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Physical Activity and Colorectal Cancer

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Physical activity has been inconsistently associated with rectal cancer despite the consistent association between physical activity and colon cancer. In this study, the authors evaluated the association between physical activity and rectal cancer using the same questionnaire used to evaluate the previously reported association with colon cancer. A population-based study of 952 incident cases of cancer in the rectum and rectosigmoid junction and 1,205 age- and sex-matched controls was conducted in Utah and northern California at the Kaiser Permanente Medical Care Program between 1997 and 2002. Vigorous physical activity was associated with reduced risk of rectal cancer in both men and women (odds ratio (OR) = 0.60, 95% confidence interval (CI): 0.44, 0.81 for men; OR = 0.59, 95% CI: 0.40, 0.86 for women). Among men, moderate levels of physical activity also were associated with reduced risk of rectal cancer (OR = 0.70, 95% CI: 0.51, 0.97). Participation in vigorous activity over the past 20 years conferred the greatest protection for both men and women (OR = 0.55, 95% CI: 0.39, 0.78 for men; OR = 0.44, 95% CI: 0.30, 0.67 for women). In summary, physical activity was associated with reduced risk of rectal cancer in these data. The reduced risk was similar to that previously observed for colon cancer.

colonic neoplasms; physical fitness; rectal neoplasms

Abbreviations: CARDIA, Coronary Artery Risk Development in Young Adults; CI, confidence interval; MET, metabolic equivalent; OR, odds ratio.

Physical inactivity has been one of the most consistently identified risk factors for colon cancer (1). Early studies examining activity at work detected inverse associations with colon cancer (1); more recent studies have shown that long-term participation in leisure time activity reduces the risk of colon cancer (1). Although the methods of assessing physical activity have varied across studies, the benefits of being physically active in reducing the risk of colon cancer have been identified for men and women, for tumors in the proximal and distal colon, and from both cohort and case-control studies (1). Despite the consistent associations between colon cancer and physical activity, studies have almost as uniformly failed to detect an association between physical activity and rectal cancer. Far fewer studies of rectal cancer and physical activity have been reported, and many that do report associations have included rectal cancer cases along with colon cancer cases with inadequate power to examine rectal cancers separately (1–5). However, some studies have suggested that physical activity also may reduce the risk of rectal cancer (2, 3). One of these studies included only male smokers (2), so it is unknown if the association was limited to a specific subgroup of the population.

The association between rectal cancer and physical activity has not been adequately described. The purpose of this study is to examine the association between physical activity and rectal cancer and to compare associations obtained for rectal cancer with those previously obtained for colon cancer. Data were collected using identical methods to eliminate the possibility of associations being the result of different physical activity questionnaires; the sample size of 952 cases and 1,205 controls was adequate to precisely estimate associations for men and women.

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TABLE 1. Description of participation in the rectal cancer study, California and Utah, 1997–2002

	Cases	Controls
Total no. of eligible participants	1,506	1,884
Total no. of nonrespondents	524	653
Dead	101	10
Ill	60	16
Physician refusal	40	NA*
Moved	5	13
Unable to locate/other	19	73
Refused	299	541
Total no. interviewed	982	1,231
Data exclusion	30	26
Total available for analysis	952	1,205
Response rate (participants interviewed/participants identified/selected) (%)	65.2	65.3
Cooperation rate (participants interviewed/participants with whom we had contact) (%)	73.2	68.8
Contact rate (participants contacted/participants identified) (%)	98.2	95.4

* NA, not applicable.

MATERIALS AND METHODS

Study population

Participants in the study were from the Kaiser Permanente Medical Care Program of Northern California and the state of Utah. All eligible cases within these defined geographic areas were identified and recruited for the study. Two study populations are included in these analyses. Cases with a first primary tumor in the rectosigmoid junction or rectum were identified between May 1997 and May 2001. Case eligibility was determined by the Surveillance, Epidemiology, and End Results cancer registries in northern California and in Utah. Cases were identified using rapid-reporting systems. For comparative purposes, rectal cancer cases and controls are compared with cases and controls from a population-based case-control study of first primary colon cancer (*International Classification of Diseases for Oncology*, Second Edition, code 18.0 and codes 18.2–18.9) diagnosed between October 1, 1991, and September 30, 1994, in Utah and California. To be eligible for the study, participants had to be between 30 and 79 years of age at the time of diagnosis, English speaking, and mentally competent to complete the interview, and they could not have had previous colorectal cancer (6) or known (as indicated on the pathology report) familial adenomatous polyposis, ulcerative colitis, or Crohn's disease.

Controls were matched to cases by sex and by 5-year age groups. At the Kaiser Permanente Medical Care Program of Northern California, controls were randomly selected from membership lists, and in Utah controls aged 65 years or more were randomly selected from Health Care Financing Administration lists, and controls aged less than 65 years were randomly selected from driver's license lists.

A total of 982 rectal cancer cases and 1,231 controls were interviewed between October 1997 and January 2002 (table 1). Of these cases and controls, 56 were excluded from the analysis because they reported Crohn's disease or ulcerative colitis at the interview or had missing data or because the data were considered by the interviewer to be of poor quality. Response, cooperation, and contact rates for rectal cancer cases and age- and sex-matched controls are shown in table 1. These response, cooperation, and contact rates are similar to those obtained from the colon cancer study for these populations (71.8 percent, 80.8 percent, and 98.6 percent, respectively, for cases and 68.0 percent, 71.6 percent, and 95.6 percent, respectively, for controls). A total of 952 rectal cancer cases and 1,205 matched controls are included in the analyses presented. These data are compared with 1,346 colon cancer cases and 1,544 matched controls from the Kaiser Permanente Medical Care Program of Northern California and Utah.

Data collection. Data were collected by trained and certified interviewers using laptop computers. Data for the rectal cancer portion of the study were collected using the same study questionnaire and the same quality control procedures as were used in the colon cancer study. Study participants were asked to recall the year 2 years prior to the date of selection (the date of diagnosis for cases or the date of selection for controls). The interview took approximately 2 hours. The quality control methods used in the study were the same as those used in the colon cancer study and have been described in detail (7, 8).

Physical activity. Study participants were asked to recall their activity patterns at home, leisure, and work. Physical activity performed at home and at leisure was ascertained using an adaptation of the Coronary Artery Risk Development in Young Adults (CARDIA) Study physical activity history (6, 9); respondents were asked to recall their activity for the referent year. Participants were asked if they performed moderate and vigorous activities for at least 1 hour in any month of the referent year. There were eight categories of vigorous activities that were defined as "those activities which make you sweat or get out of breath" and four questions about moderate level activities that were defined as "those which are done at a more moderate pace than more strenuous activities." Cue cards, which listed examples of moderate and vigorous activities, were used to assist participants in recalling their moderate and vigorous activities done at leisure, at home, and at work. Participants were asked how many months they performed each category of activity, the average amount of time performed per session, and the usual number of days per week or month that type of activity was performed. We have previously evaluated the ability to recall past activity (2–3 years ago) using the CARDIA Study physical activity questionnaire and have found that repeatability of recall of activity is extremely high (overall $r = 0.81$); for vigorous activities, it was slightly higher ($r = 0.84$) when compared with that reported 2–3 years ago (10).

Participants were asked to report up to three full- or part-time jobs during the referent year and to recall any moderate or vigorous level activities performed on those jobs. Participants were asked to recall the number of months and the number of hours per week that they performed each job activity. In addition to the activity reported for the referent year, participants were asked to recall the amount of time they performed moderate and vigorous home, leisure, and work activities for 10 and 20 years prior to the interview date. For activity performed 10 and 20 years ago, one category of moderate and vigorous activity was asked along with the amount of time spent in moderate and vigorous activity and the frequency of these activities. The total amount of time spent participating in physical activities was converted to metabolic equivalents (METs) described by Ainsworth et al. (11). Moderate level activities were assigned values of 4.5 METs per minute, and intense activities were assigned values of 6.5 METs per minute. This was done so that various categories of activity could be combined into summary variables. We created lifetime activity variables that incorporated those leisure and home activities performed during the referent year and 10 and 20 years ago. For each time period (referent year, 10 years ago, and 20 years ago), participants were given a rank order from 1 to 4, with a rank of 1 being the lowest and a rank of 4 being the highest level of reported activity. For example, for vigorous activity, a rank of 1 indicated no vigorous activity, a rank of 2 indicated 1–200 MET minutes per week in vigorous activities, a rank of 3 indicated that between 200 and 1,000 MET minutes were expended per week in vigorous activities, and a rank of 4 was given to those participants who reported over 1,000 MET minutes of vigorous activity per week. For participants who were aged less than 40 years, who were not asked to recall activity levels 20 years earlier, the activity levels reported 10 years ago were double-weighted to establish an average lifetime activity index, since the index was based on a ranked scale where points were given for the current time and 10 and 20 years ago. In the analyses presented below, we use lifetime vigorous activity, since it appeared to be most consistently associated with colon cancer.

Other information. Dietary intake was ascertained using an adaptation of the CARDIA Study diet history (8, 12). Participants were asked to recall the foods eaten, the frequency with which they were eaten, the serving size, and if fats were added in the preparation. Nutrient information was obtained by converting food intake data into nutrient data using the Minnesota Nutrition Coding Center nutrient database. Height was measured at the time of interview, and weight was reported for the 2–5 years prior to interview. The body mass index (weight (kg)/height $(m)^2$) was calculated for men and women. Information was also collected on smoking history, medical history, family history of cancer, and the use of aspirin/nonsteroidal antiinflammatory drugs.

Statistical methods

Unconditional logistic regression models were used to estimate the odds ratio and corresponding 95 percent confidence intervals of rectal cancer in relation to physical activity. We evaluated the associations with activity performed at various levels of intensity (moderate and vigorous) as well as for activities performed at leisure or around the house and at work. In these models, age and body mass index were included; other variables, such as energy intake, dietary fiber, dietary calcium, and the use of aspirin and/or nonsteroidal antiinflammatory drugs on a regular basis, and having a family history of colorectal cancer did not alter the findings and are not included in the final models. For comparative purposes, associations for tumors in the rectum were compared with those detected for the colon. Colonic tumors were defined further as proximal (cecum through transverse colon) or distal (splenic flexure, descending, and sigmoid colon). To evaluate the underlying population changes over time, we compared the values reported by controls during the 1991–1994 period with those obtained from controls interviewed during the 1997–2001 period. Age-specific analyses were performed using age 65 years as the cutpoint. Linear trend was determined by evaluating the significance of linear association across the categorized variable.

RESULTS

The race/ethnicity of the rectal study population was reported at the time of interview as 82 percent non-Hispanic White, 4.1 percent African American, 7.6 percent Hispanic, 4.6 percent Asian, 0.7 percent American Indian, and 1 percent multiple races/ethnicity (data not shown in table). Rectal cancer cases were younger than colon cancer cases, with 3.3 percent of colon cancer cases being younger than 45 years at the time of diagnosis compared with 7.7 percent of rectal cancer cases (table 2). More men than women were

TABLE 2. Description of the study population, California and Utah, 1997–2002

	Colon cancer (1991–1994)					Rectal cancer (1998–2002)					
	Cases		Controls		χ^2 *p* value, case/control	Cases		Controls		χ^2 *p* value, case/control	χ^2 *p* value,* control/control
	No.	%	No.	%		No.	%	No.	%		
Total population	1,346		1,544			952		1,205			
Center											
Utah	362	26.9	519	33.6	<0.01	338	35.5	459	38.1	0.22	0.02
KPMCP†	984	73.1	1,025	66.4		614	64.5	746	61.9		
Age (years)											
<45	44	3.3	67	4.3	0.25	73	7.7	85	7.1	0.63	<0.01
45–54	175	13.0	212	13.7		197	20.7	240	19.9		
55–64	364	27.0	373	24.2		290	30.5	349	29.0		
65–74	554	41.2	634	41.1		265	27.8	345	28.6		
75–79	209	15.5	258	16.7		127	13.3	186	15.4		
Gender											
Male	756	56.2	845	54.7	0.44	559	58.7	673	55.9	0.18	0.56
Female	590	43.8	699	45.3		393	41.3	532	44.1		
Educational level											
Less than high school	217	16.1	193	12.5	0.02	104	10.9	127	10.6	0.24	<0.01
High school	372	27.6	431	27.9		226	23.7	270	22.4		
Some college	607	45.1	708	45.9		473	49.7	578	48.0		
College graduate or more	150	11.1	211	13.7		149	15.7	229	19.0		
Recent vigorous leisure physical activity (hours/week)‡											
None	543	40.3	525	34.0	<0.01	332	34.9	317	26.3	<0.01	0.03
1–2	483	35.9	566	36.7		363	38.1	485	40.3		
3–4	159	11.8	184	11.9		103	10.3	186	15.4		
>4	161	12.0	269	17.4		154	16.2	217	18.0		
BMI† (kg/m^2)‡											
<24	345	25.8	473	30.9	<0.01	246	26.1	320	26.8	0.47	<0.01
24–26	251	18.8	351	22.9		192	20.4	236	19.8		
26.1–28	269	20.1	252	16.5		173	18.4	241	20.2		
28.1–30	178	13.3	180	11.8		114	12.1	155	13.0		
>30	293	21.9	276	18.0		218	23.1	241	20.2		

* Comparisons of differences in controls for education, body mass index, and physical activity are age adjusted.
† KPMCP, Kaiser Permanente Medical Care Program of Northern California; BMI, body mass index.
‡ Physical activity and BMI are age adjusted.

diagnosed with rectal cancer, with 58.7 percent of cases being male and 41.3 percent being female. There were no significant rectal case-control differences for education as there were for the study of colon cancer. Controls reported more physical activity than did rectal cancer cases. Of interest is the observation that both controls and cases participating in the rectal cancer study reported more physical activity than did cases and controls in the colon cancer study conducted several years prior to the rectal cancer study.

Vigorous physical activity performed at leisure and around the home was associated with reduced risk of rectal cancer (table 3). This reduced risk was observed when analyzing the reported activity levels during the referent year, 10 years prior to diagnosis, and 20 years prior to diagnosis. The protective effect was observed in both men and women. Among men, high levels of moderate activity were associated with a reduced risk of rectal cancer for all three time periods examined. Simultaneously evaluating moderate and vigorous activity showed that, after adjustment for vigorous physical activity, the significant association with moderate activity disappeared, while the association with vigorous activity remained (discussed further below). The composite measure of long-term physical activity was associated with a reduced risk of rectal cancer. Again, the strongest indicator of reduced risk was for vigorous physical activity performed at constant high levels over the past 20 years. Further adjustment for family history of colorectal cancer, smoking

TABLE 3. Associations between leisure time physical activity over time and rectal cancer, California and Utah, 1997–2002

	Men						Women					
	Cases (no.)	Controls (no.)	OR*,†	95% CI*	OR‡	95% CI	Cases (no.)	Controls (no.)	OR†	95% CI	OR‡	95% CI
Recent leisure activity§												
Moderate												
None	145	140	1.00		1.00		94	108	1.00		1.00	
2	137	176	0.77	0.55, 1.06	0.83	0.60, 1.16	117	145	0.93	0.64, 1.35	0.99	0.68, 1.46
3	132	156	0.85	0.61, 1.18	0.96	0.68, 1.35	94	152	0.74	0.50, 1.08	0.82	0.55, 1.21
High	145	201	0.70	0.51, 0.97	0.83	0.59, 1.16	88	127	0.85	0.57, 1.26	0.99	0.66, 1.50
Linear trend *p* value			0.06		0.39				0.25		0.68	
Vigorous												
None	175	150	1.00		1.00		157	167	1.00		1.00	
2	91	1,123	0.69	0.49, 0.99	0.72	0.50, 1.03	62	94	0.67	0.45, 0.99	0.67	0.45, 1.01
3	137	190	0.61	0.45, 0.84	0.63	0.46, 0.87	105	147	0.73	0.52, 1.02	0.74	0.53, 1.05
High	156	220	0.60	0.41, 0.81	0.63	0.45, 0.86	69	124	0.59	0.40, 0.86	0.60	0.40, 0.88
Linear trend *p* value			<0.01		<0.01				<0.01		0.01	
Total												
Low	78	61	1.00				54	62	1.00			
2	147	154	0.75	0.50, 1.13			122	150	0.91	0.59, 1.42		
3	141	186	0.61	0.44, 0.91			115	159	0.87	0.56, 1.36		
High	193	272	0.56	0.38, 0.82			102	161	0.75	0.48, 1.19		
Linear trend *p* value			<0.01						0.18			
10-year leisure activity												
Moderate												
None	97	88	1.00		1.00		45	56	1.00		1.00	
2	115	129	0.82	0.56, 1.20	0.85	0.58, 1.26	44	68	0.79	0.45, 1.38	0.85	0.48, 1.49
3	140	156	0.82	0.57, 1.19	0.90	0.61, 1.32	78	109	0.90	0.55, 1.48	1.04	0.63, 1.74
High	207	300	0.63	0.45, 0.88	0.71	0.49, 1.01	226	299	0.95	0.61, 1.47	1.14	0.72, 1.80
Linear trend *p* value			<0.01		0.06				0.82		0.29	
Vigorous												
None	233	232	1.00		1.00		222	254	1.00		1.00	
2	49	58	0.85	0.55, 1.29	0.86	0.56, 1.33	22	36	0.63	0.35, 1.10	0.62	0.35, 1.11
3	115	153	0.73	0.54, 0.99	0.77	0.56, 1.05	65	103	0.68	0.47, 0.99	0.66	0.46, 0.97
High	162	230	0.69	0.53, 0.91	0.77	0.57, 1.03	84	139	0.67	0.48, 0.93	0.63	0.44, 0.89
Linear trend *p* value			<0.01		0.06				<0.01		<0.01	
Total												
Low	67	62	1.00				41	46	1.00			
2	115	132	0.82	0.53, 1.26			59	87	0.74	0.43, 1.28		
3	143	143	0.92	0.61, 1.40			94	121	0.87	0.52, 1.45		
High	234	336	0.65	0.44, 0.95			199	278	0.80	0.50, 1.28		
Linear trend *p* value			0.01						0.62			

Table continues

history, alcohol consumption, dietary intake, and use of aspirin did not alter risk estimates.

Moderate levels of occupational activity were associated with a reduced risk of rectal cancer in women (table 4). The magnitude of the risk was similar to that observed for vigorous leisure time activity. No significant associations between vigorous occupational activity and rectal cancer were observed for either men or women, although there were few women reporting high levels of vigorous occupational activity. Associations were of borderline significance in women after adjustment for vigorous leisure time activity (moderate occupational activity odds ratio (OR) = 0.67, 95 percent confidence interval (CI): 0.44, 1.01; total occupational activity OR = 0.70, 95 percent CI: 0.47, 1.04).

TABLE 3. Continued

	Men						Women					
	Cases (no.)	Controls (no.)	OR*,†	95% CI*	OR‡	95% CI	Cases (no.)	Controls (no.)	OR†	95% CI	OR‡	95% CI
20-year leisure activity												
Moderate												
None	105	94	1.00		1.00		61	64	1.00		1.00	
2	97	117	0.73	0.50, 1.08	0.86	0.57, 1.29	29	36	0.78	0.42, 1.44	0.85	0.46, 1.60
3	118	132	0.80	0.55, 1.16	0.96	0.65, 1.42	66	95	0.73	0.45, 1.18	0.79	0.49, 1.29
High	239	330	0.64	0.46, 0.89	0.82	0.57, 1.17	237	337	0.72	0.48, 1.07	0.85	0.56, 1.30
Linear trend *p* value			0.01		0.36				0.13		0.54	
Vigorous												
None	217	190	1.00		1.00		195	222	1.00		1.00	
2	38	58	0.56	0.36, 0.89	0.59	0.37, 0.94	25	31	0.86	0.49, 1.52	0.88	0.50, 1.57
3	111	152	0.62	0.45, 0.85	0.65	0.46, 0.90	57	95	0.66	0.45, 0.98	0.68	0.46, 1.02
High	193	273	0.61	0.46, 0.80	0.56	0.48, 0.89	116	184	0.67	0.49, 0.91	0.68	0.49, 0.95
Linear trend *p* value			<0.01		<0.01				<0.01		0.01	
Total												
Low	79	66	1.00				49	53	1.00			
2	98	118	0.69	0.45, 1.05			47	61	0.80	0.46, 1.39		
3	121	129	0.77	0.51, 1.16			75	94	0.85	0.51, 1.40		
High	261	360	0.60	0.42, 0.86			222	324	0.71	0.46, 1.10		
Linear trend *p* value			<0.01						0.12			
Long-term activity												
Moderate												
None	211	213	1.00		1.00		98	120	1.00		1.00	
2	137	182	0.76	0.57, 1.02	0.87	0.64, 1.18	109	146	0.91	0.63, 1.32	1.01	0.69, 1.47
3	135	167	0.81	0.60, 1.10	0.98	0.71, 1.36	129	175	0.93	0.65, 1.33	1.14	0.78, 1.67
High	76	111	0.69	0.48, 0.98	0.83	0.57, 1.22	57	91	0.79	0.51, 1.22	1.04	0.65, 1.64
Linear trend *p* value			0.04		0.54				0.37		0.59	
Vigorous												
None	107	85	1.00		1.00		111	102	1.00		1.00	
2	145	149	0.76	0.53, 1.10	0.77	0.53, 1.11	104	139	0.63	0.43, 0.92	0.63	0.43, 0.92
3	137	201	0.53	0.37, 0.76	0.55	0.38, 0.80	107	155	0.58	0.40, 0.85	0.57	0.39, 0.84
High	176	238	0.55	0.39, 0.78	0.58	0.39, 0.84	71	136	0.44	0.30, 0.67	0.43	0.28, 0.66
Linear trend *p* value			<0.01		<0.01				<0.01		<0.01	
Total												
Low	173	169	1.00				97	119	1.00			
2	136	152	0.86	0.63, 1.18			102	119	1.04	0.71, 1.52		
3	129	179	0.69	0.51, 0.95			133	195	0.84	0.59, 1.20		
High	121	173	0.68	0.50, 0.94			61	99	0.78	0.51, 1.19		
Linear trend *p* value			<0.01						0.14			

* OR, odds ratio; CI, confidence interval.

† Adjusted for age, body mass index, and energy intake.

‡ Model includes both moderate and vigorous activity along with age, body mass index, and energy intake.

§ Cutpoints for moderate activity are roughly equivalent to none, 1.5 hours/week, and 4 hours/week; cutpoints for vigorous activity are roughly none, 30 minutes/week, and 3 hours/week. Cutpoints were the same for all time periods.

The associations observed for physical activity and rectal cancer were similar to those observed for colon cancer overall and for proximal and distal tumors specifically (table 5). Among women and older men, associations were slightly stronger for rectal cancer than for colon cancer. The level of vigorous activity needed to see a protective effect for rectal cancer was less than that observed for colon cancer.

TABLE 4. Associations between long-term occupational physical activity and rectal cancer, California and Utah, 1997–2002

	Men				Women			
	Cases (no.)	Controls (no.)	OR*,†	95% CI*	Cases (no.)	Controls (no.)	OR	95% CI
Moderate occupational activity								
None	175	200	1.00		175	224	1.00	
Intermediate	186	251	0.83	0.63, 1.10	161	211	0.89	0.66, 1.20
High	198	222	0.98	0.73, 1.31	55	97	0.63	0.42, 0.94
Linear trend *p* value			0.93				0.03	
Vigorous occupational activity								
None	267	339	1.00		328	423	1.00	
Intermediate	193	204	1.17	0.90, 1.51	53	95	0.65	0.45, 0.95
High	99	130	0.93	0.68, 1.28	12	14	0.97	0.43, 2.14
Linear trend *p* value			0.94				0.10	
Total occupational activity								
None	148	176	1.00		176	220	1.00	
Intermediate	201	277	0.85	0.64, 1.14	154	206	0.86	0.64, 1.16
High	210	220	1.10	0.82, 1.49	63	106	0.65	0.44, 0.95
Linear trend *p* value			0.44				0.03	

* OR, odds ratio; CI, confidence interval.
† Adjusted for age, body mass index, and energy intake.

Evaluating the combined effect of moderate and vigorous physical activity on the risk of colon and rectal cancer showed that high levels of vigorous activity reduced the risk at nearly every level of moderate activity (table 6). Evaluation of high levels of moderate activity at low levels of vigorous activity did not show a similar risk reduction. The majority of people who reported high levels of moderate activity also were at the high end of vigorous activity.

Dose-response was explored further by looking at colorectal cancer risk associated with performing various hours of moderate and vigorous physical activity per week over the past 20 years. Figure 1 shows the associations with no, less than 1 hour/week, 1–2 hours/week, 2.1–3.5 hours per week, 3.6–5.15 hours/week, and over 5.15 hours/week; 3.5 hours/week would be equivalent to 30 minutes of activity per day, and 5.15 hours would be equivalent to 45 minutes of activity per day. In these analyses, moderate activity and vigorous activity were assessed in the same model, and data from men and women were combined. Vigorous activity was associated with statistically significant reductions in risk for both colon cancer and rectal cancer with increasing levels of activity.

DISCUSSION

Using the same physical activity questionnaire and the same methods to recruit and interview cases and controls as were used to study colon cancer, we observed similar associations between physical activity and rectal cancer as we did for colon cancer. As with our previously published data on colon cancer (6), vigorous physical activity appeared to have the greatest and most consistent association with reduced risk of rectal cancer.

Most previous studies examining the association between rectal cancer and physical activity have done so within the context of colorectal cancer case-control or cohort studies (1, 13, 14). Because of few cases of rectal cancer in most of these studies, associations often were reported for colorectal cancer, where the associations were sometimes weaker than studies examining colon cancer alone. For instance, in one study of 41 rectal cancer cases, although the magnitude of association for being very active on the job was similar to associations for colon cancer, the finding was not statistically significant (OR = 0.7, 95 percent CI: 0.2, 2.5) (15). Most studies of rectal cancer and physical activity did not observe statistically significant associations. It is generally not known if the lack of association was from the small number of rectal cases, inadequate physical activity questionnaires, or a null association. Some studies, however, have detected significant reduced risk of rectal cancer with high levels of physical activity. One of these studies evaluated the association in a cohort of male smokers (2). Within the cohort there were 104 cases of rectal cancer; a significant reduction in risk was observed for moderate/heavy occupational activity (OR = 0.5, 95 percent CI: 0.26, 0.97) but not for recreational activity. In the present study, we observed similar associations with physical activity among never, former, and current cigarette smokers (data not shown). In a study in New Zealand (3), being sedentary on the job significantly increased the risk of rectal cancer, although the magnitude of the association was not large (relative risk = 1.26, 95 percent CI: 1.04, 1.52).

TABLE 5. Comparison of long-term vigorous physical activity and colon and rectal cancers for men and women by age at time of diagnosis, California and Utah, 1997–2002*

	All colon		Colon cancer proximal		Colon cancer distal		Rectal cancer	
	OR†,‡	95% CI†	OR	95% CI	OR	95% CI	OR	95% CI
Men								
All								
Low	1.00		1.00		1.00		1.00	
2	0.90	0.67, 1.21	0.88	0.61, 1.28	0.87	0.61, 1.25	0.76	0.53, 1.10
3	0.80	0.59, 1.08	0.82	0.56, 1.19	0.76	0.53, 1.10	0.53	0.37, 0.76
High	0.59	0.43, 0.80	0.59	0.40, 0.87	0.58	0.39, 0.85	0.55	0.39, 0.78
Linear trend *p* value	<0.01		<0.01		<0.01		<0.01	
<65 years of age								
Low	1.00		1.00		1.00		1.00	
2	0.74	0.44, 1.24	0.90	0.46, 1.75	0.61	0.33, 1.10	0.79	0.46, 1.34
3	0.71	0.43, 1.17	0.81	0.42, 1.56	0.60	0.33, 1.07	0.87	0.52, 1.47
High	0.49	0.29, 0.82	0.49	0.24, 1.00	0.48	0.26, 0.88	0.72	0.44, 1.20
Linear trend *p* value	<0.01		0.02		0.03		0.29	
≥65 years of age								
Low	1.00		1.00		1.00		1.00	
2	0.96	0.67, 1.39	0.86	0.55, 1.35	1.00	0.63, 1.58	0.84	0.50, 1.41
3	0.82	0.56, 1.20	0.81	0.51, 1.30	0.84	0.52, 1.36	0.30	0.18, 0.51
High	0.65	0.44, 0.97	0.66	0.41, 1.06	0.64	0.38, 1.05	0.43	0.26, 0.71
Linear trend *p* value	0.02		0.09		0.05		<0.01	
Women								
All								
Low	1.00		1.00		1.00		1.00	
2	0.65	0.49, 0.87	0.61	0.42, 0.87	0.66	0.46, 0.95	0.63	0.43, 0.92
3	0.62	0.45, 0.84	0.66	0.45, 0.96	0.59	0.40, 0.88	0.58	0.40, 0.85
High	0.58	0.42, 0.82	0.58	0.37, 0.89	0.61	0.40, 0.93	0.44	0.30, 0.67
Linear trend *p* value	<0.01		0.01		0.01		<0.01	
<65 years of age								
Low	1.00		1.00		1.00		1.00	
2	0.61	0.37, 1.00	0.47	0.25, 0.91	0.68	0.38, 1.20	0.77	0.46, 1.30
3	0.58	0.35, 0.97	0.56	0.29, 1.08	0.65	0.36, 1.17	0.59	0.36, 0.98
High	0.57	0.36, 0.95	0.53	0.28, 1.01	0.63	0.35, 1.14	0.42	0.25, 0.73
Linear trend *p* value	0.05		0.12		0.17		<0.01	
≥65 years of age								
Low	1.00		1.00		1.00		1.00	
2	0.66	0.46, 0.95	0.68	0.44, 1.05	0.61	0.38, 0.99	0.51	0.29, 0.88
3	0.63	0.42, 0.94	0.71	0.44, 1.16	0.50	0.28, 0.88	0.62	0.35, 1.10
High	0.56	0.34, 0.93	0.60	0.32, 1.13	0.55	0.28, 1.06	0.53	0.29, 0.96
Linear trend *p* value	<0.01		0.06		0.01		0.05	

* Analysis includes 1,346 cases of colon cancer and 1,544 matched controls, as well as 952 rectal cancer cases and 1,205 matched controls.
† OR, odds ratio; CI, confidence interval.
‡ Adjusted for age, body mass index, and energy intake. Comparisons are made for data collected on colon cases and controls and for rectal cancer cases and controls; control groups from the two studies are not combined.

The amount and type of activity needed to reduce cancer risk are an important public health issue. Although an equal protective effect is observed for high levels of vigorous activity for both colon and rectal cancer, it appears that lower levels of activity confer greater protection for rectal tumors than for colon tumors. Activities performed at an intense level of effort appear to be more protective for both colon and rectal cancer. It is unknown if measurement error

TABLE 6. Associations between long-term moderate and vigorous activity on risk of colorectal cancer, California and Utah, 1997–2002

Vigorous activity	Moderate activity			
	None	2	3	High
Colon (1,340 cases/1,535 controls)				
None (no. of cases/no. of controls)	174/151	103/73	53/76	42/27
2	149/165	101/127	103/78	32/59
3	77/113	99/107	100/128	53/52
High	33/50	53/100	93/122	75/107
None (odds ratio* (95% confidence interval))	1.00	1.25 (0.86, 1.81)	0.65 (0.43, 0.99)	1.41 (0.83, 2.40)
2	0.79 (0.57, 1.08)	0.68 (0.48, 0.95)	1.20 (0.83, 1.74)	0.50 (0.31, 0.81)
3	0.58 (0.41, 0.84)	0.81 (0.57, 1.15)	0.70 (0.50, 0.99)	0.88 (0.57, 1.38)
High	0.56 (0.34, 0.92)	0.47 (0.31, 0.70)	0.66 (0.47, 0.95)	0.62 (0.42, 0.89)
Rectal (952 cases/1,205 controls)				
None (no. of cases/no. of controls)	108/96	49/48	37/32	24/11
2	102/129	76/84	54/55	17/20
3	74/68	65/113	74/106	31/69
High	25/40	56/83	99/149	61/102
None (odds ratio (95% confidence interval))	1.00	0.92 (0.57, 1.50)	1.03 (0.59, 1.78)	2.09 (0.97, 4.51)
2	0.65 (0.44, 0.96)	0.77 (0.50, 1.17)	0.87 (0.54, 1.38)	0.79 (0.39, 1.59)
3	0.91 (0.59, 1.41)	0.48 (0.32, 0.72)	0.61 (0.40, 0.91)	0.38 (0.23, 0.63)
High	0.52 (0.29, 0.92)	0.56 (0.36, 0.88)	0.56 (0.38, 0.82)	0.50 (0.32, 0.76)

* Adjusted for age, body mass index, and energy intake.

contributes to these observations. It is suspected from quality control used for the study that error is introduced in the moderate activity variable from the inability to distinguish light versus moderate activity performed around the house, garden, and yard. We believe that this error is probably greater for activity recalled 10 and 20 years ago, since a global question was asked rather than several specific questions about various types of activities. It is also important to note that the majority of people who reported high levels of moderate activity also reported higher levels of vigorous activity. From various analyses that we performed, it appears that vigorous activity confounds the association with

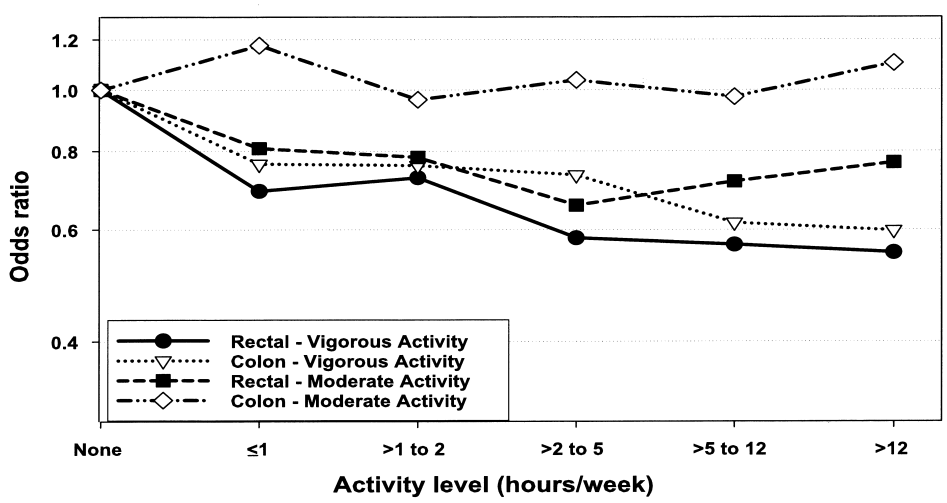

FIGURE 1. Dose-response of moderate and vigorous long-term activity levels with colorectal cancer risk, United States, 1991–2002.

moderate activity. In these data, vigorous activity in the absence of moderate activity reduces the risk of rectal cancer, while moderate activity in the absence of vigorous activity does not.

It appears that occupational activity may be important in this population as reported elsewhere (3, 15). Associations were stronger for women, who are often not engaged in physical activity as part of their paid work, than for men. It is possible that occupational activity, although seldom reported by women, is a better discriminator of activity in women than in men. Thus, although the strongest associations were detected for vigorous physical activity performed during leisure, it is possible that other components of physical activity are important, but that reported vigorous activity for many years is the best discriminator of activity in this population.

The extent to which the underlying characteristics of the population have an impact on the ability to detect associations is not clearly defined. We detected changing characteristics in the population-based control population over time. Significantly more people had a body mass index of 30 or greater than we observed when data were collected for the colon cancer study in the early 1990s. If physical activity has a greater impact among obese individuals, it is possible that this shift in population characteristics is contributing to a shift in the relative importance of disease risk factors. Likewise, it is important to note that participants in the rectal cancer study reported significantly more physical activity than those in the colon cancer study after adjusting for age. This significant difference was mainly from greater activity levels reported by women.

As in any study, possibilities for recall bias and selection bias exist. However, the response rates were comparable to those obtained for the colon cancer study, and there is no reason to believe that recall bias would be different for this study than for our colon cancer study, where results were very similar to other published data on the association between physical activity and colon cancer.

Many biologic mechanisms have been proposed whereby physical activity reduces the risk of colon cancer, including maintaining energy balance, enhancing the immune system, enhancing movement of the colon contents through the gut, regulating insulin levels, and altering prostaglandin levels (16–20). It is unclear which mechanisms are important for rectal cancer and if the same mechanisms are operational for colon cancer. There are, however, differences in the disease patterns for rectal versus colon cancer. One of the observed differences in this study is age at diagnosis, with rectal cancer cases being younger than colon cancer cases. It is unknown if genetic or environmental factors contribute to these differences. If different mechanisms are at work for colon and rectal cancer, a physical activity questionnaire that is sensitive to the biologic mechanisms for colon cancer may not be adequate to detect important biologic mechanisms for rectal cancer. The questionnaire used in this study was very extensive and may be sensitive to multiple biologic mechanisms.

In summary, the data on physical activity show that activity performed at a vigorous level of intensity reduced the risk of rectal cancer. This reduced risk was observed for both men and women in a dose-response manner. Although replication of these results in other studies is needed, these data suggest that being physically active may help to reduce the risk of both rectal cancer and colon cancer.

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