The Relationship between Obesity, Elevated Depressive Symptoms, and Physical Functioning among United Methodist Clergy: A Longitudinal Study

by

Chenxinan Ma

Global Health Program
Duke Kunshan University

Date:_____

Approved:

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Rae Jean Proeschold-Bell, Supervisor

_____
David E. Eagle

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Chenkai Wu

Thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in the Global Health Program in the Graduate School of Duke Kunshan University and Duke University

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ABSTRACT

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Abstract

Background: Employees in occupations with high job-related distress are at a higher risk of depression and obesity, both of which relate to worse physical functioning. Poor physical functioning can, in turn, lead to several adverse health outcomes. There is a high co-occurrence of obesity and depression and we, hence, sought to assess the independent and joint effects of obesity and elevated depressive symptoms on physical functioning among United Methodist Church clergy in North Carolina, the United States. Methods: We analyzed data from 1,422 clergy who participated in the Clergy Health Initiative Longitudinal Survey in both 2014 and 2016. Elevated depressive symptoms were assessed using Patient Health Questionnaire-9 and obesity was defined based on participants' Body Mass Index. The physical functioning score was measured using the Physical Component Summary of Medical Outcomes Study 12-Item Short Form Survey. We described the participants' characteristics in 2014 and analyzed the data from the 2014 and 2016 waves to assess the association between obesity, elevated depressive symptoms, and physical functioning by using Ordinary Least Squares regression. The joint effect was assessed by including the interaction term between elevated depressive symptoms and obesity in the regression model. We further adjusted covariates including age, gender, race, educational attainment, marital status, physical exercise, financial distress, and work hours per week in the regression model to

control for confounding factors. Results: The study population was largely composed of male (69.90%) and white (91.84%) individuals. Additionally, the vast majority of participants (82.56%) held a master's degree or higher level of education. The prevalence of obesity and elevated depressive symptoms was 39.52% and 7.17%, respectively, among United Methodist Church clergy in North Carolina in 2014. Obesity and elevated depressive symptoms were both independently related to poor physical functioning. The co-occurrence of obesity and elevated depressive symptoms in 2014 had a larger negative effect (β = -4.34; 95% Confidence Interval: -7.87, -0.81) on physical functioning in 2016 than the sum of the individual effects of obesity (β = -4.02; 95% Confidence Interval: -4.93, -3.11) and elevated depressive symptoms (β = -3.25; 95% Confidence Interval: -4.63, -1.17) on physical functioning. Conclusions: The results suggest that there is a joint effect of obesity and elevated depressive symptoms on worse physical functioning among United Methodist Church clergy in North Carolina. More attention should be paid to the diagnosis and treatment of depression and obesity in this population to prevent the negative health sequelae of worse physical functioning.

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Dedication

I dedicate this work to the clergy population and Dr. Rae Jean Proeschold-Bell, who inspired me in learning the role of religion plays in influencing population's health.

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Acknowledgements

To be honest, the second time to write the acknowledgments section for my work made me feel this is so “jiaoqing”, which I know its Chinese very well but never use it in English. I just looked up the English word that can convey what I would like to describe, and it is “hypocritical”. Yes, this is really “hypocritical” but it can really help me to recall what I have experienced so far along the journey from zero to this complete work.

In the past two years, I have reflected several times on whether choosing to pursue my master’s education at Duke Kunshan University (DKU) is a right decision. There were lots of disappointments: 1. Unstable classrooms: in the first year, although the physical classroom remained the same, sometimes, we had to move to Zoom to follow local COVID prevention policies; 2. Fragile friendship: without traditional team building activities, our cohort did not establish a very strong bond as other cohorts… There must be some other sad facts I cannot list all of them here. However, DKU and Duke’s supportive faculty members and staff eliminate all this sadness and disappointment on my side.

When Dr. Tang shared Rae Jean’s research projects with me, I was stunned. Clergy? What is clergy? It seemed that I have learned this word for my TOEFL or GRE test but I was so uncertain about its meaning because I have read, I think, thousands of papers but I have never read any paper studying this population. It is so unique and this

also made me think about whether I would be interested in working with her on this population's health issues. Dr. Tang persuaded me patiently and finally, I decided to have Rae Jean serve as my mentor.

In my heart, Dr. Rae Jean is a strong and impressive female research scholar. She has helped so many health scientists and social researchers along their career pathways and she, herself, also got over lots of hardships in her life.

Fieldwork project proposal, statistical analysis plan, weekly meetings with Drs. Jane Lee and Rae Jean, Dr. Joe Egger's comments and lots of help from various people allowed me to complete my master's thesis. I also express sincere thanks here to Dr. David Eagle and Dr. Chenkai Wu, who agreed to serve as my committee members.

I thank all the people who have helped me get through different kinds of hardships in the past two years. I want to list your names here: Joy, Gabriella, Michelle, Moses, Alice, Anna, Jia, Danyue, Jie, Kaikai, Bairu, Bingyi, Dr. Bradi Granger, Dr. Hanzhang Xu, and Jen.

Mom and dad, thanks for your numerous money order transactions and love! I am about to graduate and come to pursue my Ph.D. degree. I hope you can achieve "healthy ageing". God bless you!

1. Introduction

1.1 The Epidemiology and Burden of Obesity

Obesity is a multifactorial disease caused by a combination of genetic, environmental, and behavioral factors involving an excessive amount of body fat [1-3]. The worldwide prevalence of obesity has experienced a dramatic increase over the past 50 years and reached the pandemic level, which is a complex threat to global health[4]. Globally, it was estimated that approximately 2 billion adults were overweight and obese in 2015, while in the United States (US), more than 40% of adults were obese in 2017-2018[5], which was much higher than other Organisation for Economic Cooperation and Development (OECD) countries[4,6]. The higher prevalence of obesity and overweight populations in the US has been linked to the nation's poor diet, low level of physical activities and high level of sedentary lifestyle[7].

Obesity could lead to detrimental effects on health and it has been well-established that obesity is one of the most important risk factors for numerous non-communicable diseases (NCD) including cardiovascular disease[8], type 2 diabetes mellitus[9], cancers[10,11], and mortality[12]. Obesity-related diseases not only affect individuals, but also cause tremendous economic burden on healthcare systems, as obese individuals tend to spend more on medical care than their non-obese counterparts[13,14]. This economic burden includes direct medical costs, such as

hospitalizations and medication, as well as indirect costs, such as lost productivity and disability[15,16].

The multifactorial nature of obesity calls for urgent efforts to improve obesity-related healthcare. This requires addressing the complex interplay of biological, psychological, and social factors that have contributed to the current obesity pandemic[4,15]. A thorough understanding of these complex relationships is crucial to enhance the provision of obesity-related healthcare[17].

1.2 The Epidemiology and Burden of Depression

Depression, the other serious global health problem, is the most common mental disorder influencing more than 300 million people worldwide and is listed by the World Health Organization (WHO) as the single largest factor contributing to the global burden of disease[18]. The symptoms of depression include persistent feelings of sadness, hopelessness, fatigue and a loss of interest in hobbies and activities[19]. Other symptoms may include changes in appetite, sleep disorders, fatigue, and difficulty concentrating[19].

In 2019, according to the National Survey on Drug Use and Health, 7.8% of US adults had encountered at least one major depressive episode[20]. However, the burden of depression and its complications have exacerbated during the COVID-19 pandemic, particularly for those who are already at greater risk[21]. The pandemic has caused significant disruptions to people's daily lives, including isolation, job loss, financial

distress and fear of contracting the virus[21-23]. All these factors can contribute to increased levels of stress, which can, in turn, trigger or worsen depression[24].

In addition to the increasing burden of psychological disorders, the pandemic has led to a dramatic increase in the demand for mental health services such as mental health consultations and psychotherapy[25]. Despite the increasing need for mental health services, most of these services have been disrupted or even suspended due to the pandemic[25]. Additionally, in some low-resource settings, residents have very limited access to mental health services making it difficult to meet the increasing demand for these services[26-29]. This situation emphasizes the need for increased investment in mental health services and resources and innovative strategies of providing mental health services to address the growing burden of depression and other mental health disorders of concern[26,29].

Depression can also lead to physical health problems[30] such as chronic pain[31] and diabetes[32,33]. Depression can affect a person's ability to work and perform daily tasks[34]. The impact of depression is not limited to individuals but also extends to their families, communities, and society[35]. Depression can also lead to substance abuse[36], self-harm behaviors[37,38], and suicidal ideation[39], which have far-reaching consequences for society[40]. Besides the burden of disease, depression imposes a large economic burden on individuals and society, with estimated costs of over $ 320 billion (year 2020 values) per year for adults with major depressive disorder in the US alone[40]. Effective depression

treatment is crucial in reducing the economic and disease burden of this mental health condition. Effective prevention and treatment strategies are essential to reduce the impact of depression and improve the overall well-being of individuals and society.

1.3 The Relationship between Obesity and Depression

Research has consistently demonstrated that depression is strongly associated with obesity making depression more likely to co-occur with obesity[41-43]. The exact mechanism behind this relationship is not fully understood, but it is believed that the physical, social, and psychological consequences of obesity may contribute to the development of depression[44,45]. In a recent review, Yuri and his colleagues summarized the evidence of shared biological mechanisms between depression and obesity and several biological pathways such as genetic factors, the hypothalamic-pituitary-adrenal (HPA) axis, and immuno-inflammatory activation could link depression and obesity[46]. In addition to biological mechanisms, Yuri stated that behavioral and psychosocial factors such as emotional eating and sedentary lifestyles also play an important role in linking depression and obesity[47].

Additionally, social stigma and discrimination associated with being overweight or obese can also contribute to the development of depression[48]. The psychological implications of low self-esteem, negative body image, and perceived lack of control over one's weight can lead to the occurrence of depressive symptoms in individuals[44]. Moreover, current evidence suggests that weight-based stigma and discrimination could

heighten the vulnerability to psychological distress, which in turn may contribute to compromised physical health[48].

Overall, the strong association between depression and obesity can be attributed to shared biological, behavioral, and psychosocial factors, which highlight the complex nature of the relationship between these two conditions. Understanding these underlying mechanisms is crucial in the development of effective treatment strategies for individuals suffering from both conditions.

1.4. Health-related Quality of Life and Physical Functioning

Quality of life (QoL) is a subjective assessment of the positive and negative aspects of one's life, as defined by the WHO[49]. In recent years, the concept of health-related QoL (HRQoL) was developed and it encompasses the components that can be clearly shown to affect health including physical health, mental health and their correlates[50,51]. HRQoL has gained considerable attention in the field of health research[52]. HRQoL is a crucial metric to monitor in the US to assess the progress of Health People initiatives in the US and achieving the improvement in the HRQoL has been a central public health goal[53]. However, the COVID-19 pandemic posed substantial challenges on achieving this fundamental objective[54,55]. Hence, understanding the effects of the negative consequences of the pandemic on HRQoL is of great importance to relieve the public health burden.

Physical functioning (PF), the ability to perform both basic and instrumental activities of daily living such as climbing stairs and bathing, is the essential building block of HRQoL[56,57]. PF has been found to be strongly associated with health outcomes and poor PF can lead to several adverse health outcomes such as fall injuries[58] and mortality[59,60]. Maintaining good PF is, therefore, essential for achieving a high level of HRQoL and avoiding negative health outcomes.

1.5. The Effects of Obesity and Depression on Individual Physical Functioning

It is suggested that both obesity and depression may significantly influence HRQoL[52,61]. The effects of depressive symptoms and obesity on PF have been the subject of research in recent years and previous studies have demonstrated that both depression and obesity can adversely affect PF[52,62-66]. Depression has been linked to decreased physical activity, which can lead to a decline in overall PF[67-69]. Obesity can also contribute to decreased physical activity and mobility, as well as reduced HRQoL[70,71]. Most studies, however, have only examined the relationship between PF and these two conditions individually (i.e. the association between depression and PF or the association between obesity and depression). Moreover, there is limited evidence testing these three factors together and exploring their potential relationships in specific populations that are more likely to experience depression- and obesity-related risk factors.

1.6. Clergy Population and Study Aims

Prior research has indicated that several occupational conditions such as a stressful work environment and long work hours are associated with an increased risk of obesity[72,73] and depression[74,75]. Clergy are an occupational group with high work demands and unpredictable work schedules[76,77]. Although the causes are not known, higher rates of both depression and obesity have been observed among certain clergy populations, such as the United Methodist Church clergy, than the general population[76,78]. Given the growing prevalence of depression and obesity separately, there is room for concern that more people will have both simultaneously. Understanding the health impacts and care needs for people who have comorbid depression and obesity will help mobilize resources to improve well-being and provide adequate care[79].

Researchers found that people who have comorbid obesity and depression had worse health outcomes such as a higher risk of cardiovascular diseases[80] and poor work performance[81], but the relationship remains unknown for PF. In this study, we aimed to assess the effects of depression and obesity on PF separately and jointly in the clergy population. We hypothesized that both obesity and elevated depressive symptoms would be negatively associated with PF and that there would be a synergistic interaction term between obesity and elevated depressive symptoms on PF.

2. Methods

2.1 Study Design

We used data from the Clergy Health Initiative Longitudinal Survey (CHILS). The CHILS is a longitudinal study with the aim to assess the physical health, mental health, and spiritual well-being of UMC clergy in North Carolina starting in 2008[82]. The CHILS was collected in panel study format through 2016, meaning that any participant who was invited once was invited to the following data collection waves, even if that person no longer met the initial inclusion criteria. Hence, in the follow-up surveys, the CHILS also collected data on clergy who had fully retired, moved out of state, changed careers, or declined to participate in previous waves, as well as newly appointed clergy. The data from the 2014 and 2016 waves were used to examine the relationship between obesity, elevated depressive symptoms, and PF.

2.2 Setting

North Carolina, located in the Southeastern region of the US, ranks as the 28th-largest state and the 9th-most populous state in the nation with approximately 10.5 million people[83,84]. The racial composition in the state of North Carolina is mainly White, followed by Black and Hispanic[84]. The majority of North Carolina residents religiously identify in Christian[83]. The UMC is the third-largest Christian denomination in the US and has the second-largest number of adherents in North Carolina[47,85,86].

2.2 Participants

The CHILS invited both full- and part-time UMC clergy to participate in this study. Contact information of eligible clergy was obtained from the public-access UMC conference directories in the North Carolina Conference[87] and Western North Carolina Conference[88], which serve the eastern and western half of the state of North Carolina, respectively. Eligible clergy were then approached through email, mail, and telephone. Detailed study sample information for the CHILS has been described elsewhere[89]. In 2014, 2,380 clergy were eligible to participate in this study. At the end of fielding the 2014 survey, a total of 1,788 clergy completed the survey, resulting in a response rate of 78.4%. Because we wanted to investigate the influence of occupational characteristics on our study factors, we excluded clergy who were retired or on leave (N=100) in 2014. We sought a sample that took the survey in both 2014 and 2016. We, therefore, excluded clergy who were invited for the first time to take the survey in 2016 and we excluded clergy who were invited to take the survey in 2014 but did not in 2016. We further excluded clergy who were lost to follow-up between 2014 and 2016 (N=247) and clergy who had any missing values on self-reported body weight and height, the score of the depressive symptoms measure, or the score of the physical functioning measure (N=19). With these exclusion criteria, the number of the current study sample is 1,422. A flowchart of the study population selection is displayed in **Figure 1**.

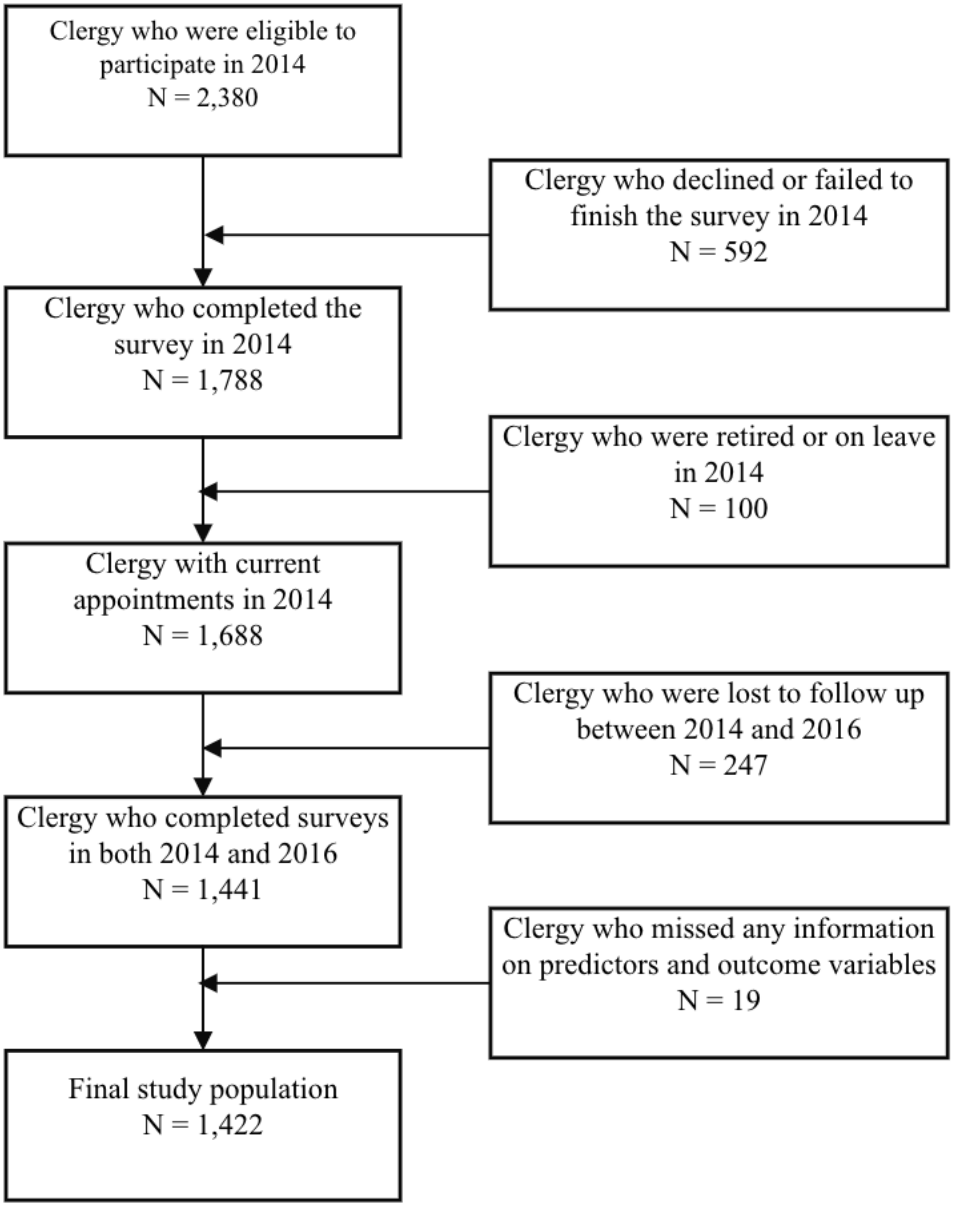


Figure 1 Study Population Inclusion Flowchart

2.3 Procedures

Prior to participation, all clergy provided informed consent. Data were collected by a social science research firm, Westat, a contract research organization to Duke Divinity School. Westat sent all eligible clergy an advance letter introducing the survey along with a prepaid incentive of $25. Clergy were emailed a web link and password to access the survey securely online and the web survey took respondents approximately one hour to finish. Westat prompted clergy four times before mailing a paper copy of the survey to them in 2014. The CHILS was conducted completely online in 2016.

All procedures of the CHILS were approved by the Duke University Campus Institutional Review Board for each wave and additionally, by the Westat Institutional Review Board for waves 2008-2016. (IRB-approved protocol: Number 2017-1197)

2.4 Measures

2.4.1 Body Mass Index

Participants reported height in inches without shoes and weight in pounds with light clothing. We converted pounds and inches into kilograms and meters, respectively, for Body Mass Index (BMI) computation by dividing participants' weight (in kilograms) by their height squared (in meters). We divided participants into standard BMI categories using the cutoff values for adults recommended by the US Centers for Disease Control and Prevention: underweight as <18.5 kg/m^2, normal weight as 18.5 to <25 kg/m^2, overweight as 25 to <30 kg/m^2, and obese as $\geqslant$30 kg/m^2 [90].

2.4.2 Depressive Symptoms

Depressive symptoms were measured using the 9-item self-report Patient Health Questionnaire (PHQ-9), which has been established as a valid screening and severity measure for depressive symptoms[91,92]. The PHQ-9 asks respondents about the frequency of depressive symptoms during the previous 2 weeks[93]. The PHQ-9 questionnaire uses a four-point response scale where respondents can choose from the following options: 0 = Not at all, 1 = Several days, 2 = More than half the days, and 3 = Nearly every day. With a total of 9 questions in the PHQ-9, participants' possible scores range from 0 to 27. For interpretation, participants with a PHQ-9 score equal to or higher than 10 were considered as having elevated depressive symptoms; validity studies show that participants with scores 10 and higher often qualify for a diagnosis of major depression[92,94,95].

2.4.3 Physical Functioning

The Medical Outcomes Study (MOS) Short Form (SF)-12, is a 12-item measure derived from the SF-36 and is an established, valid and reliable instrument to assess QoL[96,97]. Example items include climbing stairs and physical activity level[97]. In this study, we used the SF-12 version 1. We calculated the Physical Health Composite Score from the MOS-SF-12 following the scoring guideline[98]. In the general US population, the average Physical Health Composite score is 50 with standard deviations of 10[97]. Higher scores indicate better PF. The SF-12 has been shown to provide good reliability, internal

consistency, and construct validity[99,100]. All the items in the PHQ-9 and MOS-SF-12 Version 1 were listed in Appendix A.

2.4.4 Covariates

In addition to collecting participants' sociodemographic information, the survey included items to measure participants' physical and mental health and spiritual well-being. Covariates included sociodemographic factors (age, gender, race, education level, and marital status), physical exercise, financial distress, and the number of total work hours per week. Age was measured in years. In the survey, respondents were presented with five options for their educational attainment: "Less than or equal to high school education," "Associate degree," "Bachelor's degree," "Master's degree," and "Doctoral degree". Nevertheless, we observed a smaller number of participants with education below a bachelor's degree compared to those with more advanced degrees. Therefore, we reclassified participants' educational levels into three categories: less than a master's degree, master's degree, and doctoral degree. Physical exercise was categorized by converting participants' self-reported weekly exercise time into a binary outcome on the basis of whether their values met the minimal requirement of 150 minutes of moderate or intensive physical activity per week suggested by the Centers for Disease Control and Prevention[101]. Marital status was defined as whether the participant was married or living with a romantic partner or not. To assess the financial distress of clergy, we inquired about their current personal financial situation and allowed them to choose

from five options indicating the level of stress it caused them: extremely, very, moderately, slightly, and not at all stressful. We also asked the participant to report their total hours per week doing ministry work.

2.5 Analysis

First, we examined the normality of continuous variables using the Shapiro-Wilk test. For interpretation, we grouped the clergy's BMI categories into two categories: non-obese and obese. The non-obese group consisted of underweight, healthy weight, and overweight clergy, while the obese group included only those who were classified as obese based on participants' BMI values. We described the sample characteristics in 2014 by obese group using counts (percentages) for categorical variables and means (Standard deviation; SD) for numerical variables with normal distribution or medians (Interquartile range; IQR) for numerical variables with skewed distribution.

Second, we conducted ordinary least squares (OLS) regression analysis to examine the individual relationships between obesity, depression, and PF. Subsequently, we conducted a second OLS regression model adjusting for age, gender, race, education levels, marital status, physical exercise, financial distress, and work hours per week.

Third, we added an interaction term between obesity and elevated depressive symptoms on PF to the unadjusted and multivariate-adjusted OLS regression models. The regression coefficient of the interaction term (β) is the absolute difference between the joint effect and the independent effects of obesity and elevated depressive symptoms

on PF. The joint effect of obesity and elevated depressive symptoms on PF as measured on a continuous scale is contributed by the sum of the individual effects of obesity and elevated depressive symptoms and the interaction term. A synergistic effect of obesity and elevated depressive symptoms on PF is defined as $\beta > 0$, while $\beta < 0$ indicates an antagonistic effect of obesity and elevated depressive symptoms on PF. $\beta = 0$ means that there is no interaction effect of obesity and elevated depressive symptoms on PF. A two-sided p-value less than 0.05 was deemed statistically significant. All statistical analyses were performed using Stata Version 17.0 (Stata Corp., College Station, TX, United States of America).

3. Results

3.1 Sample Characteristics

In **Table 1,** we display the characteristics of the study population (N=1,422) by their obesity status. The majority of the study population was male (69.90%), white (91.84%), and married or living with a romantic partner (87.06%). The predominance of the sample (82.56%) had a master's degree or higher and 31.39% of participants perceived no financial stress. Most respondents (86.27%) served as lead/solo pastors in their churches and the median number of working hours per week in the 2014 cohort was 50.00 (IQR: 40.00-57.00). Most (73.78%) of the participants' weekly exercise time met the minimal requirement of 150 minutes per week suggested by the Centers for Disease Control and Prevention. The median score of the PHQ-9 was 2.00 (IQR:1.00-5.00) while the median BMI was 28.35 (IQR: 24.94-32.89). The prevalence of elevated depressive scores among UMC clergy who were in service in 2014 was 7.17% while the prevalence of obesity was 39.52%. The median PF score was 53.78 (IQR: 48.61-55.92).

Table 1 Characteristics of the Study Population

	Non-obese, N=860 n (%)	**Obese, N=562 n (%)**	**Total, N=1,422 n (%)**
Age, median year (IQR)	58.00 (48.00-65.00)	57.50 (51.00-64.00)	58.00 (49.00-64.00)
Gender			
Female	264 (30.70%)	164 (29.18%)	428 (30.10%)
Male	596 (69.30%)	398 (70.82%)	994 (69.90%)
Race and Ethnicity			
White	802 (93.26%)	504 (89.68%)	1,306 (91.84%)
Black	35 (4.07%)	41 (7.30%)	76 (5.34%)

Other*	23 (2.67%)	17 (3.02%)	40 (2.81%)
Education levels			
Less than master's degree	121 (14.07%)	127 (22.60%)	248 (17.44%)
Master's degree	607 (70.58%)	367 (65.30%)	974 (68.50%)
Higher than master's degree	132 (15.35%)	68 (12.10%)	200 (14.06%)
Primary appointment role			
Associate pastor	95 (14.57%)	38 (8.35%)	133 (12.01%)
Lead/solo pastor	543 (83.28%)	412 (90.55%)	955 (86.27%)
Other roles**	14 (2.15%)	5 (1.10%)	19 (1.72%)
Marital status			
Not currently married/living without a romantic partner	101 (11.74%)	83 (14.77%)	184 (12.94%)
Currently married/living with romantic partner	759 (88.26%)	479 (85.23%)	1,238 (87.06%)
Total number of hours worked per week, median (IQR)	50.00 (40.00-55.00)	50.00 (40.00-60.00)	50.00 (40.00-57.00)
Financial stress			
Not at all stressful	299 (34.81%)	147 (26.16%)	446 (31.39%)
Slightly stressful	302 (35.16%)	179 (31.85%)	481 (33.85%)
Moderately stressful	176 (20.49%)	127 (22.60%)	303 (21.32%)
Very stressful	56 (6.52%)	65 (11.57%)	121 (8.52%)
Extremely stressful	26 (3.03%)	44 (7.83%)	70 (4.93%)
Physical activity, median(IQR)	270.00 (140.00-495.00)	180.00 (90.00-390.00)	240.00 (120.00-450.00)
Exercise time meets minimal requirement			
No	185 (22.32%)	175 (32.17%)	360 (26.22%)
Yes	644 (77.68%)	369 (67.83%)	1,013 (73.78%)
PHQ-9 Score,	2.00 (1.00-5.00)	3.00 (1.00-6.00)	2.00 (1.00-5.00)

median (IQR)			
Elevated depressive symptoms			
No	821 (95.47%)	499 (88.79%)	1,320 (92.83%)
Yes	39 (4.53%)	63 (11.21%)	102 (7.17%)
Body Mass Index, median (IQR)	25.54 (23.71-27.62)	34.15 (31.87-37.88)	28.35 (24.94-32.89)
Physical Functioning Score, median (IQR)	55.26 (51.54-56.68)	51.07 (44.04-54.58)	53.78 (48.61-55.92)

Notes: *Other races and ethnicities include Latinx and Asian.

**Other primary appointment roles include co-pastor, deacon, and extension minister.

When we compared participants' characteristics across the obese group, we noticed that obese participants reported a higher number of work hours per week, engaging in less physical activity, a higher prevalence of elevated depressive symptoms, and lower PF scores than non-obese participants. In addition, obesity was positively associated with elevated depressive symptoms (Odds Ratio, OR: 2.66 (95% Confidence Interval, 95% CI: 1.76-4.02)).

3.2 The Independent and Joint Effects of Obesity and Elevated Depressive Symptoms on PF

We present the independent effect of obesity and elevated depressive symptoms in **Table 2**. We found that both obesity (β = -4.02; 95% CI: -4.93, -3.11) and elevated depressive symptoms (β = -3.25; 95% CI: -4.63, -1.17) in 2014 were associated with lower PF scores in 2016 in our study population. Even after adjustment using covariates relating to obesity and elevated depressive symptoms, the negative associations

remained. **Table 3** and **Figure 3** show the results after including an interaction term in our OLS regression model. We found a significant negative joint effect of obesity and elevated depressive symptoms on PF (β = -4.34; 95% CI: -7.87, -0.81). The interaction effect size of β = -4.34 < 0 indicated that the joint effect of obesity and elevated depressive symptoms on PF was larger than the sum of the independent effects of obesity and elevated depressive symptoms. After adjusting for covariates, the joint effect remained. However, after including the interaction term in the OLS regression model, the effect of elevated depressive symptoms on PF became weak with a wide 95% CI, while the effect of obesity on poor PF remained.

Table 2 The Longitudinal Association of Obesity and Elevated Depressive Symptoms in 2014 on Physical Functioning in 2016

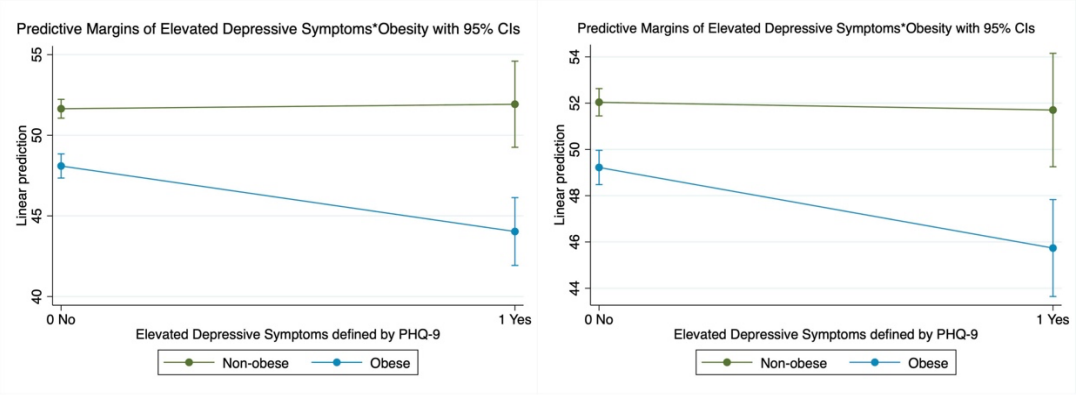
Predictors	Physical Functioning Score	
	Crude estimate	Adjusted estimate[a]
	β (95% CI)	β (95% CI)
Obesity	-4.02 (-4.93, -3.11)	-3.25 (-4.19, -2.32)
Elevated depressive symptoms	-3.25 (-5.01, -1.49)	-2.90 (-4.63, -1.17)

Notes: Beta-coefficients represent the mean change in the 2016 PF score for each 1-unit change in the predictors. a: Adjusted for age, sex, race, education levels, marital status, physical exercise, financial distress, and hours worked per week.

Table 3 The Longitudinal Independent and Joint Effects of Obesity and Elevated Depressive Symptoms in 2014 on Physical Functioning in 2016

Predictors	Physical Functioning Score	
	Crude estimate	Adjusted estimate[a]
	β (95% CI)	β (95% CI)
Obesity	-3.55 (-4.50, -2.60)	-2.86 (-3.83, -1.89)
Elevated depressive symptoms	0.28 (-2.45, 3.01)	-0.40 (-2.98, 2.18)
Obesity*Elevated depressive symptoms	-4.34 (-7.87, -0.81)	-3.50 (-6.82, -0.17)

Notes: Beta-coefficients represent the mean change in the 2016 PF score for each 1-unit change in the predictors. a: age, sex, race, education levels, marital status, physical exercise, financial distress, and hours worked per week. Interpretation instance: the joint effect of obesity and elevated depressive symptoms on PF = -3.55 + 0.28 - 4.34 = -7.61 while the sum of independent effects of obesity and elevated depressive symptoms without interaction = -3.55 + 0.28 = -3.27. The departure from additivity is contributed by = -7.61-(-3.27) = -4.34, by definition, this is the regression coefficient of the interaction term.



A B

Figure 2 The Average Effect of Obesity on Physical Functioning for Participants with and without Elevated Depressive Symptoms

Notes: A: Crude model; B: Model with adjustment for age, sex, race, education levels, marital status, physical exercise, financial distress, and hours worked per week.

4. Discussion

4.1 Research Findings

In this large occupational cohort study, we found that obesity and elevated depressive symptoms are independently associated with poor PF. Moreover, the results suggest that there is a joint effect of obesity and elevated depressive symptoms on PF in both unadjusted and adjusted models. The joint effect of obesity and elevated depressive symptoms on PF was larger than the sum of their independent effects.

Previous research has consistently shown a significant relationship between depression and PF in various populations, including the general population[102] and specific subgroups such as those with chronic medical conditions[103] and older adults[104,105]. Our research findings suggest that there is a negative relationship between elevated depressive symptoms and PF specifically among the UMC clergy population. Compared with other populations, clergy members may be faced with some unique stressors and demands, which could trigger the onset of depression and physical impairment[79,106,107]. For example, clergy members may experience emotional burdens due to their work and may be more likely to neglect self-care activities such as exercise or healthy eating habits, leading to physical health problems[108]. While our research finding is specific to the clergy population, it adds to the growing body of literature highlighting the relationship between depression and PF.

The negative association of obesity with PF has also been shown by numerous studies among various populations[66,109,110]. However, previous research mainly focused on the elderly while less attention was paid to populations with a high likelihood of obesity. As demonstrated by the results from the OLS regression model with the interaction term, the average PF for obese participants with elevated depressive symptoms was 7.61 points lower (i.e., worse) than the average PF for non-obese participants without elevated depressive symptoms. Obesity may interact with elevated depressive symptoms, resulting in a larger effect on PF. Before examining the interaction between obesity and elevated depressive symptoms, we assessed the individual effects of obesity and elevated depressive symptoms on PF and found both factors associated with poor PF. Additionally, we examined the relationship between obesity and elevated depressive symptoms and found that obese participants had higher odds of reporting experiencing elevated depressive symptoms. Moreover, after adjusting for confounders, the results remained in the same direction. Nevertheless, it is important to be cautious when interpreting our study results as true biological interactions, especially when there is heterogeneity in the effects observed after including the interaction term in the regression model. The heterogeneity could be due to several factors, including confounding, random error, misclassification, and other biases that are inherent in the study design or data collection process.

In the model that included an interaction term for obesity and elevated depressive symptoms, the significant association between elevated depressive symptoms and PF disappeared. This could be due to the relatively fewer cases in 2014 (n=102, 7.17%) with elevated depressive symptoms compared with the number of obese clergy (N=562, 39.52%) in our study sample. People with elevated depressive symptoms are more likely to be obese, which makes it even more difficult to disentangle the effects. Alternatively, if true, this absence of relationship, obesity may play a more important role in reducing individual PF. Our study findings are consistent with a previous cross-sectional study among the Dutch exploring the combined effect of obesity and mental disorders on physical HRQoL[111]. In this study of Dutch adults, researchers examined the impact of obesity, abdominal obesity, and major depression/anxiety on physical HRQoL and they found that all three conditions were independently associated with reduced physical HRQoL, and that the co-occurrence of obesity, abdominal obesity, and major depression had a greater negative impact on physical HRQoL than any one of these conditions alone[111]. Our results based on a longitudinal design add value to their research findings and further confirm the relationship between obesity, elevated depressive symptoms and PF.

4.2 Implications for Practice

It is important for individuals with elevated depressive symptoms or who are struggling with obesity to seek appropriate medical and mental health care to help

manage these conditions and improve PF. A combination of physical activity, healthy eating, and mental health support can help individuals suffering from these two health issues achieve better overall health and well-being[112-115]. The relationships between obesity, elevated depressive symptoms and PF underscore the need for targeted interventions and support for this population to address the physical and mental health implications of mental disorders including depression and chronic health illnesses that may result from obesity.

4.3 Implications for Further Research

Further research is needed to explore the underlying mechanisms linking obesity, depression and PF among the clergy population and to identify effective intervention strategies to improve the current situation. Given the fewer cases with elevated depressive symptoms in our study sample, future studies may seek data on populations with a higher burden of mental disorders to reassess these associations. Additionally, to improve the accuracy of measurements and minimize the risk of misclassifications, future studies could have trained professionals use calibrated tools to measure participants' anthropometric and PF data.

4.4 Study Strengths and Limitations

The study has several limitations. Firstly, the study population was limited to the UMC clergy population and, as we presented in the overview of the dataset, the UMC clergy population's characteristics are different from the general population in several

ways, including the high percentage of clergy who received a college education or higher (91.21%), whereas the percentage of the US population age 25 and older with a bachelor's or higher degree is approximately 40% and 33% in NC[84,116]. These differences between the UMC clergy population and the general US population may affect the generalizability of the results. However, our evidence can still be used to inform future interventions among other populations. The other limitation of our study is information bias. Misclassification may have occurred in the measurements of obesity, elevated depressive symptoms, PF, and other subjective covariates, which were collected by a self-administered survey. The study relied on self-reported depressive symptoms and this may introduce bias such as recall bias[117]. For depression measurement, a self-administrated questionnaire might overestimate the burden of the major depressive disorder in all groups of the population, namely more false positive depressive patients in our study. In the CHILS, we implemented the PHQ-9 as the depression screening tool because the PHQ-9 is freely available and has been widely validated by high-quality studies in various populations[118,119]. Additionally, the PHQ-9 has several cut-off values to detect people with different levels of depression severity. In this study, we applied the standard cut-off score of 10 or higher for the PHQ-9 in distinguishing people with likely major depressive disorder from others and this criterion has been shown to have a high sensitivity and specificity regardless of participants' age, which might reduce the risk of exposure misclassification[92], although some is likely still present. This is similar to the

bias that can occur with self-reported weight and height, where people tend to underreport their weight[120]. Moreover, in the CHILS, we used the SF-12 v1 rather than the SF-12v2 to measure participants' HRQoL because the decision was made in 2008. The major differences between the SF-12 v1 and v2 are wording and response options[121]. Previous studies demonstrated that the internal consistency of the SF-12v1 was 0.88 to 0.89 for the physical component summary, which is highly similar to the SF-12v2, while compared with the SF-12v1, the SF-12v2 had higher concurrent and construct validity[122,123]. Although PF measurement may be more accurate if measured directly, for example through wearable devices to measure objective PF like knee extensor strength or handgrip strength[124]; however, this is not feasible for a large cohort study given the great cost of such devices, making convenient tools such as reliable questionnaires more feasible for our case. Nevertheless, it is recommended that future studies use more reliable measures of anthropometric metrics, depression and PF, and reassess the association between these factors to improve the reliability of the findings.

Another limitation is non-response across waves. After excluding clergy who were retired or were on leave in 2014, there were 1,688 eligible clergy in 2014. In the 2014 cohort, 247 clergy were lost to follow-up in 2016 and the loss to follow-up rate was 14.63%. Loss to follow-up is of great importance in assessing a cohort study's validity. We described the participants' characteristics using 2014 data before excluding participants who were lost to follow-up in 2016. The number of participants with

depression was 135 (8.00%) and the number of obese participants was 662 (39.52%); we did not observe a large difference in the exposure distribution after the exclusion. The median PF score before excluding ineligible clergy was 53.71 with an IQR of 48.24-55.92, which is similar to the median score in our current study sample. These results suggest that the loss to follow-up rate of 14.63% may not pose serious threats to the validity of the current study. Finally, to deal with confounding, we adjusted the relationships between obesity and elevated depressive symptoms with PF using the covariates of age, sex, race, educational level, marital status, physical exercise time, financial distress level, and work hours per week. Although the results suggested that anxiety measured by the General Anxiety Disorder-7 is a strong confounder, we did not adjust for anxiety in the OLS regression model because we found that there was a high co-occurrence of depression and anxiety scores in our study sample. We conducted a Pearson correlation analysis and found that the coefficient between the score of the PHQ-9 and the GAD-7 was 0.7813, which is larger than 0.70, so we decided not to include anxiety as a confounder in the OLS regression model.

Our study has several strengths that make it a valuable contribution to the field. First, it is a longitudinal study that fields follow-up surveys every two years, allowing for a more comprehensive examination of the relationship between elevated depressive symptoms, obesity, and PF over an extended period of time. This frequency of follow-up surveys is sufficient to detect changes in these variables and to assess their long-term

effects. Second, our study has achieved very high response rates (75.1% in 2014 and 72.7% in 2016), which is critical for reducing potential bias and improving the generalizability of our findings. The high response rates suggest that our results accurately reflect the experiences of our study population. Finally, our study is unique in that it is an occupational cohort study of clergy, with a sample size that is relatively large compared to other research studying religious professionals.

5. Conclusion

In conclusion, obese clergy with elevated depressive symptoms had a lower PF score compared with non-obese clergy without elevated depressive symptoms. The results revealed that both elevated depressive symptoms and obesity were negatively associated with PF and there was a significant interaction effect between elevated depressive symptoms and obesity, indicating that the negative impact of elevated depressive symptoms on PF was stronger among obese clergy than among non-obese clergy. These findings highlight the importance of addressing both conditions in clinical and public health interventions due to the risk of exacerbating the decline of PF among certain populations.

Appendix A Data Collection Instruments and Scoring Guide

Table 4 PHQ-9

Questions	Not at all	Several days	More than half the days	Nearly every day
1. Little interest or pleasure in doing things	0	1	2	3
2. Feeling down, depressed, or hopeless	0	1	2	3
3. Trouble falling or staying asleep, or sleeping too much	0	1	2	3
4. Feeling tired or having little energy	0	1	2	3
5. Poor appetite or overeating	0	1	2	3
6. Feeling bad about yourself — or that you are a failure or have let yourself or your family down	0	1	2	3
7. Trouble concentrating on things, such as reading the newspaper or watching television	0	1	2	3
8. Moving or speaking so slowly that other people could have noticed? Or the opposite — being so fidgety or restless that you have been moving around a lot more than usual	0	1	2	3
9. Thoughts that you would be better off dead or of hurting yourself in some way	0	1	2	3

Table 5 MOS SF-12 Version 1

Domain	Response
1. In general, would you say your health is:	1 - Excellent; 2 - Very good; 3 - Good; 4 - Fair; 5 - Poor
2. Moderate activities, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf:	1 - Yes, Limited A Lot; 2 - Yes, Limited A Little; 3 - No, No Limited At All
3. Climbing several flights of stairs:	1 - Yes, Limited A Lot; 2 - Yes, Limited A Little; 3 - No, No Limited At All
During the past 4 weeks, have you had any of the following problems with your work or other daily activities as a result of your physical health?	
4. Accomplished less than you would like:	1 - Yes; 2 – No
5. Were limited in the kind of work or other activities	1 - Yes; 2 – No
During the past 4 weeks, have you had any of the following problems with your work or other daily activities as a result of any emotional problems (such as feeling depressed or anxious)?	
6. Accomplished less than you would like:	1 - Yes; 2 – No
7. Didn't do work or other activities as carefully as usual:	1 - Yes; 2 - No
8. During the past 4 weeks, how much did pain interfere with your normal work (including both work outside the home and housework)?	1 - Not at all; 2 - A little bit; 3 - Moderately; 4 - Quite a bit; 5- Extremely
These questions are about how you feel and how things have been with you during the past 4 weeks. For each question, please give the one answer that comes closest to the way you have been feeling. How much of the	

time during the past 4 weeks?

9. Have you felt calm and peaceful?	1 - All of the Time; 2 - Most of the Time; 3 - A Good Bit of the Time; 4 - Some of the Time; 5 - A Little of the Time; 6 - None of the Time
10. Did you have a lot of energy?	1 - All of the Time; 2 - Most of the Time; 3 - A Good Bit of the Time; 4 - Some of the Time; 5 - A Little of the Time; 6 - None of the Time
11. Have you felt downhearted and blue?	1 - All of the Time; 2 - Most of the Time; 3 - A Good Bit of the Time; 4 - Some of the Time; 5 - A Little of the Time; 6 - None of the Time
12. During the past 4 weeks, how much of the time has your physical health or emotional problems interfered with your social activities (like visiting with your friends, relatives, etc.)?	1 - All of the Time; 2 - Most of the Time; 3 - A Good Bit of the Time; 4 - Some of the Time; 5 - A Little of the Time; 6 - None of the Time

Table 6 Weights Used to Score Physical (PCS-12) and Mental (MCS-12) Scales

Item Response Choice(s)	Indicator Variable (i/o)	Physical Weight	Mental Weight
Moderate Activities (PF02)			
Limited a lot	PF02_1	-7.23216	3.93115
Limited a little	PF02_2	-3.45555	1.8684
Climbing Several Flights of Stairs (PF04)			
Limited a lot	PF04_1	-6.24397	2.68282
Limited a little	PF04_2	-2.73557	1.43103
Accomplish less than you would like (RP2)			
Yes	RP2_1	4.61617	1.4406
Limited in the kind of activities (RP3)			
Yes	RP3_1	-5.51747	1.66968
Pain interferes with normal work (BP2)			
Extremely	BP2_1	-11.25544	1.48619

Quite a bit	BP2_2	-8.38063	1.76691
Moderately	BP2_3	-6.50522	1.49384
A little bit	BP2_4	-3.8013	0.90384
In general, would you say your health is (GH1)			
Poor	GH1_1	-8.37399	-1.71175
Fair	GH1_2	-5.56461	-0.16891
Good	GH1_3	-3.02396	0.03482
Very good	GH1_4	-1.31872	-0.06064
Have a lot of energy (VT2)			
None of the time	VT2_1	-2.44706	-6.02409
A little of the time	VT2_2	-2.02168	4.88962
Some of the time	VT2_3	-1.6185	-3.29805
A good bit of the time	VT2_4	-1.14387	-1.65178
Most of the time	VT2_5	-0.42251	-0.92057
Health interferes w/social activities (SF2)			
All the time	SF2_1	-0.33682	6.29724
Most of the time	SF2_2	-0.94342	-8.26066
Some of the time	SF2_3	-0.18043	-5.63286
A little of the time	SF2_4	0.11038	-3.13896
Accomplish less than you would like (RE2)			
Yes	RE2_1	3.04365	6.826
Didn't do activities as carefully as usual (RE3)	RE3_1	2.32091	-5.69921
Yes			
Felt calm and peaceful (MH3)			
None of the time	MH3_1	3.46638	-10.19085
A little of the time	MH3_2	2.90426	-7.92717
Some of the time	MH3_3	2.37241	-6.31121
A good bit of the time	MH3_4	1.36689	-4.09842
Most of the time	MH3_5	0.66514	-1.94949
Felt downhearted and blue (MH4)			
All of the time	MH4_1	4.61446	-16.15395
Most of the time	MH4_2	3.41593	-10.77911
A good bit of the time	MH4_3	2.34247	-8.09914
Some of the time	MH4_4	1.28044	-4.59055
A little of the time	MH4_5	0.41188	-1.95934
Constant		56.57706	60.75781

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