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Social Determinants of Parkinson's Disease: Associations Between Education, Mental Health, and Exercise Among Patients with PD

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An Abstract Of
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Abstract

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By Samuel John

Importance: There is an elevated burden of depression and anxiety among PD patients when compared to the non-PD population. Exercise is a known treatment to slow the progression of PD. Social determinants of health have been linked with PD and studies support that SDOH are crucial to health outcomes. It is unclear how one social determinant, education, is associated with mental health and exercise among PD patients.

Aims & Research Questions: To determine, in an exclusively PD sample:

1. What is the relationship between education and mental health related symptoms?
2. What is the relationship between education and physical activity?
3. What is the association of physical activity and mental health symptoms?

Design/Setting, Participants: Observational study, secondary data analysis from Emory clinical research at Parkinsonism Neuroimaging Laboratory. 89 participants with PD diagnosis verified by Emory movement disorders neurologists.

Main Outcomes and Measures: To assess depression, anxiety, and cognitive function, this study used the Beck Depression Inventory (BDI II), Geriatric Depression Scale (GDS), Beck Anxiety Inventory (BAI), and Montreal Cognitive Assessment (MoCA), respectively. SPSS analysis used linear regression, Pearson correlation, and independent t test. Covariate analysis examined relationships between the three core research variables and disease duration, sex, and age.

Results: Regarding the aims, education and physical activity had a strong trend towards significance, and supports a negative relationship ($p=0.058$, beta= -0.207, $R^2=0.04$). Covariate analysis strongly supports that male participants are more depressed than females. GDS scores were significantly higher among males ($t= 1.60$, $p=0.012$) and BDI-II scores supported a strong trend towards significance ($t=1.29$, $p=0.052$). Results also suggest that disease duration and BAI score was positively correlated (beta= 0.245, $p=0.05$, $R^2= 0.06$).

Conclusion and Relevance: This pilot study generated several important hypotheses. Results suggest that education and SDOH play a vital role in PD outcomes. Literature supported that education is positively associated with physical activity, thus, future longitudinal studies should examine how SDOH evolve over time and influence physical activity. Results also support the importance of sex-based differences in PD outcomes and emphasize targeted research towards PD sub-populations, and the male-specific burden of depression merits further investigation. Studies should include more SDOH, such as ZIP code, or income or poverty level, which can provide more context to the nuanced living situations of PD participants.

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INTRODUCTION

According to Department of Health and Human Services, the phrase "social determinants of health" (SDOH) describes the conditions where people are born, live, learn, work, play, worship, and age, which have a range of health effects.[1] SDOH are grouped into 5 main categories: economic stability (e.g. income, housing), education access and quality, healthcare access and quality, neighborhood and built environment, and social and community context. [1] The overall idea is that the community setting plays a substantial role in health outcomes, in fact, SDOH can drive as much as 80-90% of health outcomes.[2] For example, people who live in areas with greater pollution are at a higher risk of lung disease and people who live in areas without grocery stores suffer from poor nutrition and higher rates of obesity.[3,4] SDOH influence a diverse array of non-communicable diseases (NCDs), such as pulmonary and cardiovascular disease, chronic diseases (e.g. diabetes), and mental and neurological health.[3,5–8] Given that NCDs account for 70% of global deaths each year, it is vital for public health professionals to focus on these diseases and the potential risk factors.[7,8] To further illustrate the importance of NCDs, 1 in 5 American adults had a diagnosable mental disorder in 2020, and 6 in 10 American adults had a chronic disease in 2021.[9,10]

One domain of NCDs is especially urgent for public health: mental and neurological health. Several studies suggest that mental health conditions commonly occur alongside chronic health conditions, in which chronic disease afflicts 1 in 3 adults worldwide.[11–13] These findings suggest that programs or policies to prevent the former may also improve outcomes with the latter.[11–13] Similarly, comorbid NCDs often interact and are associated with poorer health. In 2019, one study suggested that 36.6% of patients with chronic physical diseases also had a mental disorder.[14] Moreover, those with chronic physical illness were 3.1 times more likely to

have a mental disorder than the general population.[14] The reverse is also true: those individuals with mental disorders experience greater chronic physical conditions. In 2008, those with mental disorders were found to experience three times as many chronic physical conditions than the general population.[15]

As one of the world's fastest growing neurological conditions, Parkinson's disease (PD) represents an important area for public health interventions.[16] PD is a neurodegenerative disorder which impacts movement, and core symptoms include tremor, slowed movement, and rigidity.[17] PD is also associated with non-motor and mental health conditions, most notably depression and anxiety.[17] As the baby boomer generation is projected to age, the prevalence of PD is projected to increase substantially.[16] Between 2017 and 2037, the elderly population (greater than 65) in the United States will grow by 62%, and because of the notably higher rate of PD among older individuals, the prevalence of PD will rapidly increase from 1.04 million in 2017 to 1.64 million in 2037.[16] Moreover, PD is more common among Medicare patients, so Medicare shares a disproportionate burden of the estimated $25.4 billion medical cost of PD.[16] This cost burden further prioritizes public health efforts to safeguard neurological health, which may ease taxpayer burden and spiraling healthcare expenditures.[16]

The literature already recognizes several SDOH linked with increased risk of PD, such as greater exposure to pesticides, living in a rural community, and lower exposure to cigarette smoking.[17–19] One SDOH, socio-economic status (SES) such as income and education, is also linked with risk for PD. Yang et al. found that lower SES is associated with a lower risk of developing PD, but Yoon et al. concluded that lower income was associated with higher PD mortality.[18,20] In addition to social determinants, mental health conditions also predispose individuals to develop PD: depression and anxiety are strongly linked with PD, both as risk

factors for developing PD and as a common symptom related to PD's neuropathophysiology.[17,19] According to the Cleveland Clinic, approximately half of all individuals with PD suffer from some form of depression.[21] Other studies suggest the prevalence of depressive symptoms is closer to 13-30%, yet this prevalence is still higher than the general population.[22–24]

Depression is a serious public health issue: one study found that 32.8% of Americans experienced elevated depression symptoms in 2021, with those who are unmarried and with lower income at higher risks, both factors related to SDOH.[25] With $71 billion in costs to American healthcare, depression is the most costly among mental health and substance use disorders and the sixth most costly health condition.[26] Like many other health conditions, depression itself is also influenced by social determinants of health. Education and socioeconomic status (SES) are important social determinants which have been associated with depression. When comparing racial groups and sex, there are nuanced differences in how those determinants modify depression. In 1990, Oliver and Shapiro concluded that parental level of education is a protective factor for depression among white young adults, but this protective effect is not observed for African American young adults.[27] More recently, Assari found that greater education among African American women was a protective factor against depressive symptoms.[28] In 2013, Shapiro found that social mobility diminishes exposure to stress for whites, but similar to the 1990 study, this protective factor was not observed in African Americans.[29] In another example of the complex interactions of race, sex, and SES, Assari found that higher income among white women is a protective factor, but higher income among African American men is a risk factor for depressive symptoms.[28]

In addition to depression, anxiety is a common and serious co-morbidity among PD patients. In a 2016 meta-analysis of 45 studies, the average prevalence of an anxiety disorder

among individuals with PD was 31%.[30] Other studies have indicated a wider range of prevalence from 25% to 52%.[31–33] Beyond the widespread nature of anxiety in the PD community, anxiety appears to have a greater impact on quality of life for PD patients when compared to depression.[34,35] The impact on wellbeing reinforces the need to study factors associated with anxiety. As seen with depression, social determinants of health also influence anxiety. In 2019, Matsumura et al. found that mothers from a lower SES had a significantly higher prevalence of anxiety.[36] Similarly, Tetzner et al concluded that women and individuals with less education were more anxious than men and people with greater education.[37]

In addition, disease onset and exercise can modify mental health and are important variables to consider when planning public health interventions for people with PD. For example, anxiety is more common among earlier onset PD patients.[38] Also, literature supports the presence of apathy unrelated to cognitive impairment or depression among both early and advanced PD patients. [39–41] But, it is less clear about how the prevalence of apathy differs among earlier onset versus later onset patients. Physical exercise is another variable which can also modify mental health. Among non-PD patients, exercise reliably improves depressive and anxiety symptoms, and physical inactivity is associated with poorer mental health.[42–44] Beyond the general population, exercise may be an important tool to improve mental health among the PD community. Also, physical activity reliably improves physical health outcomes for PD patients, so exercise should be analyzed as an efficient tool to simultaneously improve physical and mental health.[45,46]

Theoretical Framework

As a study which focuses on the influence of one social determinant of health on individual and interpersonal behaviors and health outcomes, this project will employ the social

ecological model (SEM). SEM defines health as being influenced by many levels in progressing degrees of scope and influence, such as the individual level, relationship or interpersonal level, community level, and societal level.[47] The study approach will analyze how a broader, community level social determinant of health (education) is associated with an individual behavior (exercise) and individual mental health (depression and anxiety). There is likely a nuanced association between these three domains, and SEM is well positioned to guide this study's data analysis.

Aims and Hypotheses

This exploratory study aims to assess: 1) the relationship between education and mental health related symptoms in PD patients, 2) the relationship between education and physical activity in PD patients, and 3) the association of physical activity and mental health symptoms among people with PD. We hypothesize that: 1) higher educational level will be associated with less mental health symptoms of PD, 2) higher educational level will be associated with greater physical activity in PD patients, and 3) greater physical activity will be associated with reduced burden of mental health symptoms in PD patients.

LITERATURE REVIEW

Introduction

Parkinson's Disease: Symptoms and Prevalence

Parkinson's disease is a neurological disorder caused by neuron death within the basal ganglia, a region of the brain which regulates movement.[48] In particular, these neurons produce a neurotransmitter called dopamine, which is vital in several biological processes such as movement and mood. As a result, those with PD often experience movement related symptoms, such as tremor, shaking, stiffness, and poor balance and coordination which can impair walking.[48] Also, since dopamine plays a central role in mood and emotion, those with PD frequently experience depression and anxiety. In addition, those with PD lose neurons which produce norepinephrine, which in turn regulates the sympathetic nervous system. Thus, those with PD can also experience impairment in digestion, excessive fatigue, and abnormal fluctuations in blood pressure.[48]

The severity of PD is not limited to the extensiveness of the symptoms: the disease influences millions of people. Over 10 million individuals worldwide have PD and about 60,000 Americans are diagnosed with PD each year.[49] There are a few strongly supported risk factors for PD. Older age and male sex have been reliably associated with greater risk of a PD diagnosis.[48,50] While risk for PD increases as one ages, 5-10% of individuals have early onset PD diagnosed before the age of 50.[48] Men are 1.5 times as likely as women to have PD.[48] While PD is associated with some genetic risk factors, 90% of PD cases have no identifiable genetic cause.[51] Researchers are still investigating what factors predispose individuals to develop the disease, and it remains an ongoing area of research.

Depression and Anxiety Among Older Adults and Those with PD

Older adults (those in their 60s or older) are at a higher risk of depression than other age groups.[52] In particular, widows and widowers are at a higher risk of clinically-recognized depression upon losing their spouse and also after one year.[53] For all older adults, these mental

health conditions worsen cognitive decline and increase mortality risk.[54] Compared to the older adult population without PD, older adults with PD are more likely to experience depression and anxiety. Anxiety among the elderly ranges from 1.2% to 17%, compared to 25-52% of those with PD.[31,32,54–56] The prevalence of depression among older adults without PD varies from 1% to 20%, compared to 13-50% of the PD population. [21–24,52,57] Also, primary care physicians frequently underrecognize mental health symptoms in elderly patients, which further complicates mental health outcomes for this age group. Across all elderly patients, fewer than 50% of patients with depression were accurately recognized by primary care doctors. [53] While the exact predictions vary, some studies estimate that depression and anxiety are not diagnosed in half of all PD patients.[58–61] Moreover, only 3% of elderly patients see mental health professionals.[53] These findings support that mental health concerns are often undertreated in the elderly and represent a significant public health issue. Moreover, the COVID-19 pandemic has negatively impacted mental health and reduced physical activity for many in the PD community, which further emphasizes the importance of studying mental health in PD patients.[62,63]

Education and Mental Health

Literature about the general population is a useful starting point to understanding SDOH and mental health in the PD population. Several studies suggest that education level is positively associated with mental health and mental wellbeing. The commonly suggested mechanism in which education enhances mental health is that greater education: 1) enhances one's skills, 2) offers structural advantages and related socio-economic opportunities, and 3) improves coping mechanisms.[64] Several other studies of older adults support this theorized association between greater educational level and better mental health. Among a large sample of over 50,000 older Chinese adults, Zhang et al. found that higher education level is associated with lower levels of

psychological distress.[65] Among a sample of Portuguese and majority female participants, Belo et al concluded that greater education was associated with greater self-rated favorability of leisure time activity, which in turn was associated with greater physical and mental health.[66] In 2008, also among older Chinese adults, Ross et al found a significant negative association between level of education and psychological distress, which includes anxiety and depression.[67] Like Belo et al, Ross et al found that leisure activity involvement (e.g. playing mahjong, reading, watching TV) mediated this relationship.[67] In older adults, leisure activities are especially important to maintain social connections and stimulate cognitive functioning, so this is a vital consideration for mental health.[66] This result emphasizes the importance of education as a social determinant of health, which modifies social interactions and mental health outcomes.

In addition, other studies support that sex can modify the relationship between education and mental health. In 2016, Tetzner et al. collected data from over 28,000 European respondents aged 45-90 years old and found that individuals with less education and females in general are more anxious than individuals with more education and males in general.[37] This study suggests that education may have a protective effect against anxiety, but that sex can also modify this relationship. Similarly, in 2017, another study also supported that greater education is associated with better mental health, and that sex modifies this relationship. Among a middle-aged adult sample, greater education was associated with reduced depressive symptoms among African American females.[28] Given this literature about the older adult population without PD, it is reasonable to hypothesize that education can modify mental health within the PD patient population as well. The literature suggests that level of education can modify depression and anxiety in the non-PD population.[27,28,37] However, this association has not been observed in a PD specific sample, which motivated this thesis project.

Education and Physical Activity: Implications for the PD Community

Until the past few years, Stalsberg et al. notes that researchers generally believed that individuals of a higher SES group are more physically active than individuals of a lower SES group.[68] Older studies support that those of lower educational attainment are more likely to be physically inactive.[69,70] However, the reality is that physical activity among SES groups varies according to the type of physical activity, which mainly includes two categories: leisure time physical activity (activity done during free time outside of work) and occupational physical activity (activity done during work).[68,71,72] For example, one study found that educational level was positively associated with leisure time physical activity and negatively associated with occupational physical activity.[71] Individuals with a higher educational level were more likely to be physically active in their leisure time, but more sedentary during work, and vice versa for those with lower educational attainment.

Similarly, in a sample of adults between 16-75 years old, Stalsberg suggests that leisure time physical activity is the only domain of physical activity which is positively associated with SES, and other domains such as transport physical activity or occupational physical activity are not associated with SES.[68] This finding suggests that individuals in higher SES groups are more likely to have time to spend in leisure physical activities, perhaps due to more flexible work hours or reduced financial pressure to work multiple jobs. O'Donoghue et al corroborated this finding, and found that SES is positively associated with leisure time physical activity and is negatively associated with occupational physical activity.[71] The latter finding also suggests that higher SES jobs are less physically engaging and further supports Kantomaa et al's finding that higher SES individuals are more physically sedentary.[72] Overall, findings suggest that higher

SES individuals may be more physically active in leisure time, while lower SES individuals may be more physically active at their work.

Like with the relationship between educational level and mental health, sex also plays a role in the relationship between educational level and physical activity. Kantomaa et al found that higher educational level was associated with greater moderate and vigorous physical activity.[72] However, higher educational level was also associated with: greater sedentary time, low light intensity activity in weekdays among males, and low light intensity activity throughout the week and weekend among females.[72] Thus, the study does not support a general hypothesis that greater education is associated with greater physical activity, but again reinforces that education is associated with activity in nuanced ways.

There is some evidence that higher SES individuals are more likely to report greater leisure time physical activity.[71] However, this literature review suggests there is not conclusive evidence to demonstrate that education reliably predicts greater or less physical activity. Thus, due to the lack of definitive evidence, examination of this relationship is important to build a better understanding of how education modifies physical activity. This is an especially vital topic for the PD community because exercise is one of the most effective treatments for PD.[73]

Physical Activity and Mental Health

Among the non-PD population, there is robust literature which supports that physical activity improves mental wellness. VanKim et al. concluded that college students who exercise vigorously (i.e. activity for at least 20 minutes that leads to sweating or breathing hard) were less likely to report poor mental health, which included depression and anxiety symptoms.[74] Among a sample of hospitalized, depressed patients, Martinsen observed that 9 weeks of vigorous activity was associated with significantly reduced Beck Depression Inventory scores.[75,76] Beyond

depression, exercise also improves anxiety symptoms: DeBoer et al found that exercise reliably improves anxiety, through several mechanisms including increased brain-derived neurotrophic factor which is vital for neuronal health and is diminished in those with anxiety.[77]

Of closer relevance to the PD community, when examining studies of middle-aged and older adults, exercise is also associated with improved depression and anxiety. Among a sample with participants between 35-55 years old, El-Kader et al found that exercise reduced depression-related inflammation in those with chronic obstructive pulmonary disease.[78] This age group falls within the range of early onset PD.[48] In a separate study, El Kader et al also found that patients with Alzheimer's disease who experienced treadmill walking exercise also experienced a 23.5% reduction in BDI measured depression symptoms.[79] This finding is especially important because Alzheimer's disease and Parkinson's disease populations often suffer from similar co-morbidities and complications.[80] In another study with closer generalizability to the older PD patient community, Chang et al found that consistent exercise in sessions of at least 15 minutes and with at least 3 sessions per week among older adults, was associated with significantly reduced depression symptoms.[81] Overall, moderate evidence suggests that exercise improves mental health in the non-PD population, but more research is needed to demonstrate this pattern in the PD patient population, which motivated the third aim.[42–44]

Socio-Ecological Model and Social Determinants of Health: Theory and Aims

The socio-ecological model (SEM) defines the multiple factors that impact health, with a particular focus on how the environment shapes these factors.[47] The CDC defines the SEM with four main levels of the environment which influence health: individual, relationship, community, and societal.[47] From downstream to upstream, these levels describe how environmental factors contribute to health from an individual level to a broader, societal level. Social determinants of

health (SDOH) play a key role in the SEM, such as individual level of education, interpersonal relationships and social support, or the work setting. [47] SDOH shape each level of the SEM and similarly were constructed to understand how non-biological, social factors can influence health outcomes. For example, education is a vital SDOH. Education provides more than just knowledge, but also important opportunities for professional networking, and can enhance personal wellness and time management as students learn to balance classwork with other responsibilities. [64] As another example, socio-economic status is often used to understand how financial and economic influences can modify health outcomes. As discussed in the literature review section, prior findings suggest that higher SES individuals may be more physically active in leisure time, while lower SES individuals may be more physically active at their work.[68–73] However, the social context of individuals within both lower and higher SES is variable. As a theoretical example, some may find more physical activity during their job despite not pursuing leisure exercise (e.g. gardeners and construction workers), while others may not be physically active in either setting (e.g. fast food employees and cashiers). In addition, some lower SES individuals may be more active in leisure time than during work because they work part-time and are physically active when caring for children. Conversely, some individuals of higher SES jobs may enjoy a work culture which prioritizes healthy living and offers incentives for physical activity. Importantly, a SDOH framework often acknowledges that more than one social determinant explains a health outcome, and this encourages the incorporation of other determinants and covariates in research models. This mindset aligns well with SEM and how the model emphasizes the role of several societal influences. The SEM is often utilized to characterize the downstream effects of public health issues. For example, the CDC utilized SEM to describe violence as a public health concern, from an individual level when considering

personal factors such as individual attitudes towards violence to a societal level such as cultural norms towards violence.[82]

Accordingly, this project incorporates the SEM within the study aims. The first aim will investigate how an individual level factor, personal level of education, is associated with mental health symptoms. On a relationship level, individuals with greater education may have developed relationships with former classmates through past schooling. While this study did not directly assess social connections, personal friendships from past classmates may help to explain why education could be associated with resilience and better mental health during the stresses of PD. In fact, prior findings suggest that teens with good friendships have better mental health and relationship outcomes in adulthood.[83] For this study of older adults, school-based relationships may be maintained after schooling. On a community level, the school setting itself can be a facilitator for better mental health. The school setting encourages students to make friends because classmates see each other regularly and can benefit academically from studying together or socially by playing together. Thus, the school setting may facilitate better work ethic and studying skills to enhance career prospects, and may refine social skills and coping mechanisms through development of support systems. Literature supports these benefits and that education aids children's social development.[84–88]

The second aim examines the relationship between education and physical activity. For example, on a societal level, the institutional system of education may foster a culture or mindset of healthier attitudes and habits. Literature supports that those with less education are more likely to experience less control over their lives, and this risk factor predicts reduced engagement in exercise.[89] In addition, material problems related to lower education, such as poor housing or financial struggles, were both associated with reduced physical activity.[89] Individuals who

received more schooling were likely exposed to greater physical education and health classes which encourage students to exercise, and which have proven benefits to health.[90] Also, on a relationship level, students may have developed lasting relationships with teammates through school sports.[91] Child and adolescent team sports involvement has been associated with adult exercise; thus, early education and related school sports are important factors to consider.[92] Finally, the third aim investigates how physical activity is associated with mental health. On an individual level, a person's involvement in exercise can increase self-esteem, which influences individual attitudes and psychological wellbeing.[93] On a relational level, exercise has also been associated with reduced social withdrawal, and thus can be important for social wellbeing and good relationships. [93] Accordingly, this study will utilize the SEM to examine how social determinants of health and other factors influence health outcomes in participants with PD.

METHODS

Introduction

This project used SPSS to conduct secondary data analysis from an ongoing clinical research study at the Emory Parkinsonism Neuroimaging Laboratory. Data was mostly collected from participants within Georgia and the Southeast, and exclusively from those who have PD. Bivariate linear regression, and covariate analysis via correlation, were used to investigate the aims and related demographic variables.

Population And Sample

Participants were recruited at the Emory Movement Disorders Clinic by a movement disorders neurologist. All participants met clinical research consensus diagnostic inclusion and exclusion criteria, as assessed by one or two movement disorders neurologists. Participants are individuals who live within Georgia and surrounding states, and the majority of these live in the Atlanta metro area. The screening process to identify candidate participants for recruitment

consisted of 1) screening of clinical charts according to an IRB approved protocol, 2) review of potential candidates in consensus conference including one or two movement disorders neurologists, and 3) contacting screened candidates to meet inclusion and exclusion criteria for PD diagnosis to attempt recruitment for the study. The sample had an average age of 63 years old and was predominantly male (60%). Baseline demographic and clinical characteristics are shown in **Table 1**.

Research Design

Parent Study and Thesis Project Secondary Data Analysis

The Parkinsonism Neuroimaging Laboratory utilized an observational design to compare neurological health and MRI imaging patterns between those with PD and neurologically healthy controls. The study collected quantitative and qualitative data about health and demographic information. Data from each participant was collected at a single time point between 2011 and 2021. This thesis project focused on the quantitative data from PD participants to investigate the aims and employed secondary data analysis.

Procedures

The Parkinsonism Neuroimaging Lab collected this data in their clinical studies at the Emory Brain Health Center. Studies were approved by the Emory Institutional Review Board. Regarding recruitment of participants, the lab utilized physician referrals and word of mouth advertising, in addition to posting fliers on social media and sending emails to the PD community (e.g. Atlanta support groups). In addition, lab staff received access to electronic medical records to identify potential participants and then contact their physicians for potential recruitment. The lab offered a $50 incentive for the completion of a single study visit, which typically lasted about five hours. The major exclusion criteria were non-MRI safe bodily

implants, piercings, tattoos, or other accessories, not being fluent in English, and not having PD (except when recruiting controls). After chart review yielded a list of eligible participants, lab staff called potential participants over the phone to assess interest and ensure exclusion criteria were not met. With data collection, a trained clinical research coordinator administered the informed consent, and sometimes a clinical research assistant completed this component. The informed consent was approved by the Emory IRB. Then, both staff members helped to verbally administer several health history questionnaires and neurological questionnaires and assessments (see measures for full explanation and validation). In addition, blood samples, MRI imaging, and sometimes DAT scan imaging were obtained, but that data was not analyzed in this thesis project. All data was collected using written forms, was deidentified, and was then transferred to an SPSS dataset. This dataset and scanned copies of the original forms were stored on a password-protected and HIPAA compliant OneDrive folder.

Measures

The parent study administered several questionnaires to collect health history information. To collect demographic information and key information about the PD diagnosis, the study used a self-designed form and also used the validated National Alzheimer's Coordinating Center Uniform Data Set (UDS).[94] The study coordinator collected information by verbally asking participant and writing the responses. PD information included the first symptom recognized, date of PD onset, and family history of PD. In addition, the form collected education level, race, and whether the participant has four Jewish grandparents (a known risk factor for PD). To collect information about depression and anxiety, the study used the Beck Depression Inventory II (BDI II) and Beck Anxiety Inventory (BAI), to assess depression and anxiety, respectively. [95,96] Unlike the health history forms, these forms were completed directly by

participants. The BDI II asks to what extent participants endorse various symptoms of depression, including sadness, suicidal thoughts or wishes, or loss of pleasure. Answer choices provide progressively more severe options. For example, about sadness, the answers include: 0) I do not feel sad, 1) I feel sad much of the time, 2) I am sad all the time, and 3) I am so sad or unhappy that I can't stand it. Similarly, BAI asks to what extent participants endorse various symptoms of anxiety, including being unable to relax, hands trembling, and feeling hot. Likewise, answer choices provide progressively more severe options of anxiety. Both scales are widely used in research and are validated. The study also used the validated Apathy Scale to assess feelings of apathy or indifference, which is a common mental health symptom in those with PD.[97,98] Similarly to the BDI II and BAI, the Apathy Scale uses Likert scale answer choices to assess the severity of various apathy related behaviors. For example, interest in learning new things was one category, and choices included "not at all", "slightly", "some", and "a lot". In addition, the study administered the widely used and validated Montreal Cognitive Assessment (MoCA) to assess for cognitive or memory deficiencies.[99] The MoCA assesses various domains of memory, including visuospatial/executive functioning and naming. For example, one item asks the participant to draw a clock with a certain time, and to ensure the clock has all the correct components (e.g. hands and number placed appropriately). The scale gives a score from 0-30, whereby a higher score indicates better cognitive functioning, and a score below 26 indicates cognitive deficiency. To assess physical activity, the study used the validated Physical Activity Scale, which asks about daily and weekly physical activity during work and leisure time.[100] All questions ask about the time spent in each activity type. For example, one question asks, "In your work/studies, how many hours and minutes per day do you engage in sedentary work?", with two blanks for participants to write in the number of hours and number of minutes.

Data Analysis Methodology

This thesis project used secondary data analysis, which focused on linear regression to assess the three study aims, and to assess for a bivariate association. Then, the study used ANNOVA and independent one sample t-tests to examine how other covariates are related to each other. The main covariates were demographic information (age, sex, race and ethnicity, disease duration) and neurological and mental health (MoCA, BDI-II, BAI, and GDS). During the data cleaning process, PD cases were isolated and duplicate patient visits were eliminated. Some patients participated in a study which had two visits, so data from the first visit was maintained in the final dataset for consistency.

RESULTS

Demographics

This project obtained descriptive statistics on SPSS (Table 1a and 1b). The sample (n=89) was characterized as predominantly white (92%), majority male (60%), and largely middle-aged with 46% between ages 56-69 and 25% between ages 40-55. The sample was well educated, with a mean of 16.6 (3.2) years of education. Participants reported having PD for an average of 4.3 (3.7) years. Regarding depression symptoms, mean BDI II score was 7.9 (6.4), and mean GDS score was 5.4 (1.5). The range of BDI scores extended between 0-26, and the range of GDS extended between from 2-10. According to the BDI validated score categories, the mean score falls within the "minimal depression" category between 0-13, which is the lowest severity of depressive symptoms.[101] The average GDS score falls within the mild depression category of 5-8, which is the second to lowest severity of depressive symptoms.[102] With anxiety, the average BAI score was 8.2 (6.9) and the range of scores extended between 0-30. The mean BAI score fell within the "mild anxiety" category between 8-15, which is the second to lowest severity of anxiety symptoms.[103] With MoCA-evaluated cognitive ability, the average MoCA

score of about 27 (3.7), with the unrounded mean value of 26.5, both indicate normal cognitive function. Any score between 26-30 indicates normal cognitive function.[104] With physical activity, the mean hours of physical activity was 11.8 (10.3). This amount of activity exceeds the 150 minutes of weekly physical activity which CDC recommends for adults.[105]

Table 1a: Stratified Descriptive Statistics

	N (%)	**Years PD**	**BDI II** Mean (SD)	**GDS**	**BAI**	**MoCA**	**Exercise**	**Education**
AGE								

40-55	22 (25%)	2.7 (2.7)	8.4 (6.2)	6.3 (1.5)	8.9 (6.9)	28.1 (2.2)	11.9 (11.3)	17.0 (4.2)
56-69	41 (46%)	5.5 (4.1)	8.3 (6.7)	5.0 (1.2)	9.0 (7.6)	27.0 (2.6)	12.2 (10.4)	16.9 (2.9)
70-80	26 (29%)	3.6 (3.0)	7.0 (6.1)	5.3 (1.6)	6.5 (5.6)	24.4 (5.2)	11.0 (9.7)	15.8 (2.4)
SEX								
Male	53 (60%)	3.7 (2.8)	8.6 (7.1)	5.6 (1.6)	7.6 (7.1)	26.3 (3.9)	11.4 (10.1)	17.6 (3.1)
Female	36 (40%)	5.3 (4.7)	6.9 (5.2)	5.0 (1.1)	9.2 (6.6)	26.9 (3.5)	12.3 (10.7)	15.2 (2.8)
RACE/ETH.								
White	82 (92%)	4.3 (3.7)	7.9 (6.4)	5.4 (1.5)	8.2 (6.9)	26.5 (3.7)	11.8 (10.3)	16.6 (3.2)
Non-white	7 (8%)	2.2 (1.0)	6.7 (6.1)	6.0 (1.6)	9.1 (8.2)	27.0 (2.4)	11.2 (7.1)	16.4 (2.6)

Table 1b: Non-stratified Descriptive Statistics

VARIABLE	n	Mean	S.D.
Years PD	66	4.3	3.7
BDI II	87	7.9	6.4
GDS	53	5.4	1.5

BAI	88	8.2	6.9
MoCA	87	26.5	3.7
Exercise	87	11.8	10.3
Education	87	16.6	3.2

Bivariate Regression: Examining Aims

Education and Mental Health

Note, all regression was conducted using non-stratified data. Regarding the first aim, bivariate regression suggested that education and mental health do not have a statistically significant relationship (Table 2).

Education and Physical Activity

With the second aim, bivariate regression also suggested that education and physical activity had a statistically insignificant relationship. However, the p-value indicates a strong trend towards significance ($p=0.058$, beta= -0.207, $R^2=0.04$) and suggests that this relationship should be explored in further interventions and with larger samples.

Physical Activity and Mental Health

Concerning the third aim, bivariate regression suggested that physical activity and mental health do not have a significant relationship.

Covariate Analysis

Disease Duration (Years of PD) and Mental Health

Beyond the three main aims, the analysis investigated another important covariate, length of time that the participant had PD. Bivariate regression suggested that the relationship between disease duration and BAI just met significance and was positively correlated (beta= 0.245,

p=0.05, R^2= 0.06). The relationships between disease duration and the other mental health indicators (BDI II, GDS, and MoCA) were not significant.

Disease Duration (Years of PD) and Physical Activity

Bivariate regression suggested that disease duration and physical activity did not have a significant association.

Relationship Between Age and Covariates

Besides the MoCA score, all mental health indicators were not significantly associated with age (Table 3). With MoCA, age and MoCA score were negatively correlated (r=-0.344, p=0.001). Exercise, years of education, and years of PD diagnosis were all not associated with age.

Relationship between Sex and Covariates

GDS score was associated with sex, and the mean values indicate that males have significantly higher GDS scores than females (t= 1.60, p=0.012, see Table 4). Sex and BDI, another depression indicator, had a statistically insignificant relationship, but the p-value indicates a strong trend towards significance (t=1.29, p=0.052) and suggests that this relationship should be explored in further interventions and with larger samples. Years of PD diagnosis was significantly associated with sex, and the mean values suggest that females have carried a PD diagnosis for a longer period than males (t=-1.740, p=0.002).

Table 2: Bivariate Regression Results

Model	Standardized Beta	Standard Error	p-value	R-Squared
Education and Mental Health				

Education and BDI II	0.043	0.221	0.699	0.002
Education and GDS	0.211	0.060	0.134	0.025
Education and BAI	-0.048	0.239	0.658	0.002
Education and MoCA	0.109	0.128	0.318	0.012
Education and Physical Activity	-0.207	0.348	0.058	0.043
Physical Activity and Mental Health				
Physical Activity and BDI II	-0.049	0.067	0.650	0.002
Physical Activity and GDS	-0.188	0.020	0.177	0.035
Physical Activity and BAI	-0.065	0.073	0.552	0.004
Physical Activity and MoCA	0.139	0.039	0.206	0.019

Years of PD and Mental Health				
Years of PD and BDI II	0.143	0.223	0.255	0.021
Years of PD and GDS	0.016	0.058	0.912	0.000
Years of PD and BAI	0.245	0.241	[a]**0.050**	0.060
Years of PD and MoCA	-0.115	0.126	0.357	0.013
Years of PD and Physical Activity	0.030	0.323	0.811	0.001

These analyses included all age groups; no stratification by age groups was done.

[a] $p \leq 0.05$

Table 3: Pearson's Correlations between Age and Clinical and Demographic Features

	Age (Pearson's coefficient)	**P-value**

Years of PD	0.020	0.871
BDI	-0.097	0.371
GDS	-0.211	0.130
BAI	-0.117	0.279
MoCA	-0.344	[a] **0.001**
Exercise	0.014	0.897
Education	-0.182	0.092

These analyses included all age groups; no stratification by age groups was done.

[a] $p \leq 0.05$

Table 4: Sex and Covariate Associations, Independent T-Test

	Male n	**Male mean (sd)**	**Female n**	**Female mean (sd)**	**T-value**	**P-value**
BDI II	51	8.6 (7.1)	36	6.9 (5.2)	1.29	0.052
GDS	33	5.6 (1.6)	20	5.0 (1.1)	1.60	[a] **0.012**
BAI	52	7.6 (7.1)	36	9.2 (6.6)	-1.05	0.845
MoCA	52	26.3 (3.9)	35	26.9 (3.5)	-0.729	0.921
Exercise	51	11.4 (10.1)	36	12.3 (10.7)	-0.410	0.860
Education	52	17.6 (3.1)	35	15.2(2.8)	3.687	0.570
Years of PD	41	3.7 (2.8)	25	5.3(4.7)	-1.740	[b] **0.002**

These analyses included all age groups; no stratification by age groups was done.

[a, b] $p \leq 0.05$

DISCUSSION

Study Aims

This paper examined three main hypotheses: 1) educational level will be associated with non-motor symptoms of PD, including those in the mental health domain, 2) higher educational level will be associated with greater physical activity in PD patients, and 3) greater physical activity will be associated with reduced burden of mental health symptoms in PD.

Regarding these aims, regression results suggest that education is not associated with mental health and suggest that physical activity is not associated with mental health. However, the relationship between education and physical activity indicates a strong trend towards significance ($p=0.058$, beta= -0.207, $R^2=0.04$) and suggests that this relationship should be explored in further interventions and with larger samples. It was unexpected that education would be negatively associated with physical activity, and this study had hypothesized that higher education would be associated with greater exercise. The study result may suggest that those with higher levels of education may experience other unknown factors or confounding variables. Some studies support that higher education is associated with lower occupational time physical activity, and higher leisure time physical activity.[71] Also, future studies should examine other social determinants of health related to education, such as socio-economic status or income, which may better explain this nuanced relationship. For example, poverty level has been linked with increased use of public transit, which in turn may influence walking patterns to and from transit stations.[106] Moreover, future studies may investigate which physical activity questionnaire items are driving this trend with a larger sample size. As the literature review discussed, there is moderate evidence to support a relationship between those variables. Given that literature, this study's findings should not discourage future studies to analyze how social determinants of health and related health behaviors modify health outcomes in PD. This study

used previously collected data which only addressed a single SDOH, education. Future studies may consider how other environmental factors and determinants influence health, such as pollution exposure, pesticide exposure, income, or diet. This study serves as a guide to design future research projects about the social determinants of Parkinson's disease, and the literature supports examining these aims in larger samples.

The Male Burden of Depression

Importantly, the results suggest that male PD patients display significantly more depressive symptoms than females. To the author's knowledge, this is the first study to suggest a male, sex-specific burden of depression among patients with PD. This study used two depression measures, GDS for geriatric depression and BDI II for age non-specific depression. The GDS results demonstrated that males display significantly more geriatric depressive symptoms, which may indicate that elderly men may suffer from unique circumstances which predispose them to depression. One Japanese study suggests that elderly men have lower social support than women, and given that social support is protective for mental and physical health, that finding supports this particular result.[107] However, other studies in PD patient samples found that depression is either not associated with sex, or that females suffer from greater depressive symptoms than males.[108–110] Public health programs may consider an intervention which encourages social support, which has been shown to be diminished among many elderly persons in Western society and is widely demonstrated to improve mental and physical health.[111–113] All results strongly suggest that further research is needed to distinguish if a sex specific burden of depression exists, and if so, how to plan public health interventions to meet the mental health needs of elderly persons with PD. Given that some studies estimate that up to 20% of patients with PD also experience depression, it is vital to address this substantial complication of PD and a major

quality of life concern. [21–24,52,57] Lastly, the BDI II result indicates a strong trend towards significance (p=0.052) and this result also warrants future studies to examine the male burden of depression in earlier onset PD patients.

Years of PD and Association with Anxiety

First, this study found that PD duration was positively associated with anxiety symptoms. This result is supported by previous literature, such as Foster et al.[114] This finding suggests that patients with advanced PD may suffer from greater neurological impairments and related mental health difficulties. One article suggested that PD patients may feel more anxious about their functional limitations, such as freezing or gait imbalance, and this restriction on independence may influence mental health.[115] The literature suggests that future public health programs and clinical interventions may consider focused mental health programs for those who have had PD for longer periods. For example, non-pharmacological interventions such as cognitive and behavioral therapy have both demonstrated efficacy to mitigate anxiety in the literature.[31] The study also found that females carried a PD diagnosis for a longer period than males. However, the literature does not support that this finding carries a significant clinical or public health implication, especially given the small sample size.

Age and MOCA

This study also found that MOCA scores decrease as age increases. This finding is widely supported by the literature, and emphasizes the role of clinical interventions to protect cognitive ability and mitigate memory loss among older PD patients.[116]

Limitations

Despite the careful efforts to design this study in a representative and scientifically valid manner, we acknowledge some limitations to the study. First, the sample size is small for an

epidemiological study. It would have been ideal to conduct a power analysis and design data collection accordingly, however, time constraints prevented the main author from conducting a power analysis and primary data collection. Second, the sample is racially, geographically, and educationally non-diverse. Most participants are white, from the Southeast, and are college educated. Ideally, the study would include a broader range of demographic features, especially years of education since this study was mainly designed to assess social determinants of PD. Third, only one SDOH was measured in the dataset, and it would have been useful to analyze more social determinants which may have different associations with health outcomes and exercise. In particular, SES or pesticide exposure would be useful to measure because the literature supports both as social determinants of PD.[18,117] Last, this study collected data both before and during the COVID-19 pandemic, and did not directly make statistical adjustments to account for changes in mental health and health behaviors as a result of the national lockdowns and social isolation. Future studies should address how the social isolation may uniquely influence those with PD and to account for these factors in study designs.

CONCLUSION

This pilot study carries important implications for future research about PD, and has generated several future hypotheses. First, the study suggests that mental health outcomes among patients with PD are associated with sex and year of PD duration. Specifically, the male specific burden of depression was an unexpected result and merits further investigation because both depression scales supported this conclusion. Future studies should examine how gender roles and expectations can influence the male response to mental health and potential stigma that they experience. Furthermore, this finding reinforces that PD research must continue to stratify samples and conduct targeted studies, such as studies focused on sex-based, age-based, and race-based differences in PD outcomes. Those sub-populations have unique experiences of PD and

likely experience different SDOH. Also, the study suggested that social determinants of health play a role in PD outcomes and emphasizes the importance of examining SDOH in clinical research. This study suggests that education is negatively associated with leisure physical activity, which is not supported by the literature. Future longitudinal studies may consider examining how one's lifestyle during one's working years, and physical activity during that time, can influence one's lifestyle and physical activity in retirement. Also, future studies should examine how physical activity during one's job can influence leisure physical activity, and contribute to overall physical activity, with PD patients. Lastly, studies should include more SDOH, such as ZIP code, or income or poverty level, which can provide more context to the nuanced living situations of PD participants. Longitudinal studies may be especially helpful to examine how SDOH evolve over the lifespan.

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