Change in Level of Physical Activity and Risk of All-Cause Mortality or Reinfarction
The Corpus Christi Heart Project

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Background—The role of physical activity (PA) in reducing the risk of all-cause mortality or reinfarction after a first myocardial infarction (MI) remains unresolved, particularly for minority populations. The association between change in level of PA and risk of death or reinfarction was studied in 406 Mexican American and non-Hispanic white women and men who survived a first MI.

Methods and Results—MI patients were interviewed at baseline and annually thereafter about PA, medical history, and risk factors of coronary heart disease. Change in level of PA after the index MI was categorized as (1) sedentary, no change (referent group), (2) decreased activity, (3) increased activity, and (4) active, no change. Over a 7-year period, the relative risk (95% CI) of death was as follows: 0.21 (0.10 to 0.44) for the active, no change group; 0.11 (0.03 to 0.46) for the increased activity group; and 0.49 (0.26 to 0.90) for the decreased activity group. The relative risk of reinfarction was as follows: 0.40 (0.24 to 0.66) for the active, no change group; 0.22 (0.09 to 0.50) for the increased activity group; and 0.93 (0.59 to 1.42) for the decreased activity group.

Conclusions—These findings are consistent with a beneficial role of PA for Mexican American and non-Hispanic white women and men who survive a first MI and have practical implications for the management of MI survivors. (Circulation. 2000;102:2204-2209.)

Key Words: myocardial infarction ■ epidemiology ■ prevention

Coronary heart disease (CHD), including myocardial infarction (MI) and sudden death, is the leading cause of death in the US population.1 In recent years, an increasing number of patients have survived a first MI. This is due in part to increased availability of intensive care units and improved therapies for the cardiac patient and in part to the increased presence and success of primary prevention efforts, which may have led to less-severe first events.1

Known CHD risk factors continue to have relevance in persons who have recovered from an MI, particularly elevated blood pressure and serum cholesterol levels, smoking, and diabetes.2–4 Among other risk factors, regular leisure-time physical activity (PA) has been associated with a reduced risk of incident CHD and all-cause mortality in some studies.5–7 In 1992, the American Heart Association identified physical inactivity as an important risk factor for heart disease.8

Since the 1950s, exercise has been an integral part of cardiac rehabilitation. Seventeen clinical trials have been conducted to determine the effectiveness of cardiac rehabilitation with an exercise component in improving survival among mostly white male CHD patients.9 However, in only 3 of these studies was there significantly longer survival in patients enrolled in the intervention group than among those in the control group.10–12 One meta-analysis of many of these trials showed a 20% reduction in mortality among those who received the cardiac rehabilitation intervention compared with the control group.13 It should be noted that the numbers of female MI patients included in these studies were inadequate for meaningful analysis and that no data at all were available for Mexican American (MA) MI patients.

The role of leisure-time PA in improving survival and decreasing the probability of reinfarction after an initial MI remains unresolved. We assessed the relationship between the risk of all-cause mortality or the occurrence of a second MI and change in the level of PA among MA and non-Hispanic white (NHW) survivors of a first MI. Because PA habits can change during follow-up, inference based on a single measure of PA at baseline could lead to erroneous conclusions.14 The
Clinical data abstracted from the medical record included ECG and laboratory findings obtained within 72 hours after arrival at the hospital or after having an in-hospital MI. ECG findings were used to classify type and location of the MI according to the Minnesota Code.\textsuperscript{19} A modified Norris Index for predicting long-term survival was developed and used to classify the severity of the MI as mild or severe.\textsuperscript{20} This index included age, the presence of pulmonary edema or congestive heart failure, and previous history of ischemia. Heart size, which is included in the original Norris Index, was not available.

Eligible patients were asked to enroll in the study, sign an informed consent, and complete a baseline interview that occurred on or about the fourth hospital day. Data included demographic characteristics, family history of CHD, medical and health history, use of medical services, cigarette smoking, and PA before the first MI.

A telephone follow-up interview was conducted annually for up to 5 years for each participant. The interviewer obtained information about vital status, recurrent MI, general health status, and PA since discharge or the previous interview.

Outcome variables were all causes of death, recurrent MI, and survival time. Deaths were identified from obituaries, next of kin or other contact persons, hospital charts, and death certificates. Information about a nonfatal second MI was ascertained from the study participant during the telephone interview and verified through the ongoing community surveillance. Survival since the first MI was defined as the number of days from the date of hospital admission to the date of death, the occurrence of a second MI, or December 31, 1996, whichever occurred first.

The primary exposure variable was change from baseline to follow-up levels of PA after the index MI. The participant was asked the following at baseline and at each follow-up visit: “During the past year, what physical activities do you usually do outside of your working hours?” For each reported activity, the interviewer prompted the participant for frequency, level of exertion, and duration of performance and inquired about additional activities. A standardized scheme was used by the interviewer to classify the participant’s baseline and follow-up visit PA level as sedentary, minimally active, moderately active, active, or vigorously active (see Table 1). The field center director reviewed the accuracy of the coding.

For analysis, baseline PA levels classified as sedentary (n=75) or minimally active (n=181) were collapsed into a single sedentary group. Those classified as moderately active (n=127), active (n=22), or very active (n=1) were collapsed into a single active group.

The number of follow-up visits for study participants before any recurrent MI ranged from 1 to 5. A composite variable representing PA level during follow-up was developed for each participant. Study participants who were classified as sedentary or minimally active for the majority of their follow-up visits were categorized as sedentary. Those who were classified as moderately active, active, or very

### TABLE 1. Categorization of PA

<table>
<thead>
<tr>
<th>2 Activity Levels</th>
<th>5 Activity Levels</th>
<th>Activity Description*</th>
<th>Activity Examples*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sedentary</td>
<td>Sedentary</td>
<td>Essentially no PA above minimum demands of daily living.</td>
<td>Watching TV, working at desk, riding in car, taking elevators, eating.</td>
</tr>
<tr>
<td>Minimally active</td>
<td>Activity during normal daily routine, 15–30 min/d, very light to fairly light exertion.</td>
<td>Some stair-climbing, light gardening, light housekeeping, light housekeeping.</td>
<td></td>
</tr>
<tr>
<td>Active</td>
<td>Mildly active</td>
<td>Activity to exercise muscle groups, 15–30 min/d, fairly light to somewhat hard exertion.</td>
<td>Calisthenics, lifting weights, heavy gardening, heavy housekeeping.</td>
</tr>
<tr>
<td></td>
<td>( \geq 1 ) dynamic activities performed 1–3 times/wk, 15 min/session, marked increase in heart rate or somewhat hard exertion.</td>
<td>Running/jogging, swimming, bicycling, fast walking, dancing, tennis, basketball, baseball, skiing.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>( \geq 1 ) dynamic activities performed ( \geq 3 ) times/wk, 20 min/session, somewhat hard to hard exertion.</td>
<td>Vigorous calisthenics, aerobic dancing, aerobic workouts, cross-country skiing, roller-skating, soccer.</td>
<td></td>
</tr>
</tbody>
</table>

*Each subsequent activity level includes activities from previous level.

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**Methods**

**Population**

The CCHP population included all residents of Nueces County, Texas, aged 25 to 74 years, who were admitted to 1 of 6 local hospitals and survived a documented first MI. The coronary care units and other intensive care units of the 6 hospitals were monitored on a regular basis to identify patients admitted for suspected MI. Classification of definite or possible MI, or no MI, was based on modification\textsuperscript{18} of the criteria recommended by Gillum et al.\textsuperscript{17} A patient was determined to have a first MI on the basis of a history of chest pain, the presence of ECG changes, and/or elevated cardiac enzyme levels, with no previous history of MI. A first MI was distinguished from a recurrence by review of the medical record and from record linkage with previously registered events in the CCHP files. Eligible study participants were MA or NHW patients surviving at least 28 days after hospitalization for an MI between May 1, 1988, and April 30, 1990. Completeness of ascertainment of patients hospitalized for MI has been estimated to be 95% and did not differ by sex or ethnicity (authors’ unpublished data, 2000).

The follow-up study included only those patients who were interviewed during the hospital stay. The participation rate among eligible patients was 79%. Reasons for nonparticipation were physician or nurse refusal (n=5), patient refusal (n=37), illness of patient (too ill to participate, n=19), discharge of the patient before the interview could be obtained (n=38), or incompetence of the patient (n=17). Of the 453 patients with a first MI who were interviewed, 47 were excluded from further analysis because they were not of MA or NHW ethnicity (n=33), they did not survive beyond 30 days after MI (n=10), or data for \( \geq 1 \) variable of interest were unavailable (n=4). The final study population included 406 MA and NHW women and men.

**Data Collection**

The Committee for the Protection of Human Subjects at the University of Texas-Houston Health Science Center reviewed and approved the present study. With the use of standardized procedures, data were collected by trained CCHP personnel by means of medical record abstraction, in-person baseline interview, and telephone follow-up interviews.

Baseline data on medical history and sociodemographic characteristics were abstracted from the medical record after discharge. Age at first MI was determined by subtracting the birth date from the date of onset. Ethnicity was obtained from the medical record and also by self-report during the interview, according to the procedure of the 1980 US Census.\textsuperscript{18} The agreement between the 2 sources of information was 95% (κ=0.91, \( P<0.001 \)).\textsuperscript{15} When the 2 sources disagreed, ethnicity was assigned as per the interview.
active for the majority of follow-up visits were coded as active. Participants were categorized as sedentary or active during follow-up according to their activity level at their last visit if half of the visits were reported as active or sedentary. Change in level of PA was determined for each participant on the basis of his/her categorization at baseline and at follow-up as (1) sedentary, no change from baseline, (2) decreased activity, (3) increased activity, or (4) active, no change.

Statistical Analysis
The statistical package STATA, release 4.0, was used for data analysis. Two-tailed t tests were used to determine variation in the distributions of continuous variables. The Mantel-Haenszel \( \chi^2 \) statistic was used to test for variation in the distributions of categorical variables. Unadjusted mortality and reinfarction rates were estimated for each group defined by change in level of PA. The Kaplan-Meier product-limit method was used to estimate survival or reinfarction-free survival by category of PA. Survival curves were compared among PA groups by the log-rank statistic. Cox proportional hazards regression analyses were used to assess the relationships between change in level of PA and risk of all-cause mortality or fatal and nonfatal reinfarction.

Results
Eighty-three percent of the 406 survivors of a first MI completed all follow-up interviews, whereas 12.5% missed 1 or 2 interviews, and 4.5% missed 3 or 4 interviews. Participants who had a reinfarction and/or who died were older, were less likely to have completed high school, had more severe MIs, and were more likely to have diabetes (Table 2).

Unadjusted rates for reinfarction and all-cause mortality were lowest in those who were active or had increased activity (Table 3). All-cause death rate, but not the rate of reinfarction, was lower in those who were initially active and had decreased activity than in those who were sedentary (Table 3). Kaplan-Meier survival curves of reinfarction and all-cause mortality by change in level of PA show the consistency of these patterns during study follow-up (Figures 1 and 2). Similar results were observed when the data were stratified by sex, ethnicity, or severity of first MI (data not shown).

Multivariate-adjusted hazard ratios for reinfarction and all-cause mortality are presented in Table 4. After adjusting for age, sex, ethnicity, severity of MI, family history of CHD, hypertension, diabetes, high serum cholesterol, and smoking, patients who remained active after a first MI had a 60% lower risk of fatal or nonfatal reinfarction than those who remained sedentary (relative risk [RR] 0.40, 95% CI 0.24 to 0.66).

| Table 2. Demographic and Clinical Characteristics by Selected Outcomes Among 406 First-MI Patients: The Corpus Christi Heart Project, 1988–1990 |
|----------------------------------|-----------------|-----------------|-----------------|-----------------|
|                                  | No (n=256)     | Yes (n=150)     | Alive (n=300)   | Dead (n=106)    |
| Age, y                           | 58.4           | 60.2*           | 57.5            | 64.1†           |
| Sex, n (%)                       |                |                 |                 |                 |
| Male                             | 169 (67)       | 85 (33)         | 194 (76)        | 60 (24)         |
| Female                           | 87 (57)        | 65 (43)         | 106 (70)        | 46 (30)         |
| Ethnicity, n (%)                 |                |                 |                 |                 |
| MA                               | 113 (58)       | 83 (42)*        | 141 (72)        | 55 (28)         |
| NHW                              | 143 (68)       | 67 (32)         | 159 (76)        | 51 (24)         |
| Education, n (%)                 |                |                 |                 |                 |
| >High school                     | 152 (63)       | 69 (31)†        | 177 (80)        | 44 (20)†        |
| <High school                     | 104 (56)       | 81 (44)         | 123 (66)        | 62 (34)         |
| Severity of first MI, n (%)      |                |                 |                 |                 |
| Mild                             | 196 (66)       | 102 (34)†       | 238 (80)        | 60 (20)†        |
| Severe                           | 60 (56)        | 48 (44)         | 62 (57)         | 46 (43)         |
| Diabetes, n (%)                  |                |                 |                 |                 |
| Yes                              | 73 (54)        | 61 (46)†        | 83 (62)         | 51 (38)†        |
| No                               | 183 (67)       | 89 (33)         | 217 (80)        | 55 (20)         |
| Hypertension, n (%)              |                |                 |                 |                 |
| Yes                              | 133 (59)       | 93 (41)         | 160 (71)        | 66 (29)         |
| No                               | 123 (68)       | 57 (32)         | 140 (78)        | 40 (22)         |
| High serum cholesterol, n (%)    |                |                 |                 |                 |
| Yes                              | 77 (63)        | 45 (37)         | 94 (77)         | 28 (23)         |
| No                               | 179 (63)       | 105 (37)        | 206 (73)        | 78 (27)         |
| Current smoker, n (%)            |                |                 |                 |                 |
| Never                            | 77 (64)        | 43 (36)         | 91 (76)         | 29 (24)         |
| Former                           | 80 (59)        | 55 (41)         | 96 (71)         | 39 (29)         |
| Current                          | 99 (66)        | 52 (34)         | 113 (75)        | 38 (25)         |

*P<0.05; †P<0.01.
Patients who increased their activity after their first MI had a 78% lower risk of reinfarction (RR 0.22, 95% CI 0.09 to 0.50), whereas patients who decreased their PA had a nonsignificant 7% lower risk of reinfarction (RR 0.93, 95% CI 0.59 to 1.42) than patients who remained sedentary.

Similarly, MI patients who remained active or increased their activity had a 79% (RR 0.21, 95% CI 0.10 to 0.44) and 89% (RR 0.11, 95% CI 0.03 to 0.46), respectively, lower risk of death due to all causes than did patients who remained sedentary. Patients who decreased their PA after their first MI had 51% lower risk of all-cause mortality (RR 0.49, 95% CI 0.26 to 0.90) than did sedentary MI patients. No interaction was observed between change in PA level and sex, ethnicity, or severity of first MI.

If being sedentary were a reflection of a generally debilitated state, even before the first MI, the mortality differential according to PA change category would be restricted to the period soon after the occurrence of MI. To examine this possibility, the data were reanalyzed after excluding patients who died or had a recurrent MI within 2 years after their first event. Results were similar to those of the analysis in which all study participants were included (data not shown).

**Discussion**

This is the first population-based study in which an independent relationship was found between leisure-time PA and risk of all-cause mortality and reinfarction in MA and NHW women and men who survived a first MI. Our results are consistent with previous data that led to the suggestion that PA may play a role in the secondary prevention of CHD.\(^5\)\(^9\)\(^11\)\(^25\) Individuals who remained active or increased their level of PA after a first MI had a lower risk of reinfarction or death due to all causes than did those who remained sedentary. Individuals who decreased their level of PA after a first MI had a higher risk of death or reinfarction than those who increased or maintained a physically active lifestyle and a lower risk of reinfarction or death than those who remained sedentary. We did not collect information that might explain this result; however, it is likely that prior performance of PA provided protection. Results were similar for men and women, MA and NHW, and for those with either a mild or severe first MI.

Although there are some exceptions,\(^7\)\(^14\) in most studies the association between a single measure of the exposure of interest at baseline and subsequent outcomes has been investigated. Because PA habits can change substantially, analyses of observational data can be subject to misclassification, leading to erroneous estimation of the RR and misleading interpretations of the results.\(^14\) A more representative measure of PA, especially for the patient recovering from an MI, is one that reflects change in PA behavior after the index MI.

Although the observed inverse association between level of PA and risk of all-cause mortality and reinfarction supports the hypothesis that PA reduces risk, there may be alternate
explanations. One explanation may be selection bias. Among those who had a hospitalized MI in the target population, 95% of MI patients were identified through surveillance methods of the CCHP, and among these patients, 79% agreed to be interviewed at the baseline and follow-up visits. Several patients did not agree to be interviewed because they were too ill or the physician or nurse refused patient participation in the study. This would produce an undersampling of patients who were very ill or who had more severe first MIs. However, had these patients enrolled in the study, they would most likely be physically inactive in the post-MI period and at higher risk of death because of their more severe conditions and not because of physical inactivity. This would lead to a spurious beneficial association between PA and risk of a second event. However, we did account for severity of MI in the analysis, making it unlikely that the absence of these patients seriously affected the results. Another potential source of bias is the possibility that study participants reduced or did not increase their PA levels after a first MI and during follow-up because of deterioration in their ventricular function. We did not collect quality-of-life information or obtain information about clinical status that would allow us to address this issue. However, we did reanalyze the data after first excluding those patients who died within 2 years after their MIs to determine whether severe disease caused both a sedentary condition and early reinfarction, and we observed results similar to those in the original analysis.

Misclassification of disease as a possible explanation of the association also seems unlikely. Vital status was determined for all interviewed participants. For classification of suspected MI, hospital records of patients were reviewed and classified by the CCHP review committee according to study criteria. If misclassification of reinfarction had occurred, it would likely be nondifferential with respect to PA level, inasmuch as the outcome was obtained without the knowledge of any other information about the participants and would lead to an attenuation of the true association.

Misclassification of level of PA as a possible explanation of the association also seems unlikely. Because the interviewers obtained the self-reported PA information before the occurrence of the second CHD event or death, misclassification of activity level would likely be nondifferential with respect to outcome.

The possible role of confounding factors and effect modification must also be considered. The association between change in level of PA and risk of reinfarction or death persisted after adjustment for the major factors known to be related to the occurrence of a second CHD event, although an unknown confounder is always a possibility. As expected, no effect modification by ethnicity or sex was observed.

There are few published data with which to directly compare the results of this investigation. Wannamethee et al observed beneficial effects of PA among men who had a history of cardiovascular disease, including stroke, CHD, or other heart trouble. Compared with men who remained sedentary during follow-up, men who remained active, became active, or became sedentary had RRs (95% CIs) of 0.62 (0.39 to 1.00), 0.44 (0.23 to 1.82), and 1.41 (0.89 to 2.24), respectively. The study population is different from the first-MI patients in the present study. However, the results clearly indicate the benefits of PA for men with a history of cardiovascular disease.

Most studies of the association between PA and survival among MI patients were randomized clinical trials of cardiac rehabilitation programs that included an exercise component and were usually conducted exclusively among white male MI patients. Our results are consistent with the meta-analysis in which O’Connor et al reported significantly lower total mortality, CHD mortality, and fatal reinfarction in the cardiac rehabilitation group than in the comparison group.

The major strengths of the present study include its population-based surveillance study design and the completeness of follow-up. Data on all end points were available for all participants at the end of follow-up. Approximately 95% of all hospitalized MI cases were ascertained; 79% of these patients participated in the baseline interviews, and 95% completed most of their follow-up interviews. Another strength is the frequency with which PA data were updated so that change in PA patterns was captured. Finally, substantial numbers of women and MAs were included.

The limitations of the present study include some aspects of exposure assessment and the numbers of outcome events in some categories of exposure. First, the instrument used to measure level of PA was not validated within the present study population. However, our PA instrument used the core elements of the validated Paffenbarger questionnaire, including frequency, duration, and intensity of usual PAs performed.

### Table 4. Adjusted Hazard Ratios for Reinfarction and All-Cause Mortality by Change in Level of PA After First MI: The Corpus Christi Heart Project, 1988–1990

<table>
<thead>
<tr>
<th>Change in Level of Physical Activity</th>
<th>Reinfarction*</th>
<th>All-Cause Mortality†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active, no change</td>
<td>0.40 (0.24–0.66)</td>
<td>0.21 (0.10–0.44)</td>
</tr>
<tr>
<td>Increased activity</td>
<td>0.22 (0.09–0.50)</td>
<td>0.11 (0.03–0.46)</td>
</tr>
<tr>
<td>Decreased activity</td>
<td>0.93 (0.59–1.42)</td>
<td>0.49 (0.26–0.90)</td>
</tr>
<tr>
<td>Sedentary, no change</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

*Adjusted for age at first MI, sex, ethnicity, family history, and status of smoking, diabetes, hypertension, high serum cholesterol, and severity of first MI.

†Adjusted for the variables listed above and recurrent MI during follow-up.

The possible role of confounding factors and effect modification must also be considered. The association between change in level of PA and risk of reinfarction or death persisted after adjustment for the major factors known to be related to the occurrence of a second CHD event, although an unknown confounder is always a possibility. As expected, no effect modification by ethnicity or sex was observed.

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during the previous year. Our results were consistent with those of other CHD studies that compared sedentary with active individuals. Second, because we lack data about quality of life and reasons why participants were not physically active, we are limited in our ability to interpret the persistence of sedentary status or decreased activity after MI. However, first-MI patients who were active survived longer than those who were sedentary for patients with either a mild or severe first MI. Because the mortality differential between active and sedentary patients was similar throughout follow-up and not restricted to the period soon after the occurrence of MI, we conclude that the disease was not causing physical inactivity. Third, the small number of events in some exposure categories limited the precision of some of the estimates of RR.

With better medical care, increased primary prevention efforts, and improved therapies, the number of MI survivors is increasing. As a result, more MI patients are at risk of a second CHD event or death. Our findings suggest that increased PA or a continuation of a physically active lifestyle is independently and inversely associated with all-cause mortality and reinfarction among patients surviving a first MI.

The present study supports the hypothesis that survivors of a first MI who are physically active have a lower risk of a recurrent MI or death from all causes or CHD than do those who are sedentary. Most important, these results support the current recommendation that PA be an integral component of regimens for the secondary prevention of CHD in all ethnic populations.

Acknowledgments
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References
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