Assessing the economic impact and health benefits of bicycling in Minnesota

Task 10: *Secondary analysis of existing of the health benefits of bicycling*

Description: This task involves analyzing data from the Coronary Artery Risk Development in Young Adults Study, which is an ongoing cohort study of young adults followed for the past 25 years in the Minneapolis/St. Paul metro area as well as three other metropolitan regions.

Deliverable: A report that summarizes the results of secondary analysis.

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Abstract
A 'mode effect' for 13 different types (modes) of physical activity or exercise on the incidence of diabetes and metabolic syndrome was estimated from the CARDIA study. Running and bicycling showed the strongest protective association against diabetes and metabolic syndrome. The relative risks for one additional month of frequent bicycling during a year were 0.89 for diabetes and 0.92 for metabolic syndrome. These relative risks can be used for future cost-benefit analyses of infrastructure projects that increase bicycling.

Introduction

Physical activity or exercise has been shown to be protective against type 2 diabetes[1–3] and metabolic syndrome[4,5]. To determine an optimal exercise prescription to prevent and manage diabetes and metabolic syndrome, it will be important to consider how the components of exercise impact these diseases. Exercise consists of four components: the duration, or how much time is spent in a single bout of activity; the frequency, or how often the activity is performed; the intensity, or how vigorously the activity is performed; and the mode, or which type of activity is performed. Recent interest in the mode of exercise has focused on the effects of combining aerobic exercise with resistance exercise[6–8], though these results have been inconclusive.

What has not been widely considered is whether specific modes of exercise (i.e. cycling, swimming, running) may have different effects on risk of diabetes and metabolic syndrome. Physiologically, we argue that different modes of exercise train different muscle groups and muscle fiber types, which in turn may serve as the basis for a 'mode effect' (e.g. cycling v. tennis) of activity on glucose disposal and other pathways. It will be important to also consider how total volume of activity, as well as the frequency, duration, and intensity of activity bouts may relate to the 'mode effect'. Understanding how mode of exercise effects type 2 diabetes risk would help in the development of exercise interventions to prevent diabetes and in the construction of infrastructure that supports exercise of a certain type (e.g. sidewalk, greenways, bike trails, etc.). For this reason, the purpose of this study is to examine the impact of mode of exercise (cycling, running, etc.) on the development of type 2 diabetes and the metabolic syndrome. Because this study is funded by the Minnesota Department of Transportation to consider the effects of bicycling, we are specifically interested in how bicycling compares to other modes. To isolate the effect of each mode, we will use the method described by Gordon-Larsen et al[9]. This method analytically accounts for total exercise performed, to isolate the mode effect.

This study will provide relative risk estimates that can be used in future cost-benefit analyses for infrastructure for walking and cycling. Current methods of estimating cost-benefit for these projects only consider risk reductions related to mortality[10]. When cost-benefit analyses only consider reductions in mortality, the benefit of projects is underestimated because cost savings related to reduced health care costs from non-fatal concerns, like treatment of diabetes, are not considered. By providing an estimate of the risk reductions for diabetes and metabolic syndrome that are related to cycling and walking, we provide an input for cost-benefit analyses that will help project planners more accurately represent the benefits of these projects.

Methods

<u>CARDIA</u>: The CARDIA study is a longitudinal cohort study of Caucasians and African Americans designed to examine risk factors for heart disease. Participants in this study come from 4 centers: Birmingham, Alabama; Chicago, Illinois; Minneapolis, Minnesota; and Oakland, California. Participants were aged 18-30 when the study began in 1985. There have been 8 waves of data collection, most recently in 2010.

<u>Outcome</u>: The outcomes of interest for this analysis were type-2 diabetes and metabolic syndrome. Diabetes was assessed at each wave of data collection using measured fasting glucose and self report of using diabetes medication. If measured fasting glucose was greater than 126 mg/dl or if the participant reported using diabetes medication they were considered diabetic. For incident diabetes, we excluded all participants who had diabetes at the first exam. A participant was considered diabetic if they met these

criteria at any point in follow up, and their time to follow up was the time to the first exam where they met the criteria for diabetes.

Participants were considered to have metabolic syndrome if at any wave of data collection they met three of the following criteria:

1. High blood pressure: Systolic greater than 130mmhg, diastolic greater than 85mmhg.
2. Fasting High Density Lipoprotein (HDL) less than 50 mg/dl in women or less than 40 mg/dl in men.
3. Fasting Triglycerides greater than 150 mg/dl.
4. Waist Circumference greater than 88 cm for women or greater than 102 cm for men
5. Fasting glucose was greater than 100 mg/dl or a participant had diabetes

As with diabetes, for incident metabolic syndrome, we excluded all participants who had metabolic syndrome at the first exam. A participant was considered to have metabolic syndrome if they met these criteria at any point in follow up, and their time to follow up was the time to the first exam where they met the criteria for metabolic syndrome.

Exposure: The main exposure of interest was a score for 13 different modes of exercise. These modes were: Jog or Run, Vigorous Racket Sports, Bicycling more than 10mph, Swimming, Vigorous Exercise Class or Vigorous Dancing, Vigorous Job Activity, Home or Leisure Activities, Strenuous Sports, Non-strenuous Sports, Walk or Hike, Golf or Bowling, Home Exercise or Calisthenics, and Home Maintenance or Gardening. For each of these modes, the CARDIA Physical Activity Questionnaire asked: how many months did you do this activity for more than 1 hour, and for how many months did you do this activity more than *x* hours per week. The hours per week question varied from 2 (for bicycling for example) to 5 (for gardening for example). Essentially the second question asks how many months the participant frequently practiced the particular mode of physical activity. From these questions, a score was constructed for each mode. Each mode was assigned an intensity multiplier ranging from 3 for lower intensity activities like golf or bowling, to 8 for higher intensity activities like running or jogging. This intensity multiplier was then multiplied by the sum of the months of more than 1 hour of the activity and two times the months with more than *x* hours per week of the activity. For example, for the bicycling variable, the intensity multiplier was 6. Each month that a respondent reported bicycling infrequently (more than one hour per month but less than two hours per week) represents a 6 point difference in the cycling score. Each month that a respondent reported bicycling frequently (more than 2 hours per week) represents an 18 point difference in cycling score. Because of the nature of the questions asked on the CARDIA physical activity survey, it is not possible to precisely estimate the frequency, intensity and duration of physical activity that participants achieved in each of the modes. For each mode, in reporting the hazard ratios, we used a unit that would correspond to one month of reporting frequent participation in that mode. This was done, because these questions were initially reported in months, to improve the interpretability of the results and does not change the statistical significance of the results. The units used for each mode are shown in table 1.

Each participant in the study reported up to 8 follow-up surveys on exercise. The variables used in analysis were averages of these follow-up surveys reported before incidence of diabetes or metabolic syndrome. If a participant developed diabetes or metabolic syndrome over the course of the study, we excluded their reported exercise from surveys completed after the developed the diseases.

Total Physical Activity Covariate: To isolate the effect of modes of exercise from the effect of total physical activity, we adjusted each model for the total physical activity outside of the mode of interest.

This was the average over follow-up and before incidence of diabetes or metabolic syndrome of the sum of all mode scores except for the mode of interest for each individual.

Demographic Covariates: We adjusted for gender, race and age in all models.
Health Related Covariates: We adjusted for three health related covariates that may potentially confound the relationship between physical activity modes and diabetes and metabolic syndrome. We adjusted for self-reported amount of alcohol consumed per day at the baseline exam (1985). We adjusted for smoking status (current, former or never smoker) at the baseline exam. We adjusted for a healthy diet score constructed by Jacobs (personal communication) at the baseline exam.

The Model: We modeled both metabolic syndrome and diabetes using a Cox Proportional Hazards model, where survival time to incidence of metabolic syndrome or diabetes was the time to the first exam where these outcomes were reported. We excluded from analysis subjects who had the outcomes at baseline. The main effect for each model was a score for exercise for the various modes (Jacobs, personal communication). We adjusted for age, race, gender, smoking status, alcohol consumption and diet. We also added total exercise outside the mode of interest as a covariate; the purpose of this was to adjust for total exercise and determine whether a mode has an effect on diabetes or metabolic syndrome independent of total exercise.

Results

For these models, we examined the effect of average activity score over follow-up on diabetes and metabolic syndrome. The mean and standard deviations for each physical activity mode, and the units used to determine hazard ratios for each mode are shown in Table 1.

The hazard ratios for each mode of physical activity related to diabetes and metabolic syndrome are shown in Table 2. Running or jogging and vigorous bicycling (faster than 10 miles per hour) demonstrated protective correlations with diabetes and metabolic syndrome. Bowling or golfing demonstrated an unexpected adverse correlation with diabetes and metabolic syndrome. Vigorous dancing or exercise class, home or leisure activities, walking or hiking, home exercise or calisthenics, and home maintenance or gardening all show protective correlations with metabolic syndrome only, though these correlations are slightly weaker than the correlations with running or jogging and vigorous bicycling.

Discussion

The physical activity data from CARDIA has some limitations because it is self-reported and observational, and the wording of the questions rules out examining each physical activity mode at a fine level of frequency, duration and intensity. Since the questions are reported as months that the respondents engaged frequently or infrequently in each activity, we have reported the hazard ratios for each additional month of frequent participation reported. Because this is an observational study, the associations between each physical activity mode and diabetes or metabolic syndrome cannot be considered causal. Despite these limitations, the CARDIA physical activity data has unique strengths. Most importantly, these data were collected on very specific modes of physical activity that give us the opportunity to examine a possible mode effect of physical activity on diabetes and metabolic syndrome. The sample size is large and demographically diverse.

These results suggest that jogging and bicycling are associated with a decreased risk of metabolic syndrome and diabetes, and that golf and bowling are possibly associated with an increased risk of both metabolic syndrome and diabetes. Given the evidence that total physical activity is associated with a decreased risk of diabetes and metabolic syndrome[1–5], it seems unlikely that there is something inherent in golf or bowling that would increase the risk of these diseases. Rather, a more likely explanation would be that golf and bowling are associated with a range of other lifestyle variables that promote diabetes and metabolic syndrome. In a post-hoc analysis we found that golf and bowling are significantly related to poorer dietary habits. Residual confounding by diet may explain the weak harmful effect of golf and bowling on diabetes and metabolic syndrome.

Running or jogging and bicycling each demonstrated a protective association against diabetes and metabolic syndrome. The relative risks for cycling were 0.899 against diabetes and 0.916 against metabolic syndrome. We can use these relative risks as an input to a cost benefit analysis if they are combined with a reliable estimate of the health system costs of diabetes or metabolic syndrome.

Table 1: Units, Means and Standard Deviations for each Physical Activity Mode

Mode of Physical Activity	Unit used for determining Hazard Ratios*	Mean [Standard Deviation] of Average Individual Activity over Follow Up before Incidence of Diabetes**	Mean (Standard Deviation) of Average Individual Activity over Follow Up before Incidence of Metabolic Syndrome**
Running or Jogging	24	44.4 [58.4]	44.8 [58.9]
Vigorous Racket Sports	24	11.2 [28.3]	11.5 [28.8]
Bicycling (Faster than 10 MPH)	18	29.8 [36.0]	29.9 [36.2]
Swimming	18	12.1 [23.6]	12.2 [23.8]
Vigorous Dancing or Exercise Class	18	28.0 [37.0]	28.4 [37.4]
Vigorous Job Activities (i.e. Digging)	18	45.3 [52.1]	45.5 [52.9]
Home or Leisure Activities (i.e. Snow Shoveling)	15	33.0 [35.6]	33 [36.0]
Strenuous Sports (i.e. Basketball)	24	32.6 [54.1]	33.5 [55.4]
Leisurely Sports (i.e. Ping Pong)	12	23.1 [24.8]	23.5 [25.4]
Walking or Hiking	12	50.1 [34.8]	50.1 [35.2]
Bowling or Golfing	9	7.2 [14.0]	7.2 [14.1]
Home Exercise or Calisthenics	12	24.1 [28.3]	24.2 [28.5]
Home Maintenance or Gardening	12	27.7 [27.9]	27.4 [28.1]

* These Units correspond to the change in activity score that would result if a respondent reported one additional month of the year of engaging in this activity frequently

** This is the mean of the average for each individual of their level of this activity over the course of follow up, not counting any activity reported after the individual developed the outcome of interest.

Table 2: Hazard Ratios for Diabetes and Metabolic Syndrome for each Physical Activity Mode

Mode of Physical Activity	Hazard Ratio [Confidence Interval] for Diabetes*	Hazard Ratio [Confidence Interval] for Metabolic Syndrome*
Running or Jogging	0.915 [0.868-0.964]**	0.887 [0.861-0.913]**
Vigorous Racket Sports	0.975 [0.888-1.071]	0.972 [0.923-1.023]
Bicycling (Faster than 10 MPH)	0.899 [0.842-0.959]**	0.916 [0.886-0.947]**
Swimming	1.049 [0.968-1.137]	0.99 [0.945-1.037]
Vigorous Dancing or Exercise Class	0.974 [0.922-1.029]	0.939 [0.909-0.97]**
Vigorous Job Activities (i.e. Digging)	0.995 [0.963-1.029]	0.996 [0.976-1.015]
Home or Leisure Activities (i.e. Snow Shoveling)	0.964 [0.914-1.017]	0.93 [0.904-0.956]**
Strenuous Sports (i.e. Basketball)	0.985 [0.933-1.041]	0.972 [0.943-1.002]
Leisurely Sports (i.e. Ping Pong)	1.055 [0.991-1.122]	1.01 [0.981-1.04]
Walking or Hiking	1.018 [0.984-1.054]	0.968 [0.949-0.989]**
Bowling or Golfing	1.076 [1.022-1.132]***	1.037 [1.004-1.072]***
Home Exercise or Calisthenics	1.023 [0.976-1.072]	0.952 [0.927-0.978]**
Home Maintenance or Gardening	1.013 [0.968-1.061]	0.953 [0.928-0.979]**

* All models are adjusted for race, sex, age, smoking status at baseline, diet, alcohol consumption at baseline and total physical activity excluding the mode of interest.

** These modes show a statistically significant ($p < 0.05$) protective effect against the outcome.

*** These modes show a statistically significant ($p < 0.05$) harmful effect against the outcome.

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