reach peak force, and incomplete relaxation during early diastolic filling.

This last change inhibits the passive filling of the ventricle, causing the atria to make a greater contribution to the filling stage of the cardiac cycle.<sup>5,6</sup> The magnitude of this change may be quite substantial, as in older adults (> 65 years) the late diastolic filling phase may account for 37% of total filling, as compared with only 19% for adults in their third decade.<sup>7</sup> Another factor stated to contribute to an age related decline in cardiac function is an increased left ventricular regional diastolic asynchrony.<sup>8</sup>

Animal studies using rats indicate that these changes could be associated with a reduction in the rate of calcium reuptake into the myocardial sarcoplasmic reticulum, resulting in a prolonged active state.<sup>9,10</sup> Research using the isolated papillary muscles of aged rats also provides evidence for the prolonged time to peak tension of contraction which adversely affects the systolic phase of the cardiac cycle.<sup>11</sup>

## CARDIAC ADAPTATIONS RELATED TO VIGOROUS EXERCISE

Research investigating the relation between cardiac function and exercise has primarily focused upon the effects of chronic vigorous exercise such as competitive running or cycling. Studies comparing athletic and sedentary populations have shown that, compared to sedentary controls, endurance athletes tend to possess greater left ventricular mass relative to surface area (g m<sup>-2</sup>).<sup>12-14</sup> Additionally, both the transverse right ventricular cavity dimension<sup>15</sup> and the left atrial transverse dimension are commonly larger in athletes.<sup>15,16</sup> Comparisons of left ventricular diastolic function between athletic and sedentary individuals have produced mixed results, with some indicating there is no difference<sup>12,13</sup> while others suggest that athletes have higher peak transmitral flow velocity which enhances early diastolic ventricular filling.<sup>17</sup> The implications of such findings are that they are affected by endurance training and that these attributes predispose an individual to endurance activities or are key factors in determining endurance performance potential. Comparisons between athletes and sedentary individuals in the older age groups (more than 40 years) have produced similar results.<sup>14,18-20</sup> Indeed the results of these studies often indicate that the cardiac function of veteran athletes is similar to that of younger individuals. From such findings it is therefore speculated that habitual endurance exercise in

Department of Sport and Exercise Science, Canterbury Christ Church College, Canterbury, CT1 1QU, United Kingdom  
K Woolf-May  
S Bird

Cardiology Department, Kent and Canterbury Hospital, Canterbury, CT1 3NG, United Kingdom  
A Owen

Correspondence to:  
Dr S R Bird, Department of Sport and Exercise Science.

Accepted for publication  
6 November 1996

older adults could promote a cardiac function which is similar to that usually observed in younger individuals.

However, longitudinal studies investigating the effects of vigorous exercise have produced less consistent results with respect to changes in the left ventricular mass and the thickness of the ventricular wall.<sup>21</sup> A reason for this could be the relatively short duration of some of the studies,<sup>22</sup> since those which have involved several years of chronic endurance exercise generally report increases in the left ventricular volume and mass, with small increases in the wall thickness.<sup>12 13 16 23</sup> The time taken for such adaptations to become apparent indicates that, although cardiac hypertrophy may occur as a result of prolonged vigorous exercise, it may not be as immediate or as important as some of the other cardiological adaptations which have been observed.<sup>23</sup> For example, one of the initial adaptations to vigorous endurance exercise is an increase in maximum cardiac output, without an increase in the mass of the heart.<sup>24</sup> This is thought to occur through a decrease in sympathetic drive during end diastolic filling, resulting in an increase in the ventricular cavity, thus producing a higher stroke volume through the Starling mechanism.<sup>25</sup> The consequences of these changes are an increased left ventricle end diastolic dimension, an increased stroke volume, and an increase in the mean fibre shortening velocity, along with a decrease in the end systolic dimension.<sup>26</sup>

In summary, research in this field has established that vigorous endurance exercise can promote a number of beneficial adaptations in both the structure of the heart and its functioning. However, the vigorous and often competitive nature of the exercise involved means that the findings only refer to a relatively small proportion of the population and the self selection of subjects may not make the results representative. In contrast, relatively little research has been carried out into the possible effects of less intense activities on cardiac function. An example of this would be brisk walking, which has been investigated in the context of other health related variables and is an activity which is accessible to a large percentage of the population, including older adults.

#### BENEFITS OF WALKING UPON OTHER HEALTH RELATED FACTORS

Brisk walking has already been shown to promote a number of health benefits including improvements in blood lipid profiles,<sup>27-30</sup> increases in maximum oxygen uptake,<sup>27 30-34</sup> and reductions in submaximal heart rates while exercising at a set workload.<sup>31 32 34 35</sup>

The overall implications of such findings are that brisk walking can reduce the risk of coronary heart disease and related illness by beneficially affecting various associated risk factors. However, little is known about its effects upon cardiac function, and in the absence of available evidence it was the aim of this study to investigate the effects of brisk

walking upon cardiac function in previously sedentary or relatively inactive adults of age 40 years and above.

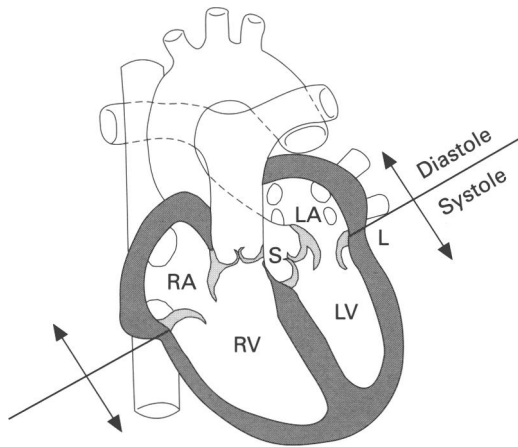
## Methods

### SUBJECT DETAILS AND SELECTION

Volunteers were recruited through an editorial in the local newspaper and a radio feature, which asked for sedentary but otherwise healthy individuals over the age of 40 years. Following a medical screening and activity questionnaire, volunteers were excluded from the study if they had high resting blood pressure (>160/>95 mm Hg, systolic/diastolic), or a previous history of cardiovascular disease, or a lifestyle which included more than a low level of activity. This was followed by a "permission to participate" form which was completed by the volunteer's general practitioner. Once cleared to participate, thirty five subjects were selected for the study (17 men and 18 women) aged between 40 and 68 years (mean 56.5, SD 6.85). Subjects were allocated into two groups, walkers (W) and controls (C), as randomly as possible, while matching the groups for age and gender. Analysis of variance indicated no significant difference between the groups ( $P > 0.1$ ) for age, height, and weight. All subjects were assessed for aerobic fitness, body composition, blood lipids, lipoproteins, apolipoproteins, and coagulation factors from venous blood samples taken at the phlebotomy department of the Kent and Canterbury Hospital (data not included here).

### ASSESSMENT OF CARDIAC FUNCTION

Before the start of the walking programme, all subjects underwent a standard echocardiographic examination (Hewlett-Packard Sonos 1000 echocardiograph, McMinnville, Oregon, USA). In addition to the standard Doppler echocardiogram, M mode echocardiograms of atrioventricular plane motion (AVPM) were obtained at the left free wall (L), septum (S), and the posterior wall (P) from the apical position (figure). Measurement of total displacement (d) and rate of relaxation (r) were made. These variables have been used previously to assess subtle changes in cardiac function which are not apparent in other indices such as the mitral velocity profile.<sup>36</sup> Atrioventricular plane motion reflects the contraction and relaxation of the myocardium in the longitudinal plane. All the examinations were performed by a single operator who was unaware of the group to which the subject had been allocated. Subjects were also requested not to discuss the study with the operator in order to minimise the risk of revealing their group. The data were rejected where an accuracy of at least 0.1 cm and 1.0 cm s<sup>-1</sup> could not be obtained in d and r respectively. This was assessed by repeating the measurements over several cardiac cycles. Upon completion of the walking programme all subjects underwent a repeat examination by the same operator, who remained blinded to the status of the subject.



*Schematic representation of the motion of the heart. In addition to the circumferential motion, there is a longitudinal motion as shown. This motion was measured at sites S and L. Site P is midway between S and L and is posterior to the plane of S and L. LA, left atrium; RA, right atrium; RV, right ventricle; LV, left ventricle.*

#### GRADED TREADMILL WALKING TEST

A graded treadmill walking test (GTWT) was used to establish the relation between the subjects' oxygen consumption and heart rate while walking. The test was conducted on a motorised treadmill (Woodway XELG70, Weil am Rhein, Germany). Subjects walked at 4.2 km h<sup>-1</sup> throughout the test. For the first stage the treadmill gradient was set at 0% if subjects were aged over 50 years and 2.5% if aged below 50 years. The test was continuous and the gradient increased by 2.5% every four minutes. Subjects completed a total of four stages. Heart rate was monitored using a Lifepulse 15 single Trace ECG monitor (HME Ltd, London Colney, United Kingdom). Expired air was collected via a Hans Rudolf breathing face mask with 2730 series large Y shaped valves (Hans Rudolf, Kansas City, USA) and low resistance ducting. Oxygen consumption ( $\dot{V}O_2$ ) was assessed using an on-line Covox Microlab analyser (Fitness Research Systems, Exeter, United Kingdom). Each subject's  $\dot{V}O_2$  max was estimated by extrapolating heart rate and oxygen consumption to their predicted heart rate maximum of  $210 - (\text{age} \times 0.65)$ .<sup>37</sup> It was intended to use this assessment postintervention as an indicator of changes in aerobic capacity, but because of technical difficulties this was not possible. Fortunately all subjects also completed a preintervention step test which was repeated postintervention, thereby providing an indication of aerobic fitness.

#### STEP TEST FOR AEROBIC FITNESS

In addition to the GTWT, all subjects completed a five minute step test. This began with a stepping cadence of 20 cycles per minute, which steadily increased after 30 seconds, reaching 24 steps a minute by the end of the second minute. This cadence was then maintained for the final three minutes of the test. Throughout the test the subjects' heart rate was monitored continuously using the PE4000 short wave telemetry system (Polar Electro Oy, Finland) and their peak heart rate recorded during the final 15 seconds of the test. Upon completion of the test the subject

was seated and a recovery heart rate recorded for 60 seconds. While seated the subject's hand was heated using warm water to promote capillary blood flow and a four minute postexercise finger prick capillary blood sample was collected using an Autolet lancet. The sample was immediately analysed using a YSI 2300 stat plus blood lactate analyser (Yellow Springs Instrument Company, Yellow Springs, Ohio, USA).

#### WALKING PROGRAMME

Subjects allocated to the W group embarked upon an 18 week walking programme which began with a total of 60 minutes walking in the first week, increasing to 200 minutes by the end of the study. The prescribed exercise programme aimed to produce an energy expenditure of around 1000 kcal week<sup>-1</sup>, this value being selected upon the basis of a review by Superko,<sup>38</sup> who suggested that it was effective in producing other health related adaptations. Members of group W were requested to walk for no less than 20 minutes in each session and since most subjects were considered to be sedentary or relatively inactive a gradual build up in activity was incorporated with the amount of energy expended estimated from the American College of Sports Medicine (ACSM) guidelines.<sup>39</sup>

In order to monitor and assist with the determination of exercise intensity while walking, subjects were allocated heart rate monitors (Polar Favor, Polar Electro Oy, Finland) and instructed to exercise at a heart rate which corresponded to 70-75% of their age predicted  $\dot{V}O_2$  max. Additionally all subjects were issued with a Borg scale of perceived exertion<sup>40</sup> which had also been used during the GTWT. To record their activities, all subjects were given two training diaries in which they were instructed to record the duration and intensity of all sessions. Completing the details in duplicate enabled one diary to be returned to the investigators on a regular basis and any queries concerning the content to be dealt with over the telephone.

Subjects completed their walking sessions in a way which fitted into their lifestyle, and they were also offered the option of supervised walking sessions on a weekly basis. Subjects in the control group were asked to maintain their current lifestyle for the duration of the study. They were also informed that upon completion of the study they would be offered the opportunity to participate in a second supervised walking programme. A summary of subject details are presented in table 1.

Fifteen of the 18 subjects allocated to group W completed the walking programme, and all 14 members of the control group indicated to the investigators that they had complied with the request to not increase their levels of activity until after the postintervention testing. Based upon the information contained within the training diaries of group W, a mean walking heart rate was calculated for each week. From this an estimated walking  $\dot{V}O_2$  was generated for each individual, using the correlation between their heart rate and  $\dot{V}O_2$  which had

Table 1 Subject details (preintervention), mean (SD)

	n	Walkers	n	Controls	P
Age (years)					
Males	9	57.3 (8.1)	8	57.3 (5.5)	
Females	6	53.0 (8.4)	6	54.3 (5.6)	
Whole group	15		14		0.96
Height (m)					
Males	9	1.75 (0.04)	8	1.74 (0.04)	
Females	6	1.62 (0.05)	6	1.62 (0.09)	
Whole group	15		14		0.86
Weight (kg)					
Males	9	82.7 (8.1)	8	75.9 (7.8)	
Females	6	65.6 (9.1)	6	63.9 (6.0)	
Whole group	15		14		0.21
Estimated $\dot{V}O_2$ max ( $l \text{ min}^{-1}$ )					
Males	9	2.21 (0.34)	8	2.68 (1.06)	0.23
Females	6	1.57 (0.34)	6	1.96 (0.23)	0.04
All	15	1.96 (0.46)	14	2.37 (0.87)	0.12
Estimated $\dot{V}O_2$ max ( $ml \text{ kg}^{-1} \text{ min}^{-1}$ )					
Males	9	26.7 (3.60)	8	3.47 (11.2)	0.06
Females	6	24.3 (5.83)	6	30.7 (1.74)	0.03
All	15	25.77 (4.60)	14	32.99 (8.57)	<0.01
Step test heart rate ( $\text{beats min}^{-1}$ )	15	131.7 (13.9)	14	118.5 (16.6)	0.03*
Lactate ( $\text{mmol l}^{-1}$ )	15	2.72 (1.03)	12	2.42 (1.19)	0.45
Echocardiographic data					
Lateral aspect (L)					
Displacement (cm)	14	1.60 (0.277)	14	1.61 (0.302)	0.95
Velocity ( $\text{cm s}^{-1}$ )	14	8.71 (2.027)	14	10.16 (2.713)	0.12
Centre septum (S)					
Displacement (cm)	13	1.42 (0.369)	11	1.44 (0.284)	0.88
Velocity ( $\text{cm s}^{-1}$ )	13	7.23 (3.314)	11	7.37 (2.074)	0.90
Posterior aspect (P)					
Displacement (cm)	13	1.53 (0.175)	11	1.61 (0.259)	0.41
Velocity ( $\text{cm s}^{-1}$ )	13	9.26 (3.098)	11	9.71 (2.777)	0.71

Table 2 Details of walking study

	Mean	SD
Total minutes walked	2514.2	312.5
Walking heart rate ( $\text{beats min}^{-1}$ )	128.0	11.6
Estimated exercise intensity (% maximum heart rate, $\text{beats min}^{-1}$ )	73.8	6.99
Estimated exercise intensity ( $\dot{V}O_2$ max)	67.8	4.99
Estimated gross energy expenditure (kcal)	16 127	5871

been produced from the GTWT data. Mean "rating of perceived exertion" (RPE)<sup>40</sup> was also calculated, along with total weekly minutes walked. From this, each individual's total energy expenditure while walking could be

Table 3 Mean displacement values (cm) for the heart when viewed from three aspects (L, S and P), comparing the measurements before (Pre) and after (Post) the 18 week walking intervention period for the walkers (W) and controls (C). Values are mean (SD)

	Pre	Post	Difference
Lateral aspect (L)			
W (n=14)	1.60 (0.227)	1.67 (0.194)	+0.07
C (n=14)	1.61 (0.302)	1.67 (0.300)	+0.06
Centre septum (S)			
W (n=13)	1.42 (0.369)	1.49 (0.227)	+0.07
C (n=11)	1.44 (0.284)	1.39 (0.281)	-0.05
Posterior aspect (P)			
W (n=13)	1.53 (0.175)	1.64 (0.210)	+0.09
C (n=11)	1.61 (0.259)	1.62 (0.359)	+0.01

Table 4 Mean velocity values ( $\text{cm s}^{-1}$ ) for the heart when viewed from three aspects (L, S and P). Comparing the measurements before (Pre) and after (Post) the 18 week walking intervention period for the walkers (W) and controls (C). Values are mean (SD)

	Pre	Post	Difference
Lateral aspect			
W (n=14)	8.71 (2.027)	10.18 (2.277)	+1.47*
C (n=14)	10.16 (2.713)	9.51 (1.867)	-0.65
Centre septum			
W (n=13)	7.23 (3.314)	7.30 (2.090)	+0.17
C (n=11)	7.37 (2.074)	7.66 (1.613)	-0.50
Posterior aspect			
W (n=13)	9.26 (3.098)	9.76 (2.430)	+0.43
C (n=11)	9.71 (2.777)	9.85 (2.052)	-0.01

\*P &lt; 0.05.

estimated.<sup>41</sup> During the study the subjects walked with an average heart rate of 128  $\text{beats min}^{-1}$  (SD 11.6) which corresponded with the findings of Porcari *et al.*,<sup>42</sup> who ascertained that brisk walking would be sufficient to attain the required exercise heart rate in these older, relatively inactive individuals. Details of the walking programme are summarised in table 2.

## Results

### ECHOCARDIOGRAPHY DATA

Because of technical difficulties it was not possible to obtain reliable measurements for all subjects on all factors; therefore the number of subjects used in the analysis varied between factors (tables 3 and 4). An analysis of covariance was carried out on the data for each factor using the method described by Oldham.<sup>43</sup> This revealed a significant increase in the rate of relaxation  $r$  as seen from the lateral aspect (site L in the figure) for W ( $P < 0.05$ ) but no significant change in the controls ( $P > 0.1$ ).

There were no significant differences ( $P > 0.1$ ) before and after the walking programme in the displacement at any of the sites studied for either group. Similarly there were no significant changes in the velocity ( $\text{cm s}^{-1}$ ) of relaxation of the left ventricle seen from the centre septum (site S in the figure) and posterior (site P in the figure) for either the W or the C groups.

### STEP TEST DATA

Using a one way analysis of variance the results of the step test showed a statistically significant reduction of 4.8  $\text{beats min}^{-1}$  in the mean peak heart rates of the walkers ( $P < 0.05$ ) but no significant change in the control group, whose mean heart rate increased by 1.9  $\text{beats min}^{-1}$  (table 5). Analysis of the post-test recovery heart rates revealed a mean reduction of 8.1  $\text{beats min}^{-1}$  in the walkers which bordered upon statistical significance ( $P < 0.07$ ) but virtually no change in the controls. Neither group showed a statistically significant change in post-test lactate ( $P > 0.1$ ).

## Discussion

Doppler echocardiography has been used in various studies investigating the effects of exercise upon cardiac function, the overall findings of such research being a difference in the left ventricular filling pattern between athletic and non-athletic individuals.<sup>18 20</sup> However, since the subjects in the "active" group of these studies have tended to be established athletes with many years participation in vigorous competitive sport, it may be inappropriate to extrapolate the findings to more moderate forms of exercise.

The results of this study provide some evidence to indicate that an 18 week walking programme can alter cardiac function, as measured by the rate of relaxation of the longitudinally arranged myocardial fibres of the left ventricle. They also support the findings of other research which have shown a reduction in submaximal heart rates while exercising at a set workload.<sup>31 32 34 35</sup>

Table 5 Step test results. Values are mean (SD) of measurements made before (Pre) and after (Post) the 18 weeks walking intervention for the walkers (W) and the controls (C)

	Pre	Post	Difference
Peak heart rate (beats min <sup>-1</sup> )			
W (n=15)	131.7 (14.0)	126.9 (10.0)	4.8*
C (n=13)	118.5 (16.6)	120.4 (17.4)	-1.9
Recovery heart rate (beats min <sup>-1</sup> )			
W (n=11)	98.4 (14.6)	90.3 (13.6)	8.1
C (n=10)	89.5 (19.4)	89.1 (16.9)	0.4
Lactate (mmol l <sup>-1</sup> )			
W (n=14)	2.77 (1.05)	2.41 (0.71)	0.36
C (n=12)	2.42 (1.19)	2.45 (1.00)	-0.03

These findings provide positive evidence of the effects of moderate intensity exercise upon cardiac function, and while an increased relaxation velocity cannot automatically be considered a health benefit, if viewed in the context of other findings it could be postulated that it is a positive change since cardiac function becomes more like that of younger and athletically fitter individuals. Furthermore it could also have implications upon related factors, such as the link between cardiac function and hypertension.<sup>44</sup>

However, while providing strong statistical evidence for these changes the characteristics of the subjects who completed the intervention make it necessary to view the data with a little caution. The underlying reason for this is that the groups were matched for age and gender before the echocardiographic analysis and fitness tests, so these latter data could not therefore be included in the stratification when matching the groups. Close inspection of the data shows that, while the average preintervention relaxation velocity of the walkers was not statistically different ( $P > 0.1$ ) from that of the controls, the mean was lower. Other differences were apparent in the fitness test data, with the preintervention estimated  $\dot{V}O_2$  max values being lower for both male and female walkers than in controls of the same gender when expressed relative to body weight (ml kg min<sup>-1</sup>). Similarly the female walkers also possessed a lower absolute  $\dot{V}O_2$  max than the female controls. This indicated a lower preintervention level of fitness in the walkers, which was further supported by the step test heart rates which were higher in this group.

This meant that in the postintervention testing, where the mean lateral ventricular relaxation and the step test heart rates of group W had significantly improved (ventricular relaxation  $P < 0.01$  and step test heart rates  $P < 0.05$ ), the postintervention values were now similar rather than significantly better than those of the controls, whose values had not changed during the course of the study.

However, this unfortunate quirk in subject selection is somewhat accounted for in the statistical tests employed. Therefore the results of the investigation do indicate that significant changes in cardiac function may be attained from exercise programmes which are relatively moderate in both intensity and volume. The duration of this study was 18 weeks, and the intensity [67.8(4.99)%  $\dot{V}O_2$  max, 73.8(6.99)% maximum heart rate] corresponded to the current ACSM guidelines,<sup>39</sup> that the exercise

should be rhythmic in nature and performed at 50-85% of  $\dot{V}O_2$  max and 60-90% of maximum heart rate. Furthermore, the mode of exercise was of a type which can usually be easily accommodated in many individuals' weekly routines. Analysis of the data indicated that the subjects in group W achieved an average walking duration of 140 min week<sup>-1</sup> over the entire duration of the study, with an average of 181 min week<sup>-1</sup> during the final six weeks. This corresponded to an estimated 18 week average energy expenditure of 900 kcal week<sup>-1</sup> and 1161 kcal week<sup>-1</sup> during the final six weeks. These values again correspond to ACSM guidelines<sup>39</sup> of 15-60 minutes exercise carried out on between three and five days per week.

The results of this study have shown that adaptations to cardiac function may be possible within a relatively short time span (18 weeks) using a moderate exercise intensity with realistic exercise volumes. Therefore this evidence provides a further indication of the potential health benefits of moderate intensity exercise, which is of a nature that can be performed by a large proportion of the adult population. Additional advantages of advocating this form of exercise are a reduced risk of injury<sup>33</sup> and better compliance than with more strenuous activities.<sup>31 45 46</sup> The importance of sustaining this level of activity throughout life is highlighted by the work of Vollmer-Larsen and associates<sup>14</sup> who showed the reversibility of cardiac function in ex-athletes, who on giving up training were found to have similar cardiac function to that of individuals who had never been actively involved in sport, rather than to their peers who had continued to train.

We would like to thank all the participants for their cooperation, Mrs L Roles for her assistance in supervising the walking programme, and Ms S Quinn for her assistance with the walking programme and the GTWT. Additionally we would like to thank Dr J Reynolds for his advice concerning the statistical analysis and Mrs J Yoke Eng Lawrence for her translation of the Su article.<sup>19</sup>

- Klausner SC, Schwartz AB. The ageing heart. *Clin Geriatr Med* 1985;1:119-41.
- Schulman SP, Gerstenblith G. Cardiovascular changes with ageing: the response to exercise. *J Cardiopulm Rehabil* 1989 9:12-15.
- Fleg JL. Alterations in cardiovascular structure and function with advancing age. *Am J Cardiol* 1986;57:33-44C.
- Lakatta EG. Changes in cardiovascular function with ageing. *Eur Heart J* 1990;11(suppl C):22-9.
- Byrg RJ, Williams GA, Lobovitz AJ. Effect of ageing on left ventricular diastolic filling in normal subjects. *Am J Cardiol* 1978 59:970-4.
- Spirito P, Maron BJ. Influence of ageing on Doppler echocardiographic indices of left ventricular function. *Br Heart J* 1988;59:672-9.
- Pearson AC, Gudipati CV, Labovitz AJ. Effects of ageing upon left ventricular structure and function. *Am Heart J* 1991;121:871-5.
- Gaasch WH, Blaustein AS, Bing OH. Asynchronous (segmental early) relaxation of the left ventricle. *J Am Coll Cardiol* 1985 5:891-7.
- Lakatta EG, Gerstenblith G, Angell CS, Shock NW, Weisfeldt ML. Prolonged contraction duration in aged myocardium. *J Clin Invest* 1975 55:61-8.
- Lakatta EG, Yin FCP. Myocardial ageing: functional alterations and related cellular mechanisms. *Am J Physiol* 1982 242:H927-41.
- Capasso JM, Malhotra A, Remily RM, Scheuer J, Sonnenblick EH. Effects of age on a mechanical and electrical performance of rat myocardium. *Am J Physiol* 1983;224:H72-81.
- Bjornstad H, Smith G, Storstein L, Meen DH, Hals O. Electrocardiographic and echocardiographic findings in top athletes, athletic students and sedentary controls. *Cardiology* 1993;82:66-74.
- Martinez-mas ML, Chorro FJ, Sanchis J, Asensi JF, Losada JA, Ruiz R, Lopez-Merino V. Doppler assessment of left ventricular diastolic function in marathon runners. *J Sports Med Phys Fitness* 1994;34:50-5.

- 14 Vollmer-Larsen A, Vollmer-Larsen B, Kelbaek H, Godtfredsen J. The veteran athlete: an echocardiographic comparison of veteran cyclists, former cyclists and non-athletic subjects. *Acta Physiol Scand* 1989;135:393-8.
- 15 Johnson RJ, Lombardo J, eds. *Current review of sports medicine*. Singapore: Imago, 1994.
- 16 Snoeckx LHEH, Abeling HFM, Lambregts JAC, Schmitz JFF, Verstappen FTJ, Reneman RS. Echocardiographic dimensions in athletes in relation to their training programs. *Med Sci Sports Exerc* 1982;14:428-34.
- 17 Di Bello V, Santoro G, Talarico L, Di Muro C, Caputo MT, Giorgi D, et al. Left ventricular function during exercise in athletes and sedentary men. *Med Sci Sports Exerc* 1996;28:190-6.
- 18 Takemoto KA, Bernstein L, Lopez JF, Marshak D, Rahimtoola SH, Vhandraratna PAN. Abnormalities of diastolic filling of the left ventricle associated with ageing are less pronounced in exercise-trained individuals. *Am Heart J* 1992;124:143-8.
- 19 Su Q. An echocardiographic study of the left ventricular diastolic functions of elite distance runners. *Sport Sci (Beijing)* 1989;9:45-9.
- 20 Forman DE, Manning WJ, Hauser R, Gervino EV, Evans WJ, Wei JY. Enhanced left ventricular diastolic filling associated with long-term endurance training. *J Gerontol* 1992;47:M56-8.
- 21 Wolfe LA, Martin RP, Watson DD. Chronic exercise and left ventricular structure and function in healthy human subjects. *J Appl Physiol* 1985;58:409-15.
- 22 Wolfe LA, Cunningham DA, Boughner DR. Physical conditioning effects on cardiac dimensions: a review of echocardiographic studies. *Can J Appl Sport Sci* 1986;11:66-79.
- 23 Perrault H, Turcotte RA. Exercise induce cardiac hypertrophy; fact or fallacy? *Sports Med* 1994;17:288-308.
- 24 Brooks GA, Fahey RD. *Exercise physiology: human bioenergetics and its applications*. New York: John Wiley and Sons, 1984.
- 25 Blomqvist CG, Saltin B. Cardiovascular adaptations to physical training. *Annu Rev Physiol* 1983;45:169-89.
- 26 DeMaria AN, Neumann A, Lee G, Mason D. Alterations in ventricular mass and performance induced by exercise training in man evaluated by echocardiography. *Circulation* 1978;57:237-44.
- 27 Duncan JJ, Gordon NF, Scott CB. Women walking for health and fitness: how much is enough? *JAMA* 1991;266:3295-9.
- 28 Hardman AE, Hudson A, Jones PMR. Brisk walking and plasma high density lipoprotein cholesterol concentration in previously sedentary women. *BMJ* 1989;229:1204-5.
- 29 Hardman AE, Hudson A. Brisk walking and serum lipid and lipoprotein variables in previously sedentary women—effects of 12 weeks regular brisk walking followed by 12 weeks of detraining. *Br J Sports Med* 1994;28:261-6.
- 30 Suter E, Marti B, Gutzwiller F. Jogging or walking—comparison of health effects. *Ann Epidemiol* 1994;4:375-81.
- 31 Jette M, Sidney K, Cambell, J. Effects of a twelve-week walking programme on maximal and submaximal work output indices in sedentary middle-aged men and women. *J Sports Med Phys Fitness* 1988;28:59-66.
- 32 Pollock ML, Miller HS, Janeway R, Linnerud AC, Robertson B, Valentino R. Effects of walking on body composition and cardiovascular function of middle aged men. *J Appl Physiol* 1971;30:126-30.
- 33 Seals DR, Hagberg JM, Hurley BF, Ehsani AA, Holloszy JO. Endurance training in older men and women I. Cardiovascular responses to exercise. *J Appl Physiol* 1984;57:1024-9.
- 34 Stensel DJ, Hardman AE, Brooke-Wavell K, Jones PRM, Norgan NG. The influence of brisk walking on endurance fitness in previously sedentary, middle-aged men. *Eur J Appl Physiol* 1994;68:513-37.
- 35 Luria MH, Koepke KR. The physical conditioning effects of walking. *J Sports Med* 1975;15:272-4.
- 36 Henein MY, Priestley K, Davarashvili T, Buller N, Gibson DG. Early changes in left ventricular subendocardial function after successful coronary angioplasty. *Br Heart J* 1993;69:501-6.
- 37 Maritz JS, Morrison JF, Peter J, Strydom NB, Wyndham CH. A practical method of estimating an individual's maximal oxygen uptake. *Ergonomics* 1961;4:97-122.
- 38 Superko HR. Exercise training, serum lipids and lipoprotein particles, is there a change in threshold? *Med Sci Sports Exerc* 1991;23:677-85.
- 39 American College of Sports Medicine. *Guidelines for exercise testing and prescription*, 4th ed. Philadelphia: Lea and Febiger, 1991.
- 40 Borg GA. Psychophysical basis of perceived exertion. *Med Sci Sports Exerc* 1982;14:377.
- 41 McArdle WD, Katch FI, Katch VL. *Exercise physiology: energy, nutrition and human performance*, 2nd ed. Philadelphia: Lea and Febiger, 1986.
- 42 Porcari MS, McCarron R, Kline G, Freedson BS, Ward A, Ross JA, et al. Is fast walking an adequate aerobic training stimulus for 30 to 69 year old men and women? *Physician Sports Med* 1987;15:119-29.
- 43 Oldham PD. *Measurement in medicine: the interpretation of numerical data*. London: English Universities Press, 1968: 148-52.
- 44 Lefkos N, Boudonas G, Vassilicos V, Eftymaidis A. Influence of left ventricular hypertrophy on the diastolic performance in hypertensive patients and in athletes. *Acta Cardiol* 1993;47:507-14.
- 45 Hovell MF, Sallis SF, Hofstetter CR, Spry VM, Elder JP, Faucher P, et al. Identifying correlates of walking for exercise: an epidemiologic prerequisite for physical activity promotion. *Prev Med* 1989;18:856-66.
- 46 McPhillips JB, Pelletiers KM, Barrett-Connor E, Wingard DL, Criqui MH. Exercise patterns in a population of older adults. *Am J Prev Med* 1989;5:65-72.