Association Between Perceived Discrimination, Race, and Physical Function in Older Adults

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Abstract. Data on $N = 7,836$ older adults were obtained from a random subset of the Chicago Health and Aging Project, with the goal of assessing the association between perceived discrimination and physical function. Physical function was measured through the Short Physical Performance Battery, and the discrimination score was evaluated through the Everyday Discrimination Scale. In a cross-sectional statistical analysis, we found no significant association between perceived discrimination and physical function in older adults adjusting for potential confounders (95% CI: (-0.11,0.01), p-value: 0.080). We also fail to find differences in the association between perceived discrimination score and physical function score by race/ethnicity (95% CI: (-0.05, 0.23), p-value: 0.199). In the longitudinal portion of the analysis, we fail to find evidence that the relationship between perceived discrimination and the slope of physical function over time differs comparing two sub-population, one of which are Non-Hispanic Black and the other Non-Hispanic White adjusting for potential confounders (95% CI: (0.00,0.38), p-value: 0.052).

Keywords: Chicago Health and Aging Project, Everyday Discrimination Scale, Short Physical Performance Battery, GEE, Stratified Random Sample, Jackknife Repeated Replication.

1 Introduction

Declining physical function represents a significant challenge faced by older adults, impacting their overall well-being and quality of life. As individuals age, various factors come into play, potentially accelerating the rate of physical function declines over time. One factor that has gained attention in recent research is perceived discrimination, which refers to the subjective experience of unfair treatment or prejudice based on race, gender, age, appearance, or sexual orientation. There have been many studies that explore the effects of perceived discrimination on mental health outcomes [7]; however, the effect on physical function has not been explored to the fullest. Our study aim is to investigate the association between perceived discrimination and the rate of decline in physical function among older adults. To accomplish our research objectives, we were provided with a random subset of a dataset containing up to five repeated measurements for each of the $N = 7,836$ individuals from the Chicago Health and Aging Project. Essentially there are three scientific questions that we want to answer, (1) we want to quantify the association between perceived discrimination and physical function, (2) furthermore, we will want to see if the association differs by race/ethnicity. Lastly, (3) we will want to test the hypotheses that people who experience perceived discrimination in their day-to-day life have a greater decline in physical function, especially among non-Hispanic Black compared to non-Hispanic White in older adults. Statistical methods to answer these questions are given in Section 2, results are presented in Section 3, and a discussion of results along with limitations and future work is given in Section 4.

2 Statistical Methods

2.1 Sampling Scheme and Data

To answer the scientific question of interest, we will utilize a random subset from the Chicago Health and Aging Project (CHAP) [2]. CHAP is a longitudinal population-based study conducted over 20 years, from 1993 to 2012, in the Chicago community. Individuals in the study were all adults over 64 years of age, who were assessed over time via interviews and underwent clinical exams. There are three unusual features in this complex sampling design, (1) stratified random sampling to identify persons to undergo a clinical evaluation, (2) combining multiple incidence samples taken from different cycles, and (3) enrolling of successive age cohorts. Utilizing these features in the sample design offers several advantages, such as substantial cost

savings by examining a subset instead of the entire cohort. However, it is important to acknowledge that stratified random sampling introduces complexity to the analysis. This requires the inclusion of appropriate weighting procedures to account for unequal selection probabilities of individuals in the sample, as well as the use of distinct variance estimation techniques to accommodate the sampling design.

In addition, the dataset also contains time-variant and invariant variables on the subjects, such as their physical function score [4] at each visit which is our outcome of interest. Baseline perceived discrimination score, which was quantified through the Everyday Discrimination Scale (EDS) [9], our primary exposure of interest. Perceived stress score, education levels, self-reported income levels, BMI, self-reported number of medical conditions, sex, and race are all measured during the first initial visit, and lastly, age is measured at each visit. We will need to identify potential confounders to adjust for in our model. We have seen that a person's age and sex are associated with their physical function score [9]. There have also been studies that showed race and ethnicity are associated with lower health in general among older adults [6]. Similarly, we see that age, sex, and race are associated with perceived discrimination, and hence we identify our potential confounder variables to adjust in our model. Also, weight and BMI levels can be thought of as predictors for physical function scores; however, studies as shown that perceived discrimination can cause an increase in blood pressure [5]; hence BMI is more of a mediator than a confounder and should not be adjusted in our model. Similarly, with perceived stress score, if a person feels discriminated in their everyday life, they will more likely be stressed, which can cause other health issues and hence be thought of as a mediator instead of a confounder and should not be adjusted in our model. We also saw that educational status has no impact on physical function score [4] and hence will not be adjusted in our model. Also, it was difficult to find articles to suggest that there is an association between a person's income and physical ability in their later years. It was difficult to argue that there is a relationship between income and physical function and hence was not adjusted in the model. Lastly, the number of medical conditions can be thought of as being associated with physical function. For example, a person who has a history of cardiovascular disease might have a reduction in their mobility. We also thought that number of medical conditions might not be associated with a person's perceived discrimination in their everyday life and hence can be thought of as a precision variable. Recall that a precision variable is related to the outcome of interest but independent of the predictor of interest.

2.2 Exploring the Relationship: Perceived Discrimination and Baseline Physical Function in Older Adults

To answer the first and second scientific questions of interest mentioned in Section 1, we will first need to hypothesize a potential mechanism to quantify the association between perceived discrimination and physical function in older adults. In standard statistical analyses, we assume the data come from a simple random sample from the target population. However, because of the complex sampling design, our data are still chosen randomly but are no longer simple. The variance estimates produced by standard software are not correct for the stratified random sampling design. Instead, we will need to include a special procedure in order to account for the sample design. We will use jackknife repeated replication (JRR), which is a common method used for complex sampling designs [1, 8]. The idea is that one estimates the model repeatedly using a subset of the full data set. Each subset is a "replicate," and we will repeat this process and collect the estimated coefficients and, thus, in the end, will obtain a more robust variance estimator by taking the standard deviation of all of the collected estimated coefficients. We will use this robust standard error to compute our confidence interval and conduct inference. We also decided to set the number of replicates to 1,000 to ensure a more robust standard error.

Now to quantify the association between perceived discrimination and physical function in older adults, we will carry out a cross-sectional statistical analysis using a linear regression model to estimate the mean physical function score as shown in Equation 1, adjusting for the specific covariates discussion in Section

2.1.

$$\begin{aligned} E[Y_i] =& \beta_0 + \beta_1 discrim_i + \beta_2(Age_i - 74) + \beta_3 \mathbb{1}(Sex_i = Male) + \beta_4 \mathbb{1}(Race_i = Black) + \\ & \beta_5 \mathbb{1}(med_i = 1) + \beta_6 \mathbb{1}(med_i = 2) + \beta_7 \mathbb{1}(med_i = 3 \text{ or more}) \end{aligned} \tag{1}$$

From Equation 1, β_1 is the coefficient of interest. β_1 is the estimated mean physical function score comparing two sub-population with similar age, sex, race, and number of medical conditions differing in one unit of perceived discrimination score. We can then use a Wald test to test the hypothesis $H_0 : \beta_1 = 0$ vs. $H_A : \beta_1 \neq 0$. In addition, we will provide its corresponding confidence interval and p-value. Next, to assess if the association between perceived discrimination and physical function in older adults differs among race/ethnicity, we will need to fit an interaction term as shown in Equation 2 and conduct a Wald test. Specifically we will test $H_0 : \alpha_6 = 0$ vs. $H_A : \alpha_6 \neq 0$.

$$\begin{aligned} E[Y_i] =& \alpha_0 + \alpha_1 discrim_i + \alpha_2(Age_i - 74) + \alpha_3 \mathbb{1}(Sex_i = Male) + \alpha_4 \mathbb{1}(Race_i = Black) + \\ & \alpha_5 \mathbb{1}(med_i = 1) + \alpha_6 \mathbb{1}(med_i = 2) + \alpha_7 \mathbb{1}(med_i = 3 \text{ or more}) + \\ & \alpha_6 discrim_i \times \mathbb{1}(Race_i = Black) \end{aligned} \tag{2}$$

From Equation 2, we can interpret α_1 as the estimated mean difference in physical function for the subpopulation of non-Hispanic White differing in one unit of perceived discrimination score adjusting for all other covariates. Similarly, $\alpha_1 + \alpha_6$ is the estimated mean difference in physical function for the subpopulation of non-Hispanic Black differing in one unit of perceived discrimination score adjusting for all other covariates.

2.3 Examining Perceived Discrimination's Impact on Physical Function Decline in Non-Hispanic Black vs. Non-Hispanic White In Older Adults

We want to evaluate among older adults whether perceived discrimination is associated with a greater decline in physical function in Non-Hispanic Black compared to Non-Hispanic White. That is, we hypothesize that the relationship between perceived discrimination and the slope of physical function over time differs comparing two sub-population, one of which are Non-Hispanic Black and the other Non-Hispanic White. To answer this question, we will need to take advantage of existing statistical methods for correlated data. We will also need to subset our data to only include people who have three or more measurements. The reason is in order to assess this difference in slope effectively, we need people who have enough data points to be able to assess the trend. It is difficult to evaluate a person's rate of change if they only have one or two points. Since we will want to quantify this difference of slope, we will fit a model shown in Equation 3 using generalized estimating equations (GEEs) [3]. Conducting exploratory data analysis (EDA) for the covariance, we will assume an exchangeable correlation structure, where $Corr(Y_{ij}, Y_{ik}) = \rho$ for $j \neq k$. Results from the EDA can be shown in Appendix B.

$$\begin{aligned} E[Y_{ij}] =& \gamma_0 + \gamma_1 t_{ij} + \gamma_2 \mathbb{1}(Race_i = Black) + \gamma_3 discrim_i + \gamma_4 \mathbb{1}(Sex_i = Male) + \\ & \gamma_5 \mathbb{1}(med_i = 1) + \gamma_6 \mathbb{1}(med_i = 2) + \gamma_7 \mathbb{1}(med_i = 3 \text{ or more}) + \\ & \gamma_8(Age_{ij} - 74) + \gamma_9 t_{ij} \times \mathbb{1}(Race_i = Black) + \\ & \gamma_{10} t_{ij} \times discrim_i + \gamma_{11} discrim_i \times \mathbb{1}(Race_i = Black) + \\ & \gamma_{12} t_{ij} \times discrim_i \times \mathbb{1}(Race_i = Black) \end{aligned} \tag{3}$$

From Equation 3, Y_{ij} is the physical function score for the i-th person at the j-th measurement for $i = 1, 2, \ldots, 3772$ and $j = 1, 2, 3, 4, 5$ and t_{ij} is denoted as time. In order to answer the question, we will need to include a higher-order interaction term to see the effect between time, perceived discrimination score, and race/ethnicity. In this model, we will need to perform a linear contrast and test if $H_0 : \gamma_{11} + \gamma_{12} = 0$ vs. $H_A : \gamma_{11} + \gamma_{12} \neq 0$. We will use a Wald test to test our hypothesis. Here $\gamma_{11} + \gamma_{12}$ is the estimated

effect in the trajectory between two sub-population, one of which are Non-Hispanic Black and the other Non-Hispanic White. The derivation of how we obtain $\gamma_{11} + \gamma_{12}$ can be shown in Appendix A. In addition, we will output the corresponding 95% confidence interval and p-value of our estimates. From Equation 3, we can also interpret $\gamma_1 + x \times \gamma_{10}$ as the estimated rate of change in physical function score for non-Hispanic White who has a baseline perceived discriminator score of x. Similarly, $\gamma_1 + \gamma_9 + x \times (\gamma_{10} + \gamma_{12})$ is the estimated rate of change in physical function score for non-Hispanic Black who has a baseline discrimination score of x. Derivation of how we obtain these estimates can be shown in Appendix A.

Lastly, we will like to provide the estimated profiles for physical function over time for different values of perceived discrimination with corresponding confidence intervals. Here, the goal is to use Equation 3 to obtain the estimated mean physical function score at a specific time for individuals with different levels of baseline perceived discrimination score. To make it simpler, let's consider individuals who are 74 years of age, non-Hispanic White, Female, with no known medical conditions. Hence we will be focusing on Equation 4, and will be varying different levels of baseline perceived discrimination score at different time points.

$$E[Y_{ij}|discrim = x, t_{ij} = t_{ij}] = \gamma_0 + x\gamma_3 + (\gamma_1 + x\gamma_5)t_{ij} \tag{4}$$

Keep in mind that we will still need to account for the bias that comes from the complexity of the sampling design from our data. What we will do to obtain robust standard error is use the jackknife repeated replication method again for our GEE model. We will use this standard error to compute confidence intervals and conduct inference. We will also use this method for obtaining the confidence interval for individuals at different times and different levels of baseline perceived discrimination score. We also decided to keep the number of replicates to 1,000.

All the statistical analyses provided were conducted using R version 4.3.0 (2023-04-21) (packages: tidyverse, ggplot2, table1, patchwork, geepack). Grammarly was used for editing purposes.

3 Results

3.1 Race/Ethnicity and Perceived Discrimination's Influence on Physical Function Disparities

To begin, we provided descriptive statistics of all $N = 7,836$ people in the sample at baseline, stratified by people who had a positive perceived discrimination score and people who had a perceived discrimination score of zero as shown in Table 1. We also categorize age in order to see more of the distribution overall. Notice that Non-Hispanic Black seem to be more likely to have a positive discrimination score compared to non-Hispanic White. Looking at the physical function score, there is not a clear difference comparing a positive discrimination score and a score of zero. Since we are evaluating the relationship between discrimination score and physical function at baseline, a scatter plot is presented, one that is stratified by race and one that is not, as shown in Figure 1.

Next, we fit a linear regression model as discussed in Section 2.2, and the results of our outputs are displayed in Table 2. Table 2 (Reduce) shows the estimated mean physical function score from Equation 1, and its corresponding 95% confidence interval and p-values. Interpreting our coefficient of interest, we estimate the difference in mean physical function score comparing two sub-population with similar age, sex, race, and number of medical conditions is 0.05 lower, differing in one unit of perceived discrimination score. Conducting the Wald test, we have a p-value of 0.080. Hence we fail to reject our null hypothesis at an alpha level of 0.05. In addition, the results from Equation 2 are displayed in Table 2 (Full) along with their corresponding 95% confidence interval and p-value. Interpreting our results, we estimate the mean difference in physical function score for the subpopulation of non-Hispanic White is 0.12 lower, differing in one unit in their perceived discrimination score, adjusting for all other covariates. Similarly, we estimate the mean difference in physical function score for the subpopulation of non-Hispanic Black is 0.03 lower,

Perceived Discrimination:	Score = 0	Score > 0	Overall
	(N=4494)	(N=3342)	(N=7836)
Physical Function			
Mean (SD)	10.9 (3.31)	10.5 (3.41)	10.7 (3.36)
Median [Min, Max]	11.0 [1.00, 15.0]	11.0 [1.00, 15.0]	11.0 [1.00, 15.0]
Age			
Mean (SD)	73.7 (6.76)	73.3 (6.41)	73.5 (6.62)
Median [Min, Max]	71.9 [64.3, 105]	71.7 [64.4, 98.9]	71.9 [64.3, 105]
Age Group			
64-69	1232 (27.4%)	982 (29.4%)	2214 (28.3%)
70-74	1466 (32.6%)	1117 (33.4%)	2583 (33.0%)
75-79	866 (19.3%)	620 (18.6%)	1486 (19.0%)
80-84	505 (11.2%)	355 (10.6%)	860 (11.0%)
85+	425 (9.5%)	268 (8.0%)	693 (8.8%)
Race/Ethnicity			
Non-Hispanic White	1943 (43.2%)	947 (28.3%)	2890 (36.9%)
Non-Hispanic Black	2551 (56.8%)	2395 (71.7%)	4946 (63.1%)
Sex			
Female	2774 (61.7%)	1995 (59.7%)	4769 (60.9%)
Male	1720 (38.3%)	1347 (40.3%)	3067 (39.1%)
Stress Score			
Mean (SD)	4.49 (3.10)	6.27 (3.28)	5.25 (3.30)
Median [Min, Max]	4.00 [0, 18.0]	6.00 [0, 18.0]	5.00 [0, 18.0]
BMI			
Mean (SD)	27.9 (5.75)	28.5 (6.32)	28.2 (6.01)
Median [Min, Max]	27.1 [12.5, 60.9]	27.7 [13.1, 77.2]	27.4 [12.5, 77.2]
Num. of Medical Conditions			
0	1304 (29.0%)	846 (25.3%)	2150 (27.4%)
1	1963 (43.7%)	1437 (43.0%)	3400 (43.4%)
2	930 (20.7%)	756 (22.6%)	1686 (21.5%)
3	247 (5.5%)	244 (7.3%)	491 (6.3%)
4	45 (1.0%)	54 (1.6%)	99 (1.3%)
5	5 (0.1%)	5 (0.1%)	10 (0.1%)
Education			
Highschool	2481 (55.2%)	1767 (52.9%)	4248 (54.2%)
Less Than High School	1039 (23.1%)	1086 (32.5%)	2125 (27.1%)
College	974 (21.7%)	489 (14.6%)	1463 (18.7%)

Table 1: Descriptive statistics of the people's characteristics in the sample, stratified by positive perceived discrimination score and a score of zero. For discrete variables, we provide the count and percentage. We provide the mean, standard deviation, minimum, median, and max values for continuous variables.

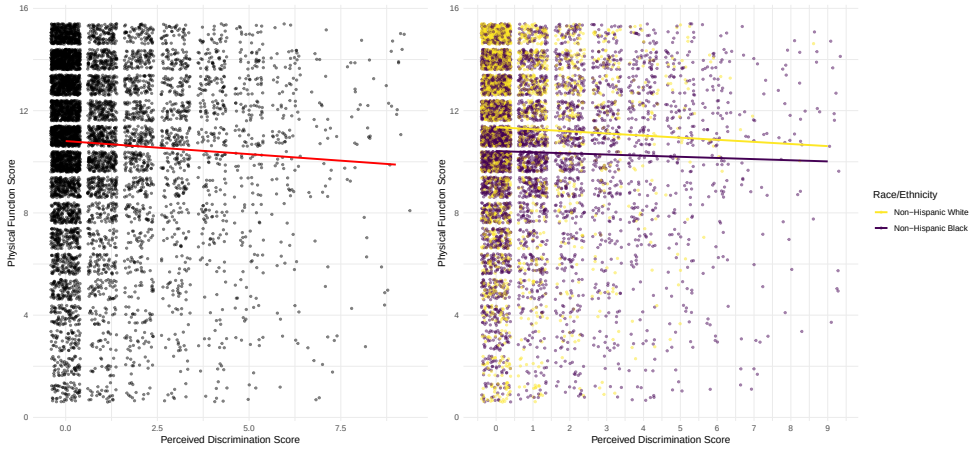

Fig 1: Scatter plot between Perceived Discrimination Score and Physical Function Score at baseline (left). Scatter plot between Perceived Discrimination Score and Physical Function Score at baseline stratified by race/ethnicity (right).

differing in one unit in their perceived discrimination score, adjusting for all other covariates. Conducting the Wald test for $H_0 : \alpha_6 = 0$ vs. $H_A : \alpha_6 \neq 0$, obtain a p-value of 0.199 (Est: 0.09, 95%CI: (-0.05, 0.23)). Hence we fail to reject the null hypothesis at an alpha level of 0.05.

Covariate	**Full Model**		**Reduce Model**	
	Est (95% CI)	P-value	Est (95% CI)	P-value
Perceived Discrimination Score	-0.12 (-0.24, 0.00)	0.041	-0.05 (-0.11, 0.01)	0.080
Age (Mean Center)	-0.20 (-0.21, -0.19)	<.001	-0.20 (-0.21, -0.19)	<.001
Sex				
Female	Reference		Reference	
Male	0.76 (0.58, 0.94)	<.001	0.75 (0.58, 0.93)	<.001
Race/Ethnicity				
Non-Hispanic White	Reference		Reference	
Non-Hispanic Black	-1.59 (-1.80, -1.38)	<.001	-1.52 (-1.71, -1.34)	<.001
Medical Condition				
No Known Medical Condition	Reference		Reference	
One Known Medical Condition	-0.38 (-0.57, -0.18)	<.001	-0.38 (-0.58, -0.18)	<.001
Two Known Medical Condition	-1.03 (-1.29, -0.78)	<.001	-1.04 (-1.29, -0.78)	<.001
Three or more Medical Condition	-2.31 (-2.72, -1.90)	<.001	-2.31 (-2.72, -1.90)	<.001
Perceived Discrimination Score				
- Race/Ethnicity				
Non-Hispanic White	-0.12 (-0.24, 0.00)	0.041		
Non-Hispanic Black	-0.03 (-0.10, 0.03)	0.326		

Table 2: The estimated mean physical function score, along with its corresponding 95% confident interval and p values. The first Column is the full model, where we have the interaction term between Perceived discrimination score and Race. The second column is the reduced model, where we do not have the interaction term.

3.2 Assessing Perceived Discrimination's Impact on Physical Function Decline: A Comparison between Non-Hispanic Black and Non-Hispanic White Older Adults

Recall from Section 2.3 we mention that in order to answer the scientific question of interest, we will need to exclude people with two or fewer measurements. Hence we have $N = 3772$ individual for our longitudinal analysis. To begin, we will first conduct descriptive statistics related to the scientific question of interest. Figure 2 shows spaghetti plots stratified by race/ethnicity for different values of perceived discrimination score at baseline. From the top left to the bottom right, we have spaghetti plots stratified by people who had a perceived discrimination score of 0, 1-3, 4-6, and 7-9 at baseline. Additionally, we fit a simple regression line to see the overall trend. Notice that only a few people had a baseline discrimination score between 7-9 at baseline, and a majority of them are non-Hispanic Black. We also see that for all cases, physical function scores seem to be decreasing as time increases.

Next, we fit our model from Equation 3, and output the results in Table 4 in the Appendix C. The estimates we are interested in are displayed in Table 3, as well as the description of what they represent. From the p-value displayed in Table 3 we fail to find evidence that the relationship between perceived discrimination and the slope of physical function over time differs comparing two sub-population, one of which are Non-Hispanic Black and the other Non-Hispanic White at an alpha level of 0.05.

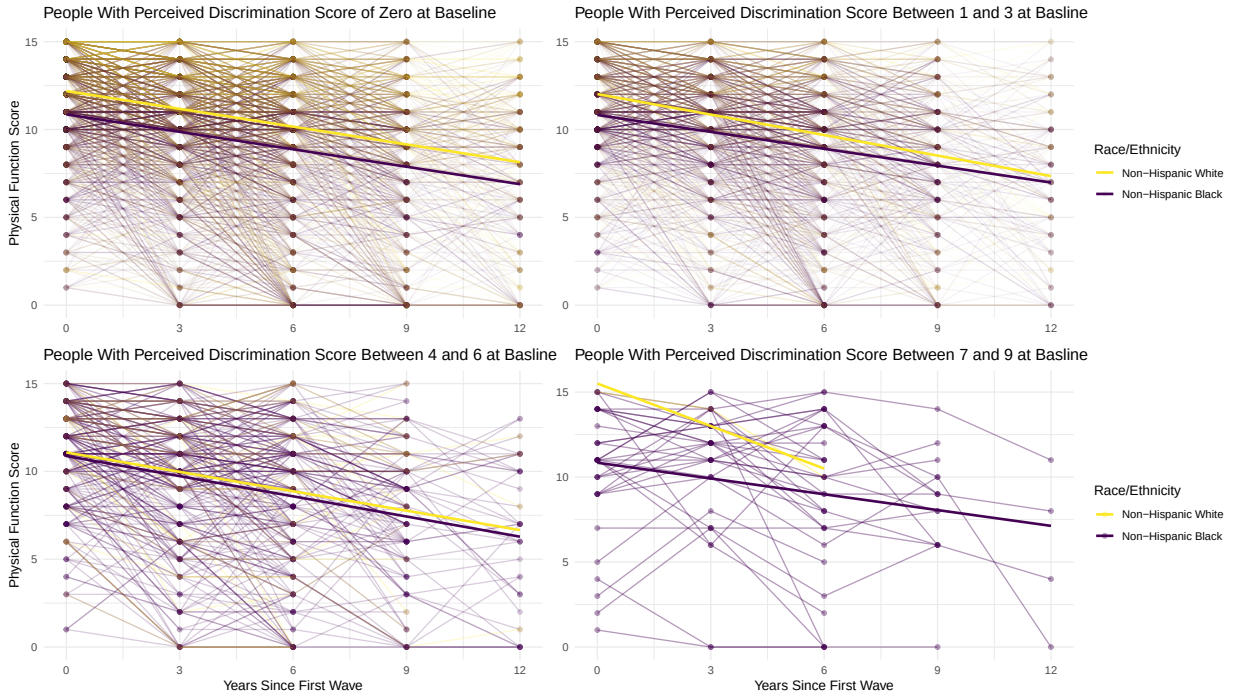

Fig 2: Spaghetti plots stratified by race/ethnicity at different baseline perceived discrimination score values. Specifically for people with baseline scores of 0, 1-3, 4-6, and 7-9.

Parameter	Est (95% CI)	P-value
$\gamma_{11} + \gamma_{12}$	0.19 (0.00, 0.38)	0.052
$\gamma_1 + (1) \times \gamma_{10}$	-0.51 (-0.64, -0.37)	$<$.001
$\gamma_1 + \gamma_9 + (1) \times (\gamma_{10} + \gamma_{12})$	-0.30 (-0.41, -0.20)	$<$.001
$\gamma_1 + (9) \times \gamma_{10}$	-0.82 (-1.69, 0.05)	0.065
$\gamma_1 + \gamma_9 + (9) \times (\gamma_{10} + \gamma_{12})$	-0.48 (-0.80, -0.16)	0.004

Table 3: Estimated rate of change in physical function score, along with its corresponding 95% confident interval and p-value

- $\gamma_{11} + \gamma_{12}$: is the estimated effect on the trajectory of physical function score comparing two sub-population, one of which are non-Hispanic Black and the other non-Hispanic White.
- $\gamma_1 + (1) \times \gamma_{10}$: is the estimated rate of change in physical function score for non-Hispanic White who has a baseline perceived discrimination score of one.
- $\gamma_1 + \gamma_9 + (1) \times (\gamma_{10} + \gamma_{12})$: is the estimated rate of change in physical function score for non-Hispanic Black who has a baseline perceived discrimination score of one.
- $\gamma_1 + (9) \times \gamma_{10}$: is the estimated rate of change in physical function score for non-Hispanic White who has a baseline perceived discrimination score of nine.
- $\gamma_1 + \gamma_9 + (9) \times (\gamma_{10} + \gamma_{12})$: is the estimated rate of change in physical function score for non-Hispanic Black who has a baseline perceived discrimination score of nine.

Lastly, we want to provide estimated profiles for physical function over time for different perceived discrimination levels with confidence intervals. We were able to plot the trajectory for baseline discrimination scores of 0, 1, 2, 3, and 9. We see from Figure 3 the different values at time 0, 1, 2, 3, and 4.

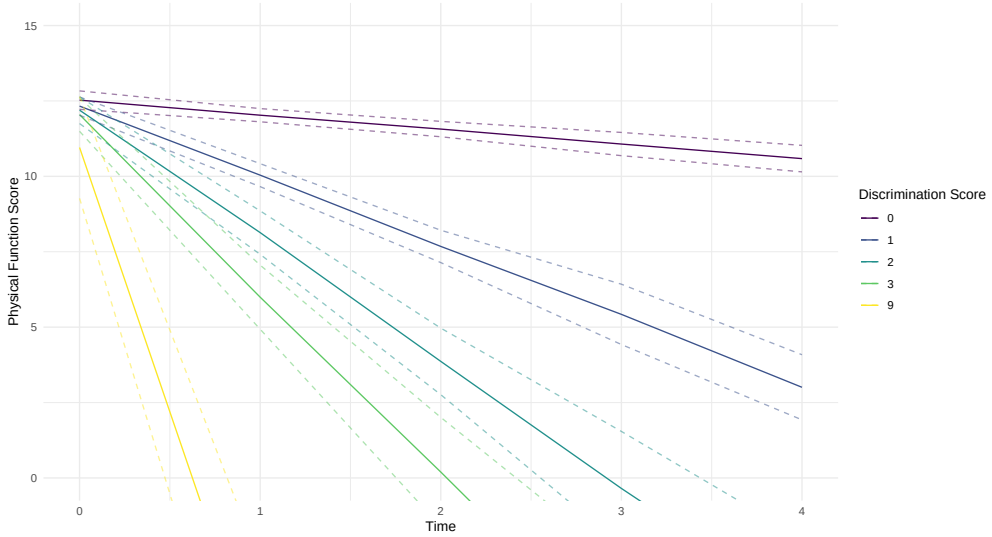

Fig 3: Estimated physical function score over time for profiles individuals discussion in Section 2.3.

4 Discussion

After a thorough statistical analysis, we were able to arrive at many conclusions that inform the relationship between physical function, perceived discrimination, and race/ethnicity. Adjusting for potential confounders and precision variables, it appears that perceived discrimination is not significantly associated with physical function in older adults at baseline (95% CI: (-0.11,0.01), p-value: 0.080). However, the p-value is close to the border and should be explored more thoroughly in future studies with new data. We also found no difference in the association between perceived discrimination score and physical function score by race/ethnicity (95% CI: (-0.05, 0.23), p-value: 0.199).

In the longitudinal portion of the analysis, we fail to find evidence that the relationship between perceived discrimination and the slope of physical function over time differs comparing two sub-population, one of which are Non-Hispanic Black and the other Non-Hispanic White adjusting for potential confounders (95% CI: (0.00,0.38), p-value: 0.052). However, the p-value is on the border and should be investigated further with new data. One possible cause is the effect of the complex sampling scheme from our data. Figure 3 shows the estimated physical function over time for different discrimination levels, and we estimate a sharper decline compared to people who score a 9 versus a score of 0.

However, keep in mind there are limitations that may have suffered from our analysis. Different methods had to be implemented to account for the bias from the complex sampling scheme of our data. However, using the Jackknife repeated replication did help with obtaining more robust standard errors; in the paper [2], they mention including weight to reflect the fact individual person have unequal chances of being in the sample. They mention weight by the inverse of their probabilities of selection. However, in the paper, they did not mention the probability they use of selecting from each strata. We believe that we need more information on the sampling design to calculate the weights. If we did obtain the weight, we would adjust accordingly and then perform the Jackknife repeated replication to account for the bias standard errors. Hence, there might still be bias in our estimates.

Also, all of our interpretations given in the paper should be with the sample frame in mind, that is, older adults aged 64 and above who lived in the Chicago community between 1993 and 2012. Specifically, older

adults who live in the adjacent neighborhoods, Morgan Park, Washington Heights, and Beverly, on the south side of Chicago. Also, there is potential confounder variables not accounting for due to data limitations. Future studies should account for these factors with new data.

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5 Appendix

A Derivation

A.1 Estimated effect on the trajectory of mean physical function score comparing to non-Hispanic Black to non-Hispanic White

Step 1: Find the difference in slope by perceived discrimination score among Non-Hispanic White

Step 1a: Find the Slope associated with $discrim = x$ among Non-Hispanic White

$$
\begin{aligned}
&= E[Y_{ij}|discrim = x, t_{ij} = 0, Race = 0] - E[Y_{ij}|discrim = x, t_{ij} = 1, Race = 0] \\
&= \gamma_0 + x\gamma_3 - (\gamma_0 + \gamma_1 + x\gamma_3 + x\gamma_{10}) \\
&= -\gamma_1 - x\gamma_{10}
\end{aligned}
$$

Step 1b: Find the Slope associated with $discrim = x + 1$ among Non-Hispanic White

$$
\begin{aligned}
&= E[Y_{ij}|discrim = x + 1, t_{ij} = 0, Race = 0] - E[Y_{ij}|discrim = x + 1, t_{ij} = 1, Race = 0] \\
&= \gamma_0 + (x + 1)\gamma_3 - (\gamma_0 + \gamma_1 + (x + 1)\gamma_3 + (x + 1)\gamma_{10}) \\
&= -\gamma_1 - x\gamma_{10} - \gamma_{10}
\end{aligned}
$$

Step 1c: Take the difference:

$$
\begin{aligned}
&= \text{step 1a} - \text{step 1b} \\
&= -\gamma_1 - x\gamma_{10} - (-\gamma_1 - x\gamma_{10} - \gamma_{10}) \\
&= \gamma_{10}
\end{aligned}
$$

Step 2: Find the difference in slope by perceived discrimination score among Non-Hispanic Black

Step 2a: Find the Slope associated with $discrim = x$ among Non-Hispanic Black

$$
\begin{aligned}
&= E[Y_{ij}|discrim = x, t_{ij} = 0, Race = 1] - E[Y_{ij}|discrim = x, t_{ij} = 1, Race = 1] \\
&= \gamma_0 + \gamma_2 + x\gamma_3 + x\gamma_{11} - (\gamma_0 + \gamma_1 + \gamma_2 + x\gamma_3 + \gamma_9 + \gamma_{10} + x\gamma_{11} + x\gamma_{12}) \\
&= -\gamma_1 - \gamma_9 - x\gamma_{10} - x\gamma_{12}
\end{aligned}
$$

Step 2b: Find the Slope associated with $discrim = x + 1$ among Non-Hispanic Black

$$
\begin{aligned}
&= E[Y_{ij}|discrim = x + 1, t_{ij} = 0, Race = 1] - E[Y_{ij}|discrim = x + 1, t_{ij} = 1, Race = 1] \\
&= \gamma_0 + \gamma_2 + (x + 1)\gamma_3 + (x + 1)\gamma_{11} - (\gamma_0 + \gamma_1 + \gamma_2 + (x + 1)\gamma_3 + \gamma_9 + \gamma_{10} + (x + 1)\gamma_{11} + (x + 1)\gamma_{12}) \\
&= -\gamma_1 - \gamma_9 - x\gamma_{10} + \gamma_{10} + \gamma_{11} - x\gamma_{12} - \gamma_{12}
\end{aligned}
$$

Step 2c: Take the difference:

$$
\begin{aligned}
&= \text{step 2a} - \text{step 2b} \\
&= -\gamma_1 - \gamma_9 - x\gamma_{10} - x\gamma_{12} - (-\gamma_1 - \gamma_9 - x\gamma_{10} + \gamma_{10} + \gamma_{11} - x\gamma_{12} - \gamma_{12}) \\
&= \gamma_{10} + \gamma_{11} + \gamma_{12}
\end{aligned}
$$

Step 3: Take the difference from Step 2 and Step 1

$$\begin{aligned} &= \text{step 2} - \text{step 1} \\ &= \gamma_{10} + \gamma_{11} + \gamma_{12} - \gamma_{10} \\ &= \gamma_{11} + \gamma_{12} \end{aligned}$$

Hence we see that $\gamma_{11} + \gamma_{12}$ is the estimated effect on the trajectory comparing two sub-population, one of which are non-Hispanic Black and the other non-Hispanic White.

A.2 Estimated rate of change in physical function score among different Race/Ethnicity

To look at the estimated rate of change in physical function score for non-Hispanic White consider the following

$$\begin{aligned} E[Y_{ij}|discrim = x, Race = 0] &= \gamma_0 + \gamma_1 t_{ij} + x\gamma_3 + x\gamma_{10} t_{ij} \\ &= \gamma_0 + x\gamma_3 + (\gamma_1 + x\gamma_{10}) t_{ij} \end{aligned}$$

Similarly, to look at the estimated rate of change in physical function score for non-Hispanic Black consider the following

$$\begin{aligned} E[Y_{ij}|discrim = x, Race = 1] &= \gamma_0 + \gamma_1 t_{ij} + \gamma_2 + x\gamma_3 + \gamma_9 t_{ij} + x\gamma_{10} t_{ij} + x\gamma_{11} + x\gamma_{12} t_{ij} \\ &= \gamma_0 + \gamma_2 + x(\gamma_3 + \gamma_{11}) + (\gamma_1 + \gamma_9 + x(\gamma_{10} + \gamma_{12})) t_{ij} \end{aligned}$$

B Exploratory Data Analysis For the Covariance

We conducted exploratory data analysis to help us choose a proper working correlation structure for our GEE model. Below we output the empirical covariance and correlation matrix along with the sample size for each visit as well. We also plotted the residual Variogram shown in Figure 4. We see from the figure that we have almost no serial process, we also have measurement errors and random intercepts. We decided that we would implement an exchangeable correlation structure.

$$\text{Corr} = \begin{array}{c} \begin{array}{ccccc} \text{Visit 0} & \text{Visit 1} & \text{Visit 2} & \text{Visit 3} & \text{Visit 4} \end{array} \\ \begin{pmatrix} 1 & 0.6 & 0.52 & 0.43 & 0.40 \\ 0 & 1 & 0.65 & 0.48 & 0.43 \\ 0 & 0 & 1 & 0.59 & 0.50 \\ 0 & 0 & 0 & 1 & 0.62 \\ 0 & 0 & 0 & 0 & 1 \end{pmatrix} \end{array} \quad \text{Cov} = \begin{array}{c} \begin{array}{ccccc} \text{Visit 0} & \text{Visit 1} & \text{Visit 2} & \text{Visit 3} & \text{Visit 4} \end{array} \\ \begin{pmatrix} 8.78 & 6.17 & 6.28 & 5.18 & 4.99 \\ 0 & 12.05 & 9.21 & 6.86 & 6.31 \\ 0 & 0 & 16.78 & 9.94 & 8.59 \\ 0 & 0 & 0 & 16.76 & 10.70 \\ 0 & 0 & 0 & 0 & 17.52 \end{pmatrix} \end{array}$$

$$\text{N} = \begin{array}{c} \begin{array}{ccccc} \text{Visit 0} & \text{Visit 1} & \text{Visit 2} & \text{Visit 3} & \text{Visit 4} \end{array} \\ \begin{pmatrix} 3772 & 3772 & 3772 & 1959 & 702 \\ 0 & 3772 & 3772 & 1959 & 702 \\ 0 & 0 & 3772 & 1959 & 702 \\ 0 & 0 & 0 & 1959 & 702 \\ 0 & 0 & 0 & 0 & 702 \end{pmatrix} \end{array}$$

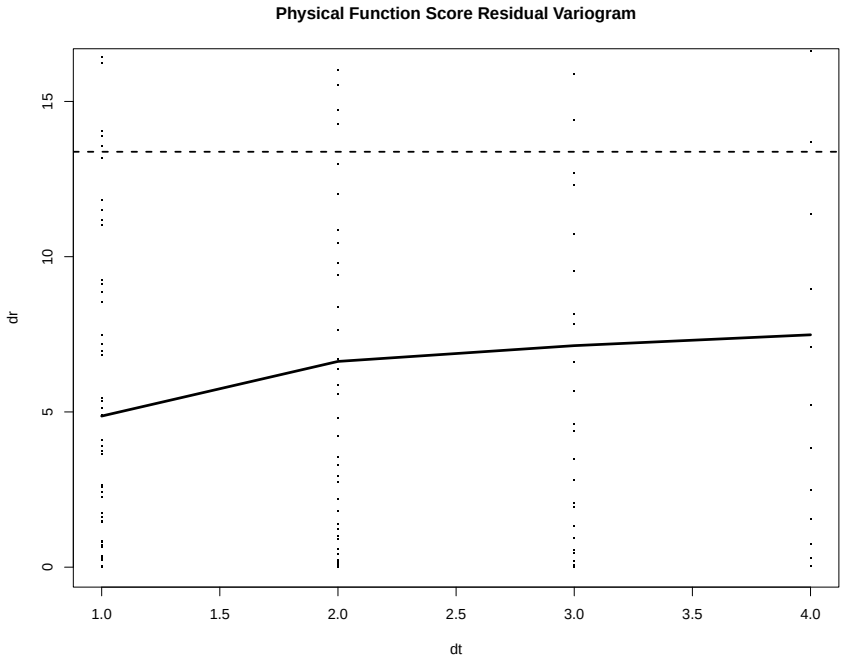

Fig 4: Plot of the Residual Variogram for the Physical Function Score

C GEE Estimates

Below we displayed the outputs from our GEE model from Equation 3, with their corresponding confident interval and p-value.

Covariate	**Adjusted Model**	
	Est (95% CI)	P-value
Time	-0.47 (-0.60, -0.34)	<.001
Perceived Discrimination Score	-0.15 (-0.33, 0.02)	0.089
Race/Ethnicity		
Non-Hispanic White	Reference	
Non-Hispanic Black	-1.83 (-2.11, -1.55)	<.001
Sex		
Female	Reference	
Male	0.79 (0.56, 1.02)	<.001
Medical Condition		
No Known Medical Condition	Reference	
One Known Medical Condition	-0.54 (-0.79, -0.30)	<.001
Two Known Medical Condition	-1.12 (-1.46, -0.77)	<.001
Three or more Medical Condition	-2.46 (-2.99, -1.94)	<.001
Age (Mean Center)	-0.24 (-0.26, -0.22)	<.001
Time:Discrim	-0.04 (-0.14, 0.06)	0.449
Time:Non-Hispanic Black	0.19 (0.04, 0.33)	0.011
Discrim:Non-Hispanic Black	0.17 (0.01, 0.33)	0.036
Time:Discrim:Non-Hispanic Black	0.02 (-0.09, 0.12)	0.754

Table 4: The estimated mean physical function score, along with its corresponding 95% confident interval and p-value.

D Code

The analysis was performed in the R programming language Version 4.3.0 (2023-04-21) (packages: tidyverse, ggplot2, table1, patchwork, geepack). Data management and data wrangling was done using tidyverse. Longitudinal modeling via GEEs was computed using the geepack package. Plots and tables in this paper were generated using ggplot2, patchwork, and table1. Many functions used to perform linear contrast were adapted from Dr. Dan Gillen. Access to the code used to perform the analysis will be granted to those who contact the author.