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Associations Between Diagnosis with Type 2 Diabetes and Changes in Physical Activity among Middle-Aged and Older Adults in the United States

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Abstract

Background and Objectives: Physical activity (PA) is an effective strategy for diabetes self-management and is central to the diabetes regimen. Diagnostic events present an opportunity for health behavior change; however, many older adults with type 2 diabetes (T2D) do not engage in regular PA. The relationships between diagnosis events and subsequent changes in PA are not well understood. Drawing upon life-course theory, this is the first study to examine whether the diagnosis of T2D is followed by a change in PA, whether these changes are sustained, and the sociodemographic characteristics associated with these changes.

Research Design and Methods: We examined associations between T2D diagnosis and PA changes among 2,394 adults ages 51+ from the Health and Retirement Study (2004–2014). PA changes were measured using metabolic equivalents of task (METs) estimated values accounting for the vigor and frequency of self-reported PA. Using piecewise mixed models, we examined initial and sustained changes in METs over time and tested whether these changes were modified by race/ethnicity, educational level, gender, and age at diagnosis.

Results: Across participants, a significant postdiagnosis increase was observed in self-reported PA following the diagnostic event (β: 0.54, 95% CI: 0.10, 0.97). The steepness of decline in PA participation over time did not change significantly following T2D diagnosis. Age at diagnosis and race/ethnicity significantly moderated these relationships: participants diagnosed at older ages were less likely to improve PA following diagnosis and non-Hispanic whites experienced relatively steeper rates of decline following diagnosis with T2D.

Discussion and Implications: Modest diagnosis-related increases in PA were observed among participants overall. The usual rate of decline in PA appears unaffected by diagnosis overall. Age at diagnosis and race/ethnicity moderated these relationships. Key implications for future research and clinical practice are discussed.

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Translational Significance: There is little understanding regarding whether physical activity levels change following diagnosis with type 2 diabetes and whether these changes are sustained over time. Prior to this study, we lacked understanding regarding how these patterns differ according to subgroup of the U.S. population. The findings from this study can inform clinical interventions and community-based strategies to promote participation in physical activity over time. These findings can also inform future research and policy strategies to enhance and sustain these changes, with particular attention to relatively older populations.

Keywords: Age at diagnosis, Chronic disease self-management, Event-oriented model, Life-course perspective, Piecewise regression, Race/ethnicity

Type 2 diabetes (T2D) is a public health priority in the United States and internationally. The World Health Organization estimated that T2D was the seventh leading cause of death worldwide in 2014 and that approximately 8.5% of adults aged 18 years and older (around 422 million) had diabetes (World Health Organization, 2016). In the United States, the prevalence of T2D in 2015 was 12.2% among adults aged 18 years and older (Centers for Disease Control and Prevention, 2017). The prevalence is expected to more than double nationally over the next 25 years (Balk et al., 2015). This increase in diabetes prevalence is becoming a greater public health concern as the medical expenditures and health resources associated with diabetes care continue to rise (Zhang et al., 2010).

Physical activity (PA) is an effective strategy for diabetes management because it improves glucose tolerance and lowers the risk of developing complications, cardiovascular disease, and overall mortality risks among individuals with T2D (Colberg et al., 2016). Despite these noted benefits, regular PA remains both an individual and public health challenge for older adults with T2D. The majority of older adults do not meet recommended PA guidelines (Nelson, Reiber Boyko, & NHANES III, 2002) and there is some evidence that PA levels typically decline—rather than increase—following diagnosis with T2D (Hackett, Moore, Steptoe, & Lassale, 2018).

The concept of a chronic disease diagnosis as a turning or trigger point has been characterized as a potential "teachable moment" in the literature (e.g., Xiang, 2016). Evidence for the "teachable moments" concept is provided by studies of health behavior changes following diagnosis with cancer and other chronic diseases (Demark-Wahnefried, Aziz, Rowland, & Pinto, 2005; Demark-Wahnefried, Peterson, McBride, Lipkus, & Clipp, 2000; Sabatino et al., 2007; Xiang, 2016). Prior studies on longitudinal, population-based samples have found evidence of some positive health behavior changes following T2D diagnosis, such as reduced smoking and alcohol consumption and increases in fruit and vegetable consumption (Hackett et al., 2018). Another study using longitudinal, population-based data on middle-aged and older adults newly diagnosed with chronic illness (e.g., stroke, cancer, lung disease, heart disease, or T2D) also found benefits of diagnosis including decreased substance use, smoking cessation, and increased utilization of primary and secondary preventive services (Keenan, 2009). However, it is not clear these findings can be extrapolated to the examination of PA change following diagnosis with T2D specifically.

Observational studies of middle-aged and older adults with T2D in the United States (Newsom et al., 2012a; Xiang, 2016), Australia (Chong et al., 2017; Dontje et al., 2016), and England (Hackett et al., 2018) found that PA participation was unchanged or declined following diagnosis of T2D. Such findings suggest that T2D diagnosis does not serve as a "turning point" for improved PA over time (Chong et al., 2017; Dontje et al., 2016; Hackett et al., 2018; Newsom et al., 2012a; Xiang, 2016). In contrast, population-based studies of older Canadians (Newsom et al., 2012b) and postmenopausal U.S. women (Schneider et al., 2014) have found that PA participation improved among participants following diagnosis with T2D. Given these mixed findings, it is unclear whether or not PA improves, declines, or is unaffected by the event of diagnosis with T2D among middle-aged and older adults in the United States.

The extent to which diagnosis with T2D serves as a turning point or alters the trajectory of PA could also vary by subgroup of the U.S. population. In studies of oncology patients, diagnosis-related experiences were found to have differential impacts on PA participation based on the severity of symptoms and other related barriers following diagnosis (Blanchard et al., 2003; Lynch, Cerin, Newman, & Owen, 2007). This is consistent with qualitative research studies of middle-aged and older women with T2D, which found that individual and community resources were important predictors of recommended changes in diet and PA following diagnosis (Nicklett & Damiano, 2014). Individuals with fewer financial resources available to make recommended changes—as well as individuals living in communities with fewer opportunities to engage in PA—likely confront greater barriers to making recommended changes compared to those with greater financial resources and those living in more affluent communities (Hernandez, Margolis, & Hummer, 2018; Satariano & McAuley, 2003).

Race/ethnicity and educational level are associated with the resources and constraints available to make changes in PA following diagnosis with T2D (Hernandez et al., 2018; Zhao, Ford, Li, & Balluz, 2011); therefore, differential

access to individual and community resources to promote PA could provide an explanation for relatively lower levels of PA participation among racial/ethnic minorities and individual with lower levels of education (Hackett et al., 2018; Hernandez et al., 2018; Zhao et al., 2011). Furthermore, individuals diagnosed at older ages confront relatively greater physical challenges and barriers to PA compared to their younger counterparts, such as functional limitations, muscle weakness, mobility limitations, arthritis, fear of falling, and risk of injury (e.g., Chentli, Azzoug, & Mahgoun, 2015). In summary, there is reason to believe that changes in PA following diagnosis with T2D could differ according subgroup of the U.S. population.

Physical activity promotion and intervention programs have aimed to address the relatively low uptake of PA among the older adult population in the United States, and among older adults with T2D in particular (Hackett et al., 2018). Interventions promoting PA have been found to initially benefit diabetes management and diabetes outcomes, with intervention-related benefits then leveling off over time (Cradock et al., 2017). The extent to which these findings can be extrapolated to characterize nonintervention populations is still unclear, given the mixed findings of observational studies with population-based samples in the United States and elsewhere. Even less is known regarding how these processes vary according to population subgroup, who, as noted, might experience differential barriers and facilitators to PA change following diagnosis.

The life-course perspective is a useful framework for examining diagnosis as a potential trigger or turning point (Elder, 1999). As described by Li, Cardinal, and Settersten (2009), the life-course perspective "intertwines individuals and contexts, always with a cross-cutting emphasis on time—connecting segments of a trajectory to what came before or to what comes after, connecting the action on one trajectory to action on others …." (p. 337). Therefore, the "teachable moment" of diagnosis could benefit some subgroups of the population more than others. Such changes, assert Li and colleagues (2009), "can prompt common experiences for all members of a population, but they can also bring differential effects for subgroups of the population" (p. 339). In other words, the impact of T2D diagnosis on PA could contribute to cumulative advantage and disadvantage as an explanation for health disparities over the life-course (Dannefer, 2003).

Additional studies are needed to determine whether the event of diagnosis with T2D (a) serves as a turning point; (b) alters the trajectory of PA; and (c) how this differs among middle-aged and older adults with T2D in the United States. The present study examines the natural history of PA participation and T2D diagnosis-related changes as potential turning points and trajectories. Furthermore, this study examines whether or not diagnosis-related changes in PA—after diagnosis and over time—differ according to subgroup of the U.S. population, specifically, by age at diagnosis, race/ethnicity, educational level, and gender.

Drawing upon theory and applications in life-course and cumulative disadvantage (Dannefer, 2003; Elder, 1999; Li et al., 2009), and based on the findings of prior observational studies that investigated PA change following T2D diagnosis, we developed a series of hypotheses pertaining to the potential impact of T2D diagnosis on changes following diagnosis and over time. First, we hypothesized that the event of diagnosis would be associated with a subsequent increase in PA. Second, we hypothesized that postdiagnosis gains in PA would be more pronounced and sustained among those diagnosed earlier in life, among non-Hispanic whites (compared to other racial/ethnic groups), among women, and among those with higher levels of education. Third, we hypothesized that the anticipated aging-related declines in PA overall would be more attenuated among participants of younger age at diagnosis, among non-Hispanic whites (relative to racial/ethnic minorities), among men, and among participants with lower levels of education.

Method

Data

The data for this study came from the Health and Retirement Study (HRS), a nationally representative biennial longitudinal survey of adults over age 50 in the United States. We utilized the RAND version of the data, a cleaned and user-friendly version of much of the core data (Bugliari et al., 2016). HRS utilizes a multistage area probability design with geographic stratification and clustering. More details the HRS study design and content are available elsewhere (Sonnega et al., 2014). HRS is funded by the National Institute on Aging (NIA U01AG0097) and is housed at the University of Michigan Institute for Social Research. All respondents have provided written consent, and the study protocol has been approved by the University of Michigan Institutional Review Board.

Analytic Sample

To evaluate PA changes following diagnosis, we selected participants who reported a doctor diagnosis of T2D in any wave from 2004 through 2014 (n = 29,642). We excluded 22,107 participants who were not diagnosed with T2D by the 2014 interview or by their last observation in the study. In order to observe changes before and after diagnosis, we excluded 4,950 participants who reported T2D at entry into the study. Of the remaining 2,585 participants, 191 were excluded because they were aged 50 years or younger at baseline. The final analytic sample was 2,394 participants.

Measures

Diabetes diagnosis

HRS does not collect information on the date of diagnosis with T2D at the baseline interview. At entry into the HRS,

however, participants were asked whether or not they had ever been told by a doctor that they had diabetes or high blood sugar. In each subsequent wave, participants were asked, "Since we last talked to you, has a doctor told you that you have diabetes or high blood sugar?" Based on these responses, T2D status was assigned "0" (not yet diagnosed) and "1" (following diagnosis with T2D). T2D status was carried forward into subsequent waves. We estimated the diagnosis to be the wave in which T2D was first reported (e.g., 2006, 2008, 2010, 2012, 2014). Survey waves were centered around the wave of diagnosis, with a range of −5 to 4.

Physical activity

We developed a measure to examine the frequency and vigor of reported PA. Beginning in 2004, HRS participants were asked about the frequency of engagement in vigorous, moderate, and mildly energetic forms of PA: "We would like to know the type and amount of physical activity involved in your daily life. How often do you take part in sports or activities that are vigorous, such as running or jogging, swimming, cycling, aerobics or gym workout, tennis, or digging with a spade or shovel?" "And how often do you take part in sports or activities that are moderately energetic such as gardening, cleaning the car, walking at a moderate pace, dancing, floor or stretching exercises?" and "And how often do you take part in sports or activities that are mildly energetic, such as vacuuming, laundry or home repairs?" The response scale that followed each of the three questions in the original HRS questionnaire was: 1 = "more than once a week," 2 = "once a week," 3 = "one to three times a month," 4 = "hardly ever or never," and, if the respondent volunteered the response, "every day," which was coded as 7. In the RAND version of the data, "every day" was recoded to 1 with the rest of the scale adding one point. We reverse-coded the RAND variable so that greater values reflected more frequent levels of PA, and to reflect no regular activity, we anchored "hardly ever or never" at 0. The response scale was therefore revised as: 0 = hardly ever or never, 1 = one to three times a month, 2 = once a week, 3 = more than once/week, and 4 = every day. Following Ainsworth and colleagues (2000), we then developed a weighted scale using all three activity variables by assigning MET-equivalent activity points to estimate expended energy (ranging from 0 to 17), which is given in Table 1.

Table 1. MET-Equivalent Activity Points Based on the Frequency and Rigor of Self-reported Physical Activity

MET-Equivalent Activity Points	Rigor of Activity	Frequency of Activity
0	Mildly energetic	Hardly or never
1	Mildly energetic	1–3 times per month
2	Mildly energetic	Once a week
3	Mildly energetic	More than once a week
4	Mildly energetic	Every day
0	Moderate	Hardly or never
2.5	Moderate	1–3 times per month
5	Moderate	Once a week
7.5	Moderate	More than once a week
10	Moderate	Every day
0	Vigorous	Hardly or never
4.25	Vigorous	1–3 times per month
9	Vigorous	Once a week
13	Vigorous	More than once a week
17	Vigorous	Every day

Note: Recommended minimum of MET-equivalent activity points: 10–12. Recommended levels of physical activity are based upon American Diabetes Association (ADA) and U.S. Department of Health and Human Services (DHHS) recommendations of 90 minutes per week of vigorous physical activity or 150 minutes per week of moderate physical activity, occurring 3 or more times per week (Zhao et al., 2011).

Health-related covariates

We controlled for depressive symptoms, chronic illness comorbidities, and functional status due to the potentially confounding relationships between these factors, timing of T2D onset, and PA behaviors. Depressive symptoms were assessed using the 8-item Center for Epidemiologic Studies Depression scale (CES-D) (range 0–8) (Fisher et al., 2005). The measure of chronic illness comorbidities was constructed based on the number of chronic conditions reported by participants in addition to T2D, which could include high blood pressure, cancer, lung disease, heart disease, stroke, and arthritis (range 0–6). Functional status was assessed by Activities of Daily Living (ADLs) and Instrumental Activities of Daily Living (IADLs). The number of activities in which participants reported having at least some difficulty performing (ranging from 0 to 5) were indicated separately for ADLs (bathing, eating, dressing, walking across a room, and getting out of bed) and IADLs (using the phone, taking medications, managing money, shopping for food, and preparing meals). Data were collected from participants in each HRS wave. The time-varying feature of these health-related covariates enables changes to be examined over time.

Sociodemographic covariates and moderators

Sociodemographic covariates included age at diagnosis, race/ethnicity, educational level, and gender. The age at the wave in which T2D was first reported is the estimated age at diagnosis. Examined racial/ethnic groups included non-Hispanic black, Hispanic/Latino, non-Hispanic white, and "other" racial/ethnic group. Examined educational levels included less than high school, high school or equivalent, some college, and college or more. Gender included male and female groups. Data on sociodemographic covariates were based on self-reported responses at the baseline interview and were carried forward into subsequent interview waves.

We examined whether or not these potential turning points and trajectories differed according to age at diagnosis, race/ethnicity, educational level, and gender. Using these sociodemographic characteristics as moderators, we examined whether or not there were significant differences in (i) postdiagnosis changes in PA and (ii) sustained changes in PA following diagnosis with T2D according to subgroups.

Statistical Analysis

To examine whether changes in PA occurred following diagnosis (turning points) and whether any changes were sustained over time (trajectories), we estimated piecewise linear mixed-effects models. This approach enabled us to partition the effect of independent variables into intervals—with separate regression lines for each interval—and included random intercepts to account for observations nested within respondents. Piecewise analysis is considered an appropriate strategy for examining trajectories and transitions in PA, particularly as they relate to a critical period or specific event (Li et al., 2009; Naumova, Must, & Maird, 2001; Xue et al., 2017).

The first regression line was estimated for the survey waves leading up to the diagnosis, reflecting changes in PA before diagnosis. The second regression line was estimated for the survey waves after diagnosis (including the wave of diagnosis), representing changes in PA following diagnosis. These two regression lines were estimated in a combined model, allowing us to determine the change in the slope (reflecting change in the rate of PA decline between the prediagnosis and postdiagnosis intervals) and the change in the intercept (reflecting a change in PA shortly after diagnosis).

To strike a balance between model fit and parsimony, we estimated a series of nested models in a hierarchical regression framework by adding variables to a previous model at each step. The first model estimated the unadjusted effects of diagnosis on PA. Estimation of piecewise regression models involves the creation of several variables to estimate change in the regression intercept and slope in a single model. Specifically, we created four variables for which the regression coefficients, respectively, reflect (i) prediagnosis linear slope, (ii) change in slope postdiagnosis from prediagnosis, (iii) predicted mean PA level for someone who is infinitely close to a diagnosis (but not quite), and (iv) the jump that occurs at wave of diagnosis, representing the predicted mean PA for someone who was just diagnosed minus the predicted mean for someone who is infinitely close to being diagnosed. Model 2 added age, sociodemographic, psychological, and health covariates. Model 3 examined age at diagnosis, gender, race/ethnicity, and educational level as potential moderators of the changes in PA as a function of diagnosis. Moderators that were statistically significant were retained in the final model. To facilitate the interpretation of results, we used Stata's Margins command to calculate the predicted PA levels for each subgroup. We computed scaled weights and robust standard errors and accounted for sampling strata using methods detailed in Heeringa, West, and Berglund (2017). All analyses were conducted in Stata 15.1 SE (StataCorp, 2017, College Station, TX).

Results

Sample Characteristics

Descriptive characteristics of the analytic sample are presented in Table 2. The average age of participants was 63.42 (*SD* = 8.78) years at baseline and 68.60 (*SD* = 9.30) years at diagnosis. More than half of the sample was female (53.41%) and most identified as non-Hispanic white (60.84%), followed by non-Hispanic black (20.04%), Hispanic/Latino (10.17%), and other racial/ethnic group

Table 2. Unweighted Sociodemographic and Health Characteristics of Sample Diagnosed with Diabetes between 2004 and 2014, The Health and Retirement Study (*N* = 2,394)

Characteristics	*N* (%)	Mean (*SD*)
Mean age at baseline	63.42	(8.78)
Mean age at diagnosis	68.50	(9.30)
Age groups		
51–64	903	(37.75)
65–74	876	(36.38)
75 and older	615	(25.86)
Gender		
Male	1,114	(46.59)
Female	1,277	(53.41)
Race/ethnicity		
Non-Hispanic white	1,454	(60.84)
Non-Hispanic black	479	(20.04)
Hispanic/Latino	243	(10.17)
Other	214	(8.95)
Educational level		
Less than high school	570	(23.81)
High school of equivalent	885	(37.97)
Some college	531	(22.18)
College or more	408	(17.04)
Mean CES-D at baseline	1.60	(2.12)
Comorbidities at baseline		
0	391	(17.69)
1	644	(29.14)
2	660	(29.86)
3 or more	515	(23.30)
Mean ADLs at baseline	0.29	(0.85)
Mean IADLs at baseline	0.10	(0.42)
Mean physical activity (METs)		
Prediagnosis	11.29	(7.63)
Postdiagnosis	10.22	(7.91)

Note: ADL = Activities of Daily Living; CES-D = Center for Epidemiologic Studies Depression scale; IADL = Instrumental Activities of Daily Living; MET = Metabolic equivalents of task.

(8.95%). The sample was fairly diverse in terms of educational achievement, with the largest percentage (37.97%) having completed high school or an equivalent level of education. The majority of participants (82.31%) experienced some chronic disease comorbidity at baseline, with 23.30% reporting three or more comorbidities. PA declined from a mean level of 11.29 (*SD* = 7.63) before the diagnosis to a mean level of 10.22 (*SD* = 7.91) after the diagnosis with T2D.

Diagnosis and Physical Activity

Table 3 shows the results of the multivariate analysis. The prediabetes slope was negative and significant, suggesting that PA decreased over time before diagnosis (β: −0.29, 95% CI: −0.45, −0.13). The indicator for intercept change in PA at diagnosis showed a small but significant increase (β: 0.54, 95% CI: 0.10, 0.97), suggesting a small increase in PA levels around the time of diagnosis. The indicator for change in slope postdiagnosis was not significant (Chi^2 = 1.11, p = 0.29), suggesting that PA continued to decline slightly after diagnosis at a similar rate as before diagnosis (β: −0.12, 95% CI: −0.32, 0.09).

In addition to the effects of diagnosis, several covariates were significantly associated with PA change in the multivariate model. Women's MET scores were on average 1.41 points lower than men's score (95% CI: −1.90, −0.92), suggesting lower levels of PA participation among women. Higher levels of education were associated with greater PA, with those completing college or more having 2.36 higher MET scores than those with less than a high school education (95% CI: 1.34, 3.37). Older age at diagnosis was associated with lower PA (β: −0.10, 95% CI: −0.13, −0.07). In addition, higher levels of depressive symptoms (β: −0.43, 95% CI: −0.52, −0.33), ADLs (β: −1.10, 95% CI: −1.30, −0.06), IADLs (β: −0.42, 95% CI: −0.78, −0.06), and comorbidity (β: −0.44, 95% CI: −0.69, −0.19) were all significantly associated with lower PA.

Moderators

Table 4 shows results of the moderation analyses. Age at diagnosis and race/ethnicity were statistically significant moderators of changes in PA as a function of diagnosis and thus remained in the final model. Educational level and gender did not significantly moderate the impact of diagnosis on PA and were excluded from the final model.

The interaction term of age at diagnosis and postdiagnosis change in intercept was significant and negative (β: −0.07, 95% CI: −0.10, −0.05), suggesting that the jump in PA shortly after diagnosis was smaller for those diagnosed at older ages. Change in slope postdiagnosis did not differ by age at diagnosis, suggesting that the rate of decline in PA was similar according to age at diagnosis.

The interaction term of race/ethnicity and postdiagnosis change was not significant, suggesting that the short-term

Table 3. The Associations between Diagnosis with Type 2 Diabetes and Changes in Physical Activity among Middle-Aged and Older Adults in the United States: The Health and Retirement Study, 2004–2014 (*n* = 2,394)

Predictors	β	95% CI[a]	*p*
Prediagnosis linear slope	−0.29	−0.45, −0.13	<.001
Change in slope postdiagnosis	−0.11	−0.32, 0.09	.26
Change in intercept postdiagnosis	0.54	0.10, 0.97	.02
Age at diagnosis	−0.10	−0.13, −0.06	<.001
Female sex (reference: male)	−1.41	−1.90, −0.92	<.001
Race/ethnicity			
White, non-Hispanic	Reference		
Black, non-Hispanic	−0.30	−0.98, 0.38	.39
Hispanic/Latino	0.37	−0.61, 1.35	.46
Other, non-Hispanic	0.37	−0.59, 1.34	.45
Education			
Less than high school	Reference		
High school	0.16	−0.52 , 0.84	.65
Some college	1.01	0.28, 1.73	.006
College or more	2.36	1.34, 3.37	<.001
Depressive symptoms (CES-D score)	−0.43	−0.52, 0.33	<.001
Activities of Daily Living limitations	−1.10	−1.30, −0.90	<.001
Instrumental Activities of Daily Living limitations	−0.42	−0.78, −0.06	.02
Comorbidity count[b]	−0.44	−0.69, −0.19	.001
Constant (prediagnosis intercept)	12.43	11.39, 13.46	<.001

Note: CES-D = Center for Epidemiologic Studies Depression scale.

[a]Confidence interval. [b]Comorbidity count is the number of chronic conditions other than diabetes, including high blood pressure, cancer, lung disease, heart disease, stroke, and arthritis. This variable was top coded at 3.

Table 4. Moderation of the Associations between Diabetes Diagnosis and Physical Activity among Middle-Aged and Older Adults in the United States: The Health and Retirement Study, 2006–2014 (n = 2,394)

	β	95% CI[a]	p
Postdiagnosis change in intercept			
Postdiagnosis change in intercept × age at diagnosis	−0.07	−0.10, −0.05	<.001
Prediagnosis slope			
Prediagnosis slope × non-Hispanic black	0.25	−0.02, 0.52	.07
Prediagnosis slope × Hispanic/Latino	0.47	0.05, 0.88	.05
Prediagnosis slope × non-Hispanic other	−0.28	−0.67, 0.12	.17
Postdiagnosis change in slope			
Postdiagnosis change in slope × non-Hispanic black	0.30	−0.20, 0.79	.24
Postdiagnosis change in slope × Hispanic/Latino	−0.16	−0.75, 0.44	.60
Postdiagnosis change in slope × non-Hispanic other	1.11	0.38, 1.83	−.003

Note: [a]Confidence interval.

jump in PA after diagnosis was similar across racial/ethnic groups. There were, however, significant differences in both prediagnosis slope and postdiagnosis change in slope by race/ethnicity. Prior to receiving a diabetes diagnosis, non-Hispanic whites reported a slight decline in PA over time (β: −0.31, 95% CI: −0.47, −0.14, results not reported in tables). As shown in Table 4, the prediagnosis rate of change in PA was 0.47 METs higher among Hispanics/Latinos relative to non-Hispanic whites (β: 0.47, 95% CI: 0.05, 0.88), making the prediagnosis slope a positive one for Hispanics/Latinos (β: −0.31 + 0.47 = 0.16, 95% CI: −0.24, 0.56, results not reported in tables). The prediagnosis slope for non-Hispanic blacks and other racial/ethnic groups did not significantly differ from non-Hispanic whites. Among non-Hispanic whites, the rate of decline in PA postdiagnosis was 0.28 METs lower (β: −0.28, 95% CI: −0.67, 0.12) relative to the prediagnosis period, making the overall postdiagnosis rate of PA decline −0.58 for non-Hispanic whites (95% CI: −0.74, −0.43, results not reported in tables). While non-Hispanic whites experienced a steeper decline in PA, change in slope postdiagnosis was 1.11 METs higher among non-Hispanic other racial/ethnic group relative to non-Hispanic whites (β: 1.11, 95% CI: 0.38, 1.83), making the overall postdiagnosis rate of PA change a positive one for non-Hispanic "other" racial/ethnic group participants. Change in slope postdiagnosis for non-Hispanic blacks and Hispanics/Latinos did not significantly differ from non-Hispanic whites.

Sensitivity Analyses

We conducted sensitivity analyses to evaluate the potential role of mortality attrition in key findings. Over the 10-year period of observation, attrition was observed among 343 participants (317 participants experienced mortality and 26 were nonrespondents). Mortality risk was associated with being male, non-Hispanic white and non-Hispanic black (relative to other race/ethnicity), with diagnosis at 75 years of age and older, and with having less than a high school education. However, no differences between respondents and nonrespondents (due to attrition/mortality) were observed related to gender, race/ethnicity, educational level, or age at diagnosis. We repeated the regression analysis removing those nonrespondents (due to attrition/mortality) following T2D diagnosis. The results were substantively similar.

Discussion

This study provides the first evidence of a salutary effect of T2D diagnosis on PA among a longitudinal, population-based sample of middle-aged and older men and women with T2D. Differences in the apparent turning points and trajectories of PA following diagnosis by age at diagnosis and race/ethnicity, respectively, were observed.

Turning Points and Trajectories: Overall Sample

In the broader context of decreasing PA throughout the period of observation, we found that T2D diagnosis was associated with a slight increase in PA among participants overall, but we found substantial variability in these putative turning points and trajectories. The 0.54 MET unit increase following diagnosis can be interpreted as an average increase in mildly energetic activity[1] from "hardly ever or never" to "one to three times per month". While this is a modest effect, it may represent an effort to respond to a new diagnosis with healthier behavior.

This evidence of a turning point in PA behavior following diagnosis is consistent with previous findings of health behavior changes upon receiving a diagnosis with cancer and other forms of chronic disease (Demark-Wahnefried et al., 2000, 2005; Sabatino et al., 2007; Xiang, 2016). Prior studies on longitudinal, population-based samples report evidence of some positive health behavior changes following

[1] Also referred to as "light physical activity" (see Ainsworth et al., 2000).

chronic disease diagnosis, such as reduced smoking and alcohol consumption and increases in fruit and vegetable consumption (Hackett et al., 2018; Quiñones et al., 2017). Among prior studies specifically examining changes in PA following diagnosis with T2D, these findings are consistent with observational samples of middle-aged and older Canadians (Newsom et al., 2012b) and postmenopausal women (Schneider et al., 2014). However, the bulk of observation research studies examining changes in PA following diagnosis with T2D found no improvements in PA following diagnosis (Chong et al., 2017; Dontje et al., 2016; Hackett et al., 2018; Newsom et al., 2012a; Xiang, 2016).

Consistent with findings from prior intervention studies (as characterized by Cradock et al., 2017), the initial increase (or turning point) observed in PA appeared to level off, having minimal impact on the overall trajectory of aging-related PA declines for participants overall. Moreover, the postdiagnosis slope was not significantly different than the prediagnosis slope, indicating that PA did not decline at a faster rate in the years after T2D diagnosis compared to the years prior, as prior studies have observed (Nelson et al., 2002). Although an increase or flatter decline following diagnosis would indicate a more dramatic effect of diagnosis, it would also not be expected in the absence of a targeted intervention.

Moderation: Age at Diagnosis

The age of diagnosis emerged as an important predictor of changes in PA following diagnosis with T2D. Participants of relatively younger age experienced substantially greater gains in PA after diagnosis. This finding is consistent with research on exercise changes following diagnosis with cancer, which found greater diagnosis-related improvements in exercise among those diagnosed at relatively younger ages (Chong et al., 2017; Ganz et al., 2002). This is understandable, as adults of more advanced age are more likely to experience barriers to PA such as muscle weakness, mobility limitations, functional limitations, arthritis, fear of falling, and risk of injury. Changing PA at older ages presents a unique challenge but is of first-order importance.

Moderation: Race/Ethnicity

Noteworthy racial/ethnic differences were observed in the trajectories of PA following diagnosis with T2D, but not in the direction hypothesized. Non-Hispanic whites in the sample appear to have been the drivers of steepened rates of decline following diagnosis with T2D. Non-Hispanic blacks and Hispanics/Latinos showed no significant change in slope between pre- and postdiagnosis, while those reporting "other" race/ethnicity experienced a slight improvement in PA postdiagnosis. These moderation effects challenge prior literature, suggesting that non-Hispanic whites engage in more PA than racial/ethnic minority groups (Zhao et al., 2012). While functional limitations and chronic illness comorbidity were included as control variables in this analysis, it is possible that lower self-efficacy, social support, or leisure time account for why non-Hispanic whites show worse PA outcomes in our sample.

These findings provided support to our first hypothesis, that the event of diagnosis would be associated with a more pronounced increase in PA participation. As hypothesized, this increase was more substantial for those diagnosed at relatively younger ages. More pronounced increases were not found by race/ethnicity, educational level, or gender. Interestingly, these findings challenged our hypothesis that postdiagnosis change would be sustained among certain groups, with non-Hispanic whites experiencing steeper rates in PA decline relative to other groups. We did not find evidence to support our hypotheses regarding gender or education-related differences in PA change following diagnosis or over time.

Limitations

The findings of this study are also subject to several limitations. Our study examined only recreational PA and excludes occupation-associated PA, which might lead to an underestimate of PA in respondents with physically demanding occupations. The PA measure is based on self-reported data, which has been found in prior studies to be subject to overreporting bias (Brenner & DeLamater, 2014). In this study, however, it is likely that the frequency of PA at regular and more frequent levels is underreported, as the original HRS questionnaire did not differentiate PA activity levels more frequent than "more than once a week" unless volunteered as "every day" by participants, which could lead to more conservative estimates.

The duration of T2D is estimated based on respondents' reports of a diagnosis. That said, our study design was not able to validate or consider the impact of the timing of diagnosis itself. Assessments and counseling regarding risk factors and prevention strategies for diabetes and prediabetes, for example, provide opportunities for earlier behavioral interventions, while delayed diagnosis with T2D could delay the therapeutic benefit of counseling and other health promotion strategies. Because the timing of diagnosis is often tied with access to care and other socioeconomic factors (Nicklett & Damiano, 2014), socioeconomic predictors of PA turning points and trajectories might be underestimated in this study. The exclusion of undiagnosed cases and prediabetes behavioral and pharmacological interventions could result in further underestimation of these differences.

Another limitation is that this study does not compare those with T2D diagnoses to those without diagnoses, so we cannot parse out decline due to age that occurs in the general population. Despite this limitation, our study is able to describe changes in PA postdiagnosis and explore

trends in PA specifically within the T2D population. Our subgroup analysis did not consider the nuance of intersection between sociodemographic characteristics. Finally, given the longitudinal design and the older age of the study population, differential mortality could affect our ability to accurately examine longitudinal trends. One study examined changes in sample composition over nine waves of the HRS and found that the sample becomes "healthier" over time (Zajacova & Burgard, 2013). However, as noted, our sensitivity analyses that did not include those who died after T2D diagnosis produced very similar results.

Conclusions

Despite these limitations, our event-oriented study makes several important contributions to the understanding of diagnosis with T2D and PA behaviors. Namely, our metric of PA included both rigor and frequency, capturing a broad range of activities of quite differing levels, which allowed us to capture the modest increase in PA at diagnosis. The longitudinal and representative nature of the HRS is also an advantage, allowing our study to provide novel insight into patterns of PA among middle aged and older adults in the United States with T2D diagnoses. Our ability to separately examine initial changes following diagnosis and sustained changes over time—using the piecewise mixed model approach—is a major contribution of this study. Through the examination of sociodemographic moderators, we were able to identify differences in initial changes and trajectories by age at diagnosis and race/ethnicity, respectively. Overall, our results highlight the potential for T2D diagnosis to be an important points of intervention for behavior change and suggest that there is ample room for improvement in maximizing the impact of these teachable moments.

Conclusions and Implications

The increase in PA following diagnosis points to the diagnostic event as an opportune point of intervention for encouraging PA. A greater understanding of barriers faced by older adults, and particularly among those diagnosed with T2D at older ages, to engaging in PA will inform clinical practice and policies aiming to improve PA and chronic disease self-management more generally among older adult populations. Future research should focus on how to increase the size and the sustainability of this behavior change. More research is also needed which identifies who is at heightened risk of declining PA following diagnosis (e.g., non-Hispanic whites, those diagnosed in more advanced age) in order to inform targeted intervention strategies to enhance chronic disease self-management efforts among these subgroups.

Tailored interventions in which patients are active participants improves the success of sustained PA improvements among older adults with T2D (Nelson et al., 2002). Such strategies should address and reduce barriers individuals might confront, whether they be biological, behavioral, or environmental in nature (Satariano & McAuley, 2003). Clinicians encouraging PA in older adults receiving a diabetes diagnosis may need to give more time and care to creating a behavior change plan that fits the needs and abilities of patients of advanced age (Chentli et al., 2015; Hayes & Kriska, 2008; Satariano & McAuley, 2003). To enhance the effectiveness of teachable moments, clinicians are encouraged to incorporate their patient's learning preferences, health literacy levels, and socioeconomic resources into treatment plans.

While clinical and primary care interventions are moderately effective (Cradock et al., 2017; Nelson et al., 2002), it is imperative to also engage in broader, community-level strategies to promote opportunities for PA participation for all ages (Nelson et al., 2002). A few examples in overcoming age-related barriers to PA could include exercise classes that are adaptable based on physical abilities and needs (adaptive sports, chair-based yoga) and exercise facilities that are affordable and accessible. Community strategies to enhance access to maintained walking paths and parks have found to be effective as well (Satariano & McAuley, 2003). National strategies, such as the Silver Sneakers program, have the potential to reduce barriers to PA among older adults as well, which could result in better health outcomes and prevention of diabetes-related complications later on. Policy strategies should continue to target programs that reduce barriers and enhance access to PA among those with T2D and among middle-aged and older adults more generally. Future studies that examine the impact of community- and neighborhood-level resources that are conducive to greater PA participation following T2D diagnosis are needed. Such studies would have important implications on community health promotion and health policy concerning healthy aging among those with T2D.

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Conflict of Interest

The authors have no conflicts of interest to report.

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