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Maintaining Physical Activity Is Associated with Reduced Major Adverse Cardiovascular Events in People Newly Diagnosed with Diabetes

Duhoe Kim[1], Jaehun Seo[1], Kyoung Hwa Ha[2,*], Dae Jung Kim[2,*]

[1]Ajou University Hospital, Suwon; [2]Department of Endocrinology and Metabolism, Ajou University School of Medicine, Suwon, Korea

Background: We investigated the association between changes in physical activity and the risk of a major adverse cardiovascular event (MACE) in people with newly diagnosed diabetes.
Methods: Using a nationwide database, we identified 8,596 people with newly diagnosed diabetes who underwent national health examinations within a year before and after a diabetes diagnosis. Cox proportional hazards models, hazard ratios (HRs) and 95% confidence intervals (CIs) for MACE risks were calculated according to changes in physical activity before and after a diagnosis of diabetes.
Results: During a median follow-up of 2.3 years, study participants who engaged in sustained physical activity after a diagnosis of diabetes had a 34% lower MACE risk compared to those with sustained inactivity (HR, 0.66; 95% CI, 0.44–0.98). An advantage was observed in those with a history of cardiovascular disease, although this was of borderline statistical significance (HR, 0.63; 95% CI, 0.40–1.01; P=0.054). In people considered obese, physical activity was significantly associated with a decreased risk of a MACE, regardless of the period preceding and following the diabetes diagnosis. Those who became inactive to active had the lowest risk of a MACE (HR, 0.38; 95% CI, 0.18–0.79).
Conclusion: Maintaining active physical activity before and after a diagnosis of diabetes is essential to preventing cardiovascular disease. Early intervention strategies are necessary to promote physical activity and exercise routines after a diagnosis of diabetes in people with obesity and those with pre-existing cardiovascular disease.

Key words: Cardiovascular disease, Diabetes mellitus, Exercise

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*Corresponding author
Kyoung Hwa Ha

https://orcid.org/0000-0002-3408-7568

Department of Endocrinology and Metabolism, Ajou University School of Medicine, 164 World cup-ro, Yeongtong-gu, Suwon 16499, Korea
Tel: +82-31-219-7462
Fax: +82-31-219-7464
E-mail: khha@ajou.ac.kr

*Co-Corresponding author
Dae Jung Kim

https://orcid.org/0000-0003-1025-2044

Department of Endocrinology and Metabolism, Ajou University School of Medicine, 164 World cup-ro, Yeongtong-gu, Suwon 16499, Korea
Tel: +82-31-219-5128
Fax: +82-31-219-4497
E-mail: djkim@ajou.ac.kr

The first two authors contributed equally to this study.

INTRODUCTION

In Korea, the prevalence of diabetes in adults 30 years of age and older was 13.8% in 2018.[1] Diabetes is a significant risk factor for cardiovascular disease (CVD), which is a leading cause of death in people with diabetes. Physical activity is an important modifiable factor that prevents CVD.[2] Exercise improves endothelial function, reduces cardiovascular risk factors such as glycemia and lipid levels, and reduces the incidence of CVD.[3-6] The World Health Organization recommends 150 minutes of moderate or 75 minutes of vigorous exercise per week.[7] The Committee of Clinical Practice Guidelines of the Korean Diabetes Association also recommends moderate or vigorous physical activity for at least 150 minutes per week.[8]

In those with diabetes, the effect of physical activity on CVD is unclear. In the Action for Health in Diabetes (Look AHEAD) trial, intensive lifestyle intervention focusing on weight loss through decreased caloric intake and increased physical activity did not reduce the rate of cardiovascular events in overweight or obese adults with type 2 diabetes.[9] However, the Anglo-Danish-Dutch Study of Intensive Treatment in People with Screen-detected Diabetes in Primary Care (ADDITION)–Cambridge study found that, after a diagnosis of diabetes, changes in two or more healthy behaviors, including increasing physical activity and intake of vitamin C and fiber, and decreasing intake of alcohol, energy and fat, had a significant CVD prevention effect.[10]

This study used the Korean National Health Insurance Service (NHIS) claims database to examine the association of a change in physical activity with major adverse cardiovascular event (MACE) during the period preceding and following a diagnosis of diabetes.

METHODS

Data source

The NHIS is a mandatory single-payer national health care insurance system in Korea. It provides general health examinations to insured employees of all ages and self-employed individuals or dependents ≥40 years of age every 1–2 years and is controlled by legislation and regulations. The NHIS-National Sample Cohort (NSC), which enrolled 2.2% of eligible Koreans using a systematic sampling method, is a population-based cohort established by the NHIS. The NHIS-NSC contains information on sociodemographic characteristics, reimbursement claims (including the International Classification of Disease, 10th revision [ICD-10], and Anatomical Therapeutic Chemical [ATC] codes), general health check-up results, and deaths. Details of the NHIS-NSC can be found elsewhere.[11] The Institutional Review Board of Ajou University Hospital approved the study protocol (IRB No. AJIRB-MED-EXP-17-253). The requirement for informed consent was waived as this database was de-identified.

Study population

We identified adults ≥20 years of age newly diagnosed with diabetes between 2009 and 2015. Newly diagnosed diabetes was defined with the ICD-10 codes E10–E14 and a simultaneous prescription for glucose-lowering medications (ATC code A10) without a history of diabetes from January 1, 2002, to the date of the new diabetes diagnosis. Among 70,674 participants newly diagnosed with diabetes, we identified 10,048 who underwent national health examinations within a year before and after a diagnosis. After excluding participants with a history of cancer or missing values, we included 8,596 participants in the final analysis (Supplementary Fig. 1). The index date was defined as the date of the examination after a diagnosis of diabetes.

Physical activity and MACE

Physical activity was measured by a self-administered questionnaire using the last seven-day recall method. Each participant reported the weekly frequency of physical activity in three categories: vigorous activities (≥20 min/day; exercise that causes intense breathing, such as running, aerobics, bicycling quickly, and mountain hiking), moderate activities (≥30 min/day; exercise that causes mild breathing, such as brisk walking, tennis, and bicycling at usual speeds), and walking (≥30 min/day; usual-pace walking for at least 10 min at a time). Each type of activity was assigned a metabolic equivalent task (MET) score based on the energy expenditure (vigorous physical activity received a score of 8.0; moderate physical activity, 4.0; and walking, 3.3).[12] The energy expended for each activity, calculated as duration × frequency per week × relevant MET score, was summed across all activities to estimate the total energy expenditure per week. Physical activity was classified as inactive (no leisure-time physical activity beyond basic movements) or active (≥1 MET-minute per week). The change in physical activity was classified as sustained inactive, active to inactive (i.e., moved from active to inactive), inactive to active (i.e., moved from inactive to active), and sustained active. We also evaluated changes in physical activity according to the type of physical activity, using the International Physical Activity Questionnaire, regardless of the amount of physical activity.[12]

We defined MACE as a composite of hospitalization for myocardial infarction (ICD-10 codes I21–I22), stroke (ICD-10 codes I60–I64), and cardiovascular death (ICD-10 codes I00–I99). The follow-up time was defined as the period from the date of the health examination after a diagnosis of diabetes to the date of the first occurrence of the outcome, date of death from any cause, or end of the study period (December 31, 2015).

Covariates

Details of the health examinations are described elsewhere.[13] Body mass index (BMI) was calculated by dividing the weight (kg) of the patient by the square of the height (m^2) and obesity was defined as a BMI ≥ 25.0 kg/m^2 according to the Korean Society for the Study of Obesity.[14] Blood pressure was measured by trained medical staff using auscultatory or oscillometric methods. Fasting glucose and lipid levels were measured in blood samples. Data on alcohol consumption and smoking status were obtained using self-administered questionnaires. Household income was categorized as the lowest 30%, middle 40%, and highest 30% using insurance premium. The prescribed drugs were classified using the ATC

Table 1. Baseline characteristics within a year after a diagnosis of diabetes according to changes in physical activity

Variable	Sustained inactive (n=803)	Active-to-inactive (n=1,090)	Inactive-to-active (n=1,273)	Sustained active (n=5,430)	*P*
Age at diagnosis of diabetes (yr)	58.9±11.7	57.9±11.5	56.9±10.9	55.2±11.0	<0.001
Age (yr)	60.3±11.8	59.3±11.5	58.2±11.0	56.6±11.0	<0.001
Men	376 (46.8)	509 (46.7)	644 (50.6)	3,290 (60.6)	<0.001
Household income					<0.001
Lower 30%	214 (26.7)	282 (25.9)	307 (24.1)	1,170 (21.6)	
Mid 40%	307 (38.2)	385 (35.3)	488 (38.3)	1,887 (34.7)	
Upper 30%	282 (35.1)	423 (38.8)	478 (37.6)	2,373 (43.7)	
Body mass index (kg/m²)	25.0±3.7	25.0±3.4	25.1±3.4	24.9±3.4	0.111
Waist circumference (cm)	84.4±9.0	84.0±9.1	84.5±8.9	84.2±8.9	0.404
Systolic blood pressure (mmHg)	127.8±16.4	127.1±15.1	125.5±14.8	125.6±14.0	0.001
Diastolic blood pressure (mmHg)	78.0±10.0	78.2±9.8	77.3±9.5	77.8±9.4	0.684
Fasting glucose (mg/dL)	106.0 (94.0–125.0)	106.0 (94.0–123.0)	107.0 (95.0–124.0)	107.0 (94.0–125.0)	0.781
Triglyceride (mg/dL)	130.0 (91.0–192.0)	128.0 (91.0–185.0)	130.0 (90.0–189.0)	125.0 (87.0–182.0)	0.129
Total cholesterol (md/dL)	191.7±42.3	194.3±41.2	194.1±39.8	191.5±44.5	0.172
HDL cholesterol (mg/dL)	51.8±13.0	52.0±12.8	53.0±22.2	52.7±15.8	0.410
LDL cholesterol (mg/dL)	10.9.5±37.6	112.2±37.4	111.0±35.3	109.7±42.6	0.505
Smoking status					<0.001
Never	541 (67.4)	766 (70.3)	780 (61.3)	2,973 (54.8)	
Former	108 (13.5)	152 (13.9)	244 (19.2)	1,384 (25.5)	
Current	154 (19.2)	172 (15.8)	249 (19.6)	1,073 (19.8)	
High alcohol consumption	117 (14.6)	127 (11.7)	189 (14.8)	783 (14.4)	0.086
Use of insulin	15 (1.9)	15 (1.4)	23 (1.8)	90 (1.7)	0.822
Use of antihypertensive drugs	492 (61.3)	616 (56.5)	700 (55.0)	2,883 (53.1)	<0.001
Use of statin drugs	286 (35.6)	426 (39.1)	484 (38.0)	2,072 (38.2)	0.469
Use of anti-platelet drugs	130 (16.2)	153 (14.0)	198 (15.6)	716 (13.2)	0.033
History of CVD	397 (49.4)	534 (49.0)	565 (44.4)	2,334 (43.0)	<0.001
Index year					<0.001
2010	10 (1.3)	10 (0.9)	18 (1.4)	51 (0.9)	
2011	132 (16.4)	201 (18.4)	234 (18.4)	873 (16.1)	
2012	194 (24.2)	218 (20.0)	273 (21.4)	1,120 (20.6)	
2013	181 (22.5)	238 (21.8)	270 (21.2)	1,048 (19.3)	
2014	147 (18.3)	235 (21.6)	239 (18.8)	1,212 (22.3)	
2015	139 (17.3)	188 (17.3)	239 (18.8)	1,126 (20.7)	

Values are presented as mean±standard deviation, number (%), or median (interquartile range).
HDL, high-density lipoprotein; LDL, low-density lipoprotein; CVD, cardiovascular disease.

codes for anti-hypertensive drugs (C02–C03 or C07–C09), statins (C10AA), and anti-platelet drugs (B01) within a year of the health examination. A history of CVD hospital visits (outpatient or inpatient visits) was defined as an individual diagnosed with codes I20–I25, I50, or I60–I64 (ICD-10) within 2 years of the health examination.

Statistical analysis

Normally distributed data are presented as the mean ± standard deviation, whereas non-parametric data are presented as the median and interquartile range based on the change in physical activity. Categorical data were expressed as numbers and frequencies (%). Baseline characteristics were compared using one-way analysis of variance for continuous variables and chi-square tests for categorical variables. We calculated the rates of MACEs per 100 person-years of follow-up based on changes in physical activity. Cox proportional hazards models were used to evaluate the associations of changes in physical activity with MACE, as well as to calculate hazard ratios (HRs) and 95% confidence intervals (CIs), and to adjust for the potential confounders of sex, age, household income, waist circumference, systolic blood pressure, fasting glucose, triglyceride, high-density lipoprotein (HDL) and low-density lipoprotein (LDL) cholesterol, drinking status, smoking status, use of drugs (antihypertensive, statin, and anti-platelet drugs), history of CVD, and index year in national health examinations within a year after a diagnosis of diabetes. When analyzing according to the type of physical activity, we also adjusted for changes in the amount of other physical activities. All statistical analyses were performed using SAS Enterprise Guide 7.1 (SAS Institute, Cary, NC, USA).

RESULTS

Table 1 supplies the proportions of participants with a change in physical activity and baseline characteristics within a year after the diagnosis of diabetes. Of the 8,596 participants, the proportions of those with sustained inactive, active-to-inactive, inactive-to-active,

	No. of people	Person-years	No. of events	Event rate (per 100 PY)	Adjusted HR (95% CI)
Total physical activity					
Sustained inactive	803	1,951	35	1.79	1.00
Active-to-inactive	1,090	2,630	35	1.33	0.83 (0.52–1.34)
Inactive-to-active	1,273	3,102	31	1.00	0.72 (0.44–1.17)
Sustained active	5,430	12,446	103	0.83	0.66 (0.44–0.98)
Vigorous physical activity					
Sustained inactive	3,600	8,507	109	1.28	1.00
Active-to-inactive	1,423	3,268	39	1.19	1.11 (0.75–1.63)
Inactive-to-active	1,541	3,696	27	0.73	0.75 (0.48–1.17)
Sustained active	2,032	4,658	29	0.62	0.73 (0.47–1.12)
Moderate physical activity					
Sustained inactive	3,065	7,276	98	1.35	1.00
Active-to-inactive	1,517	3,555	39	1.10	0.93 (0.63–1.38)
Inactive-to-active	1,723	4,171	33	0.79	0.74 (0.49–1.12)
Sustained active	2,291	5,127	34	0.66	0.75 (0.50–1.13)
Walking activity					
Sustained inactive	1,049	2,552	37	1.45	1.00
Active-to-inactive	1,371	3,325	41	1.23	0.98 (0.62–1.54)
Inactive-to-active	1,592	3,861	43	1.11	0.96 (0.61–1.50)
Sustained active	4,584	10,391	83	0.80	0.76 (0.51–1.13)

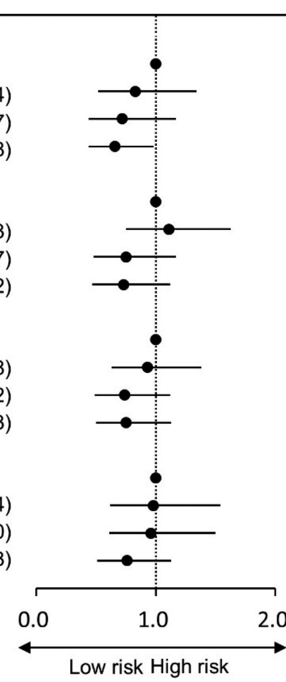

Figure 1. Associations between the change in physical activity and major cardiovascular events before and after a diagnosis of diabetes. Adjustments were made for sex, age, waist circumference, systolic blood pressure, fasting glucose, triglyceride, high-density lipoprotein cholesterol, low-density lipoprotein cholesterol, drinking status, smoking status, household income, use of antihypertensive drugs, use of statins and anti-platelet drugs, history of cardiovascular disease, and index year. Additional adjustments were made for the change in the amount of other physical exercises, when analyzing according to the type of physical activity. PY, person-years; HR, hazard ratio; CI, confidence interval.

	Person-years	No. of events	Event rate (per 100 PY)	Adjusted HR (95% CI)	*P* for interaction
Age groups					
20–64 years					0.908
Sustained inactive	1,240	11	0.89	1.00	
Active-to-inactive	1,729	13	0.75	0.92 (0.41–2.06)	
Inactive-to-active	2,218	13	0.59	0.72 (0.32–1.62)	
Sustained active	9,365	47	0.50	0.68 (0.35–1.33)	
≥ 65 years					
Sustained inactive	711	24	3.38	1.00	
Active-to-inactive	901	22	2.44	0.80 (0.45–1.44)	
Inactive-to-active	884	18	2.04	0.71 (0.38–1.33)	
Sustained active	3,081	56	1.82	0.65 (0.40–1.08)	
Sex					
Men					0.677
Sustained inactive	916	16	1.75	1.00	
Active-to-inactive	1,189	17	1.43	0.84 (0.42–1.68)	
Inactive-to-active	1,560	22	1.41	0.95 (0.50–1.83)	
Sustained active	7,550	66	0.87	0.70 (0.40–1.23)	
Women					
Sustained inactive	1,035	19	1.83	1.00	
Active-to-inactive	1,441	18	1.25	0.82 (0.43–1.57)	
Inactive-to-active	1,542	9	0.58	0.43 (0.19–0.97)	
Sustained active	4,896	37	0.76	0.62 (0.35–1.10)	
Current smoking					
Yes					0.447
Sustained inactive	382	6	1.57	1.00	
Active-to-inactive	406	5	1.23	0.82 (0.24–2.80)	
Inactive-to-active	616	8	1.30	1.09 (0.36–3.25)	
Sustained active	2,454	22	0.90	0.92 (0.36–2.36)	
No					
Sustained inactive	1,569	29	1.85	1.00	
Active-to-inactive	2,224	30	1.35	0.82 (0.49–1.37)	
Inactive-to-active	2,486	23	0.93	0.62 (0.36–1.08)	
Sustained active	9,992	81	0.81	0.59 (0.38–0.92)	
Obesity					
Yes					0.848
Sustained inactive	933	19	2.04	1.00	
Active-to-inactive	1,267	13	1.03	0.47 (0.23–0.96)	
Inactive-to-active	1,530	12	0.78	0.38 (0.18–0.79)	
Sustained active	5,683	48	0.84	0.46 (0.27–0.81)	
No					
Sustained inactive	1,018	16	1.57	1.00	
Active-to-inactive	1,363	22	1.61	1.26 (0.66–2.41)	
Inactive-to-active	1,572	19	1.21	1.24 (0.63–2.44)	
Sustained active	6,763	55	0.81	0.89 (0.50–1.59)	
History of CVD					
Yes					0.804
Sustained inactive	970	26	2.68	1.00	
Active-to-inactive	1,263	28	2.22	0.90 (0.53–1.54)	
Inactive-to-active	1,340	22	1.64	0.71 (0.40–1.26)	
Sustained active	5,303	69	1.30	0.63 (0.40–1.01)	
No					
Sustained inactive	981	9	0.92	1.00	
Active-to-inactive	1,367	7	0.51	0.67 (0.25–1.83)	
Inactive-to-active	1,762	9	0.51	0.64 (0.25–1.64)	
Sustained active	7,143	34	0.48	0.68 (0.32–1.46)	

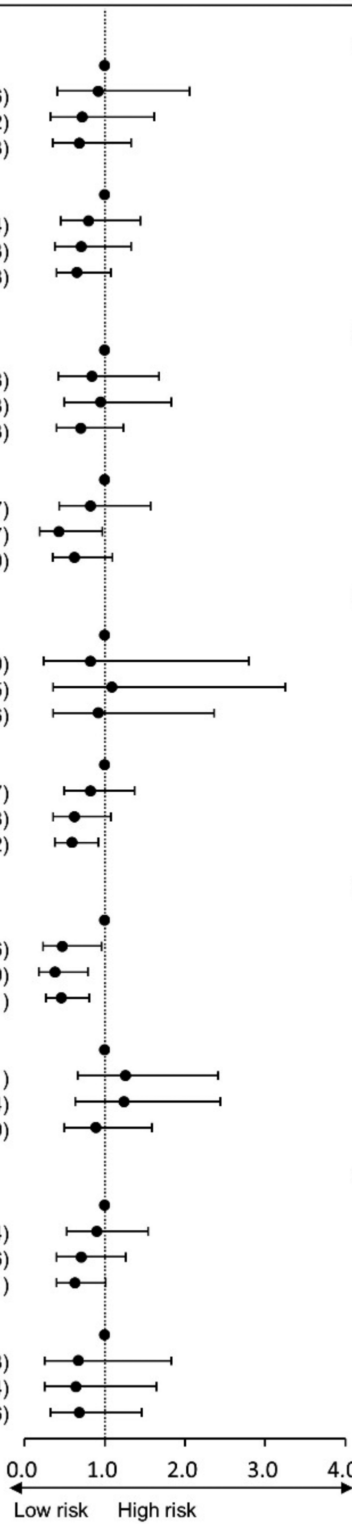

Figure 2. Stratified analysis of the association between a change in physical activity and major cardiovascular events before and after the diabetes diagnosis. Adjustments were made for sex, age, waist circumference, systolic blood pressure, fasting glucose, triglyceride, high-density lipoprotein cholesterol, low-density lipoprotein cholesterol, drinking status, smoking status, household income, use of antihypertensive drugs, use of statins, use of anti-platelet drugs, history of CVD, and index year. PY, person-years; HR, hazard ratio; CI, confidence interval; CVD, cardiovascular disease.

and sustained active physical activity before and after a diabetes diagnosis were 9.3%, 12.7%, 14.8%, and 63.2%, respectively. Age and the proportion of those with low incomes were higher in the sustained inactive group. Waist circumference, BMI, and fasting glucose and lipid levels were similar across the groups, while the use of drugs and a history of CVD were more common in the sustained inactive group.

During a median (25th–75th percentiles) follow-up of 2.3 years (1.1–3.5), compared with those with sustained inactivity, the HRs for MACE were 0.49 (95% CI, 0.31–0.77) for those who changed from an inactive state to an active physical activity and 0.47 (95% CI, 0.33–0.66) for those who sustained an active physical activity following a diagnosis of diabetes (Supplementary Table 1). However, after adjusting for potential confounders, the lower risk of a MACE was significant only for those who sustained active physical activity (HR, 0.66; 95% CI, 0.44–0.98) (Fig. 1, Supplementary Table 1). When classified by the type of physical activity, we observed that a decrease in the risk of a MACE was associated with all sustained active physical activities, although the association was not significant (Fig. 1, Supplementary Table 1). The estimates were similar when evaluating each component of MACE–sustained active physical activity that reduced the risk of cardiovascular death (HR, 0.18; 95% CI, 0.06–0.57) (Supplementary Fig. 2).

Fig. 2 depicts the associations between a change in physical activity and the risk of a MACE stratified by age, sex, smoking status, and comorbidities (obesity and CVD). The overall pattern was similar for most subgroups. In obese individuals, active physical activity was significantly associated with a reduction in the risk of a MACE. In particular, those who changed from inactive to active physical activity had the lowest risk of a MACE (HR, 0.38; 95% CI, 0.18–0.79). When stratified by the history of CVD, the MACE incidence rates for those with or without a history of CVD were 1.63 per 100 person-years and 0.52 per 100 person-years, respectively. Sustained physical activity was associated with a lower risk of a MACE in those with a history of CVD, although this was of borderline statistical significance (HR, 0.63; 95% CI, 0.40–1.01; $P=0.054$). The estimated HRs of sustained physical activity in those with no history of CVD were similar to those in patients with a history of CVD, but they were not statistically significant (HR, 0.68; 95% CI, 0.32–1.46).

DISCUSSION

In this nationwide retrospective cohort study, we found an association between sustained active physical activity and a decreased risk of MACE in people with newly diagnosed diabetes. In particular, continuing physical activity regardless of the type or amount of exercise may prevent CVD occurrence. The Korean Diabetes Association recommends that people with diabetes regularly engage in moderate or vigorous physical activity.[8] Previous studies have shown that frequent physical activity reduces the incidence of CVD and mortality in people with diabetes. In Finnish patients with type 2 diabetes during a mean follow-up of 18.7 years, moderate or high levels of physical activity were significantly associated with decreased cardiovascular death.[15] In the Health Professionals' Follow-up Study of 2,803 men with diabetes, those who were physically active had a lower risk of CVD, although the association was not significant.[16] In the Whitehall II study, any duration of moderate-to-vigorous physical activity in people with type 2 diabetes lowered the risk of all-cause death. However, the risk of cardiovascular death was lower in patients who participated only in moderate-to-vigorous physical activity that met the recommendations.[4] Further analysis involved defining active physical activity according to the recommendations of the guidelines. When active physical activity was defined as moderate-to-vigorous physical activity, the results were similar to those of the main analysis, but they were not statistically significant because the number of sustained active physical activities decreased (Supplementary Table 2). Generally, people with diabetes have a much lower level of physical activity than the recommended level, indicating that it is difficult to adhere to the recommendations. The guidelines of the American Diabetes Association recommend decreasing the amount of time spent in sedentary behavior by engaging in light physical activity such as walking, as well as moderate or vigorous physical activity.[17] This is because interrupting prolonged sitting by briefly standing, walking, or performing other light physical activities improves glycemic control in people with diabetes.[18] According to the Italian Diabetes and Exercise Study 2, a randomized clinical trial, light-intensity physical activity was sustained through behavioral intervention in people with type 2 diabetes during the three-year follow-up period. During the same period, moderate- to vigorous-intensity physical activity increased at the beginning of the intervention, but this was not sustained.[19] The Korean Society for the Study of Obesity suggests that people who do not engage in regular physical activity start with low- and moderate-intensity physical activity, while people with regular physical activity start with moderate-intensity physical activity and gradually increase the intensity of activity.[20] These findings suggest it may be necessary to recommend simple physical activity regardless of the intensity or amount so that people with diabetes can continue to engage in physical activity.

In this study, in obese individuals, not only who sustained active physical activity but also those who changed from inactive to active physical activity within the first year of being diagnosed with diabetes had a reduced risk of CVD. The ADDITION–Cambridge study and Nurses' Health Study showed that changes in healthy behavior before and after a diagnosis of diabetes led to a lower risk of CVD.[10,21] In the ADDITION–Cambridge study, a loss of ≥5% of body weight within the first year of diabetes reduced the risk of CVD at 10 years compared with maintaining weight.[22] In the current study, although there was no difference in BMI before and after the diagnosis of diabetes, weight loss through physical activity helped prevent CVD in obese individuals (Supplementary Table 3). We also found that those who changed from active-to-inactive physical activity within the first year of being diagnosed with diabetes had estimated HRs that were similar to those of patients who sustained active physical activity (active-to-inactive: HR, 0.47; 95% CI, 0.23–0.96 vs. sustained active: HR, 0.46; 95% CI, 0.27–0.81). The effects of discontinuing physical activity on CVDs are not known. High levels of cardiorespiratory fitness in overweight and obese populations are more important in reducing morbidity and mortality than weight loss.[23] Furthermore, in the meta-analysis, obese individuals with a healthy level of cardiorespiratory fitness had similar mortality risks compared to normal-weight individuals. In contrast, obese individuals who had an unhealthy level of cardiorespiratory fitness had a higher mortality risk (the "fat but fit" phenomenon).[24] Given the short follow-up period of the current study, a higher level of fitness of obese individuals before diabetes diagnosis may affect CVD prevention continuously and this tends to negate the adverse CV effects of obesity.

Physical activity plays an important role in both the primary and secondary prevention of CVD.[25] Although the effects of physical activity in patients with CVD have been studied much less than those in primary prevention, physical activity reportedly reduces the impact of disease, slows its progression, and prevents recurrence in patients with CVD.[26-31] In particular, sustained physical activity in patients with coronary heart disease regardless of the intensity of physical activity reduced all-cause mortality.[29] In the current study, the association between changes in physical activity and CVD occurrence exhibited similar patterns in primary and secondary cardiovascular prevention. However, we found a borderline significant decline in CVD occurrence only in patients with CVD due to the short follow-up period. A long-term follow-up study that considers a history of CVD is needed.

This study had some limitations. First, the use self-reported data on physical activity may have led to recall bias. Second, although there are various types of physical activity, such as occupational activity, we included only leisure-related physical activity. Third, we did not consider healthy lifestyle behaviors, such as adopting a high-quality diet. Fourth, our definition of people with diabetes included only those diagnosed with diabetes who were simultaneously prescribed glucose-lowering drugs. Further analysis of those diagnosed with diabetes regardless of the prescription of glucose-lowering drugs produced results similar to those of the main analysis, but they did not reach statistical significance after adjusting for confounding variables (Supplementary Table 4). When defining diabetes using only a diagnosis of diabetes in the claims database, individuals with prediabetes may be included. The effect of physical activity on the risk of a MACE may therefore be reduced because prediabetes, which poses a lower risk of CVD than diabetes, was included in further analysis. Fifth, although we included individuals with newly diagnosed diabetes and adjusted fasting glucose levels, we lacked information on glycemic control and diabetes severity. Finally, we could not establish a causal relationship between the change in physical activity and the risk of CVD, possibly because of residual confounding factors.

In conclusion, sustaining physical activity before and after the diagnosis of diabetes is essential for preventing CVD. Physical activity is important for both glycemic management and the prevention of CVD in people with diabetes. We recommend that even light physical activity should be performed continuously in people with newly diagnosed diabetes. It is particularly necessary to establish strategies for early intervention to promote physical activity and exercise after the diagnosis of diabetes in obese individuals. More attention should also be paid to strategies to sustain physical activity for the secondary prevention of CVD.

CONFLICTS OF INTEREST

Dae Jung Kim has been the editorial board member of the *Journal of Obesity & Metabolic Syndrome*. However, he was not involved in the selection of peer reviewers, evaluation, or the decision process for this article. No other potential conflicts of interest relevant to this article are reported.

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AUTHOR CONTRIBUTIONS

Study concept and design: KHH and DJK; acquisition of data: KHH and DJK; analysis and interpretation of data: all authors; drafting of the manuscript: DK, JS, and KHH; critical revision of the manuscript: KHH and DJK; statistical analysis: KHH; obtained funding: DJK; administrative, technical, or material support: DJK; and study supervision: KHH and DJK.

SUPPLEMENTARY MATERIALS

Supplementary materials can be found online at https://doi.org/10.7570/jomes22007.

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