American Journal of Public Health Research, 2024, Vol. 12, No. 4, 54-63
Available online at http://pubs.sciepub.com/ajphr/12/4/1
Published by Science and Education Publishing
DOI:10.12691/ajphr-12-4-1

Sleep Quality and Physical Activity Predict Patient Health Questionnaire (PHQ) Scores in Adults

Peter D. Hart[1,2,*]

[1]Health Promotion Research, Havre, Montana, USA
[2]Kinesmetrics Lab, Tallahassee, Florida, USA
*Corresponding author: pdhart@outlook.com

Received September 07, 2024; Revised October 09, 2024; Accepted October 15, 2024

Abstract **Background**: Both sleep quality (SQ) and physical activity (PA) are known factors associated with positive health outcomes. Less is known about the extent to which both SQ and PA independently relate to symptoms of depression. The purpose of this study was to examine the ability of SQ and PA to predict scores from the patient health questionnaire (PHQ). **Methods**: A cross-sectional convenience sample of 6,205 adults was used for this study. Sleep quality was assessed using six questionnaire items asking about sleep time, sleep interruptions, patient-reported sleep issues, and overall sleepiness. Each sleep item was dichotomized to indicate poor sleep quality (PSQ) and summed to create a score from 0 (no PSQ issues) to 6 (maximal PSQ). Four different PA variables were used and included walking and biking for transportation activity (WBTA, min/week), moderate-to-vigorous work activity (MVWA, min/week), moderate-to-vigorous PA (MVPA, min/week), and sedentary time (ST, min/day). The nine-item PHQ served as the outcome variable with discrete scores ranging from 0 (no depression symptoms) to 27 (maximal depression symptoms). Control variables included body mass index (BMI, kg/m^2), body shape index (BSI, T-score), age, sex, race, and income. Statistical analyses included a series of competing generalized linear models appropriate for count data that included Poisson, negative binomial, and zero-inflated distributions. Finally, binary logistic regression was used to model zero scores on the PHQ. **Results**: Approximately 36.0% (95% CI: 34.8 - 37.2) of adults met the weekly requirements for PA guidelines and 8.2% (7.5 - 8.9) met the PHQ criteria for at least moderate depression. In bivariate analyses, PSQ, MVWA, and ST were positively associated and MVPA negatively associated with PHQ scores. The negative binomial model was the best fitting model as judged by AIC, χ^2/DF ratio, and parsimony. The fully adjusted model indicated mean PHQ score changed by 0.92 (0.85 – 0.99) for those with some WBTA (compared to none), by 0.88 (0.82 – 0.95) for those in the lowest tertile of MVWA (compared to the highest tertile), by 0.83 (0.76 – 0.91) and 0.86 (0.80 – 0.93) for those in the lowest and middle tertiles (respectively) of ST (compared to the highest tertile), by 1.22 (1.13 – 1.31) for those in the lowest tertile of MVPA (compared to the highest tertile) and by 1.36 (1.32 – 1.39) for each one point increase in PSQ score. Finally, binary modeling of a zero PHQ score indicated the odds of zero changed by 1.20 (1.05 – 1.37) for the highest MVPA tertile (compared to lowest tertile), by 1.30 (1.11 – 1.51) and 1.26 (1.10 – 1.45) for the lowest and middle tertiles (respectively) of ST (compared to the highest tertile), by 0.70 (0.60 – 0.83) and 0.85 (0.74 – 0.97) for the middle and highest tertiles (respectively) of MVWA (compared to the lowest tertile) and by 0.64 (0.61 – 0.67) for each one point increase in PSQ score. **Conclusion**: Results from this study indicate that inadequate sleep, being active at work, and sedentary behavior predict depression in adults. Additionally, greater amounts of recreational activity may independently protect against symptoms of depression in this population. Health promotion specialists should incorporate sleep quality strategies into physical activity programming.

Keywords: *sleep quality, depression, physical activity, Patient Health Questionnaire (PHQ)*

Cite This Article: Peter D. Hart, "Sleep Quality and Physical Activity Predict Patient Health Questionnaire (PHQ) Scores in Adults." *American Journal of Public Health Research*, vol. 12, no. 4 (2024): 54-63. doi: 10.12691/ajphr-12-4-1.

1. Introduction

The prevalence of depression in 2020 was estimated at 18.4% (95% CI: 18.1 - 18.6) among U.S. adults [1]. Subpopulations with larger amounts of depression include younger adults 18 to 24 years of age (21.5%, 20.6 – 22.5), women (23.4%, 22.9 – 23.8), multiracial (28.5%, 26.3 – 30.8), and those with less than high school education (21.0%, 20.0 – 22.1). These statistics are particularly alarming since research indicates strong links between depression and negative outcomes such as premature mortality, chronic disease, disability, poor quality of life, and increased health care costs [2,3,4]. Depression (aka: major depression, major depressive disorder, or clinical depression) is a mental health disorder characterized by symptoms of persistent sadness, feelings of hopelessness, irritability, frustration, guilt, lack of energy, and even thoughts of suicide [5]. Although treatment for depression can require psychotherapy and/or medication, certain health behaviors, such as physical activity (PA) and sleep quality (SQ) can improve a depressed person's mood.

The nine-item patient health questionnaire (PHQ-9 hereafter PHQ) is a popular tool used to screen for depression in population-based surveillance and clinical settings [6,7,8]. Scores from the PHQ take on discrete values ranging from 0 to 27 where values of 5, 10, 15, and 20 represented mild, moderate, moderately severe, and severe depression, respectively [9]. A cutoff score of 10 has been suggested for the diagnosis of major depression and is applied regularly in the literature [9, 10].

Since scores from the PHQ take on discrete non-negative integers, count data models are often used to predict participant responses. A cursory and admittedly simple search in the pubmed website database using keyword phrases of "patient health questionnaire" and "Poisson regression" retrieved over 110 abstract citations [11]. However, replacing "Poisson" with "Negative binomial" retrieved fewer than 30 citations [11]. The negative binomial model is a type of generalized linear model (and a generalization of the Poisson model) also able to analyze count data [12,13]. The negative binomial model has an advantage over Poisson regression in that it can account for overdispersion (i.e., when the distribution's variance is greater than its mean), which is a common characteristic especially when many zeros are in the data [12,13]. Thus, the negative binomial model should at least be considered as a competing model in these statistical scenarios.

Current research supports the association between PA variables and depression scores from instruments like the PHQ [14,15,16]. Additionally, current data substantiate the SQ and PHQ relationship in adults [17,18]. Less is known, however, about the independent effects of PA and SQ on depression scores. Moreover, few if any studies have examined these independent effects on PHQ scores while also exploring the performance of several different competing count data models. Therefore, the aim of this study was to examine the ability of SQ and PA to predict scores from the PHQ using different modeling approaches.

2. Methods

Study design

The research design has been explained in detail elsewhere [19,20]. Briefly, this study used a cross-sectional design and collected data from 2017 to 2020. Participants were recruited to include a representative sample across different demographic characteristics and should be considered a sample of convenience. Data for this study were primarily collected using self-report questionnaires with body measurements assessed by trained medical professionals.

Patient Health Questionnaire (PHQ)

The PHQ is a nine-item depression symptom scale with an overall score ranging from 0 (not depressed) to 27 (severely depressed). Each of the PHQ items have the following stem: "Over the last 2 weeks, how often have you been bothered by the following problems." Specific items include the following difficulties: 1) little interest in doing things, 2) feeling down, depressed, or hopeless, 3) trouble falling or staying asleep, or sleeping too much, 4) feeling tired or having little energy, 5) poor appetite or overeating, 6) feeling bad about yourself, 7) trouble concentrating on things, 8) moving or speaking so slowly that other people could have noticed, and 9) thoughts that you would be better off dead. Participant response options for each item include: 0 = "not at all," 1 = "several days," 2 = "more than half the days," and 3 = "nearly every day." Summing responses across the nine items yields the PHQ score. A binary "depressed" variable was also created where scores of PHQ $\geq$ 10 indicated depression.

Sleep Quality (SQ)

Six different sleep quality variables were used to create a poor SQ (PSQ) scale. Two items asked about usual sleep time (weekdays and weekends). Both sleep time items were dichotomized to indicate sleep quality of poor ('1') if a participant slept less than 7.0 hours per day. Two items asked about sleep interruptions (snoring and snorting) while asleep. Both sleep interruption items were dichotomized to indicate sleep quality of poor ('1') if a participant reported either "occasionally" or "frequently". One item asked about patient-reported sleep issues to a health care professional. This item was dichotomized to indicate sleep quality of poor ('1') if a participant reported that they told a doctor or other health professional that they had trouble sleeping. A final item asked about the frequency of overall sleepiness. This item was dichotomized to indicate sleep quality of poor ('1') if a participant reported either "often" or "almost always". Summing across the binary items of 1s and 0s served as a PSQ score ranging from 0 to 6.

Physical Activity (PA)

Four different PA variables were used and included walking and biking for transportation activity (WBTA), moderate-to-vigorous work activity (MVWA), moderate-to-vigorous PA (MVPA), and sedentary time (ST). WBTA was assessed with a question that asked participants how much they walk or use a bicycle for traveling and transportation purposes in a typical week for at least 10 minutes continuously. WBTA units were in minutes per day (min/week). MVWA was assessed with questions that asked participants to include PA such as paid or unpaid work, household chores, and yard work engaged in for at least 10 minutes continuously. Vigorous-intensity work activity (VWA) asked about vigorous-intensity activities that cause large increases in breathing or heart rate and included examples like carrying or lifting heavy loads, digging or construction work. Moderate-intensity work activity (MWA) asked about moderate-intensity activities that cause small increases in breathing or heart rate and included examples like brisk walking or carrying light loads. MVWA was computed from both VWA and MWA by adding MWA plus two times VWA and used units of min/week. MVPA was assessed from questions that asked participants to exclude work-related and transportation-related PA and to include sport, fitness and recreational activities engaged in for at least 10 minutes continuously. Vigorous-intensity PA (VPA) asked about vigorous-intensity activities that cause large increases in breathing or heart rate and included examples like running or basketball. Moderate-intensity PA (MPA) asked about moderate-intensity activities that cause small increases in breathing or heart rate and included examples like brisk walking, bicycling, swimming, or volleyball. MVPA was computed from both VPA and MPA by adding MPA plus two times VPA and used units of min/week. ST was assessed using a single question asking participants how much time they usually spend sitting on a typical day, including school, home, transportation, and work, and excluded sleep. ST units were in minutes per day (min/day).

Covariates

Control variables used in this study included body mass index (BMI, kg/m^2), body shape index (BSI, T-score), age, sex, race, and income. BMI was measured from participant's height and weight with weight measured on a digital scale and height measured using a stadiometer. BMI was also categorized into tertiles for descriptive purposes. BSI was computed with measured study variables of height (cm), weight (kg), and waist circumference (cm) and subsequently standardized to a T-score scale (Mean = 50 and SD = 10) [21]. Age was used as a continuous variable, ranging from 18 years to 80+ years. Sex included males and female and dummy coded when appropriate (1=male and 0=female). Race/ethnicity was used as a categorical variable and included White, Black, Hispanic, and Other groupings. Income was used as a continuous variable and computed as a ratio of the family income to poverty, ranging from 0 to 5. Income was also categorized into quartiles for descriptive purposes.

Statistical analyses

Descriptive statistics were computed to describe the sample and its characteristics. This included percentages and chi-square (χ^2) tests for categorical data. In cases where categorical variables were ordinal-level, the Cochran-Armitage trend test was added. Numeric variables were also summarized across PHQ tertile groups with Spearman correlations, Kruskal-Wallis nonparametric ANOVA, and Jonckheere-Terpstra test of trend used to describe the bivariate relationships.

Seven different regression models were employed and compared for fit. Each model was run using the SAS PROC GENMOD procedure and differed in terms of their distribution, link function, and/or zero modeling of covariates. The models included 1) negative binomial with log link, 2) zero-inflated negative binomial with log link, 3) zero-inflated negative binomial with log link and covariates added to the zero model, 4) Poisson with log link, 5) zero-inflated Poisson with log link, 6) zero-inflated Poisson with log link and covariates added to the zero model, and 7) normal with identity link (i.e., ordinary regression). Model performance of the fully adjusted models was compared using the full log likelihood (FLL), Akaike information criterion (AIC), and Pearson chi-square (χ^2) to degrees of freedom (DF) ratio (χ^2/DF). In all cases, smaller statistics represent better relative model fit. Adjustments to the scale parameter (and standard errors) was only considered, if needed, for the final model. Because several different PA variables were modeled simultaneously, collinearity was inspected using SAS PROC REG and dummy variables exported from PROC GLMSELECT and the &_glsmod macro variable. Lack of multicollinearity was assessed using the VIF option on the fully adjusted model and all values were cleared (all VIFs < 2.2).

Visual aids were also constructed using means and 95% confidence intervals (CIs) of the predicted PHQ score from the best fitting count model. Linear contrasts were formed to test for trend in means across MVPA tertiles within ST tertile groups. To gain a deeper understanding of the zero PHQ score population, a binary logistic regression model, with odds ratios (ORs) and 95% CIs, was employed using the same predictors.

To help summarize and aid interpretation, several variables were converted to categorical form. WBTA was split at the median which resulted in one group with zero WBTA min/week and one group with 10+ WBTA min/week. PHQ, MVPA, and MVWA were each categorized into tertile groups where the lowest tertile contained participants with zero PHQ, MVPA, and MVWA, respectively. Finally, ST was categorized into tertiles where the lowest tertile contained ST between zero and 210 min/day. A complete case analysis was employed with two-tailed *p*-values reported and significance set at $p < 0.05$. SAS version 9.4 was used for all analysis, modeling, and graphs [12,22,23].

3. Results

Table 1 contains the sample characteristics by PA and depression status where approximately 36.0% (95% CI: 34.8 - 37.2) of adults met PA guidelines and 8.2% (7.5 - 8.9) were considered at least moderately depressed. A significant linear trend in meeting PA guideline was observed across age, income, and BMI status groups. Additionally, a significant linear trend in moderate depression was observed for income and BMI status groups. Figure 1 displays participant PHQ scores with summary statistics. The mean of 3.15 and variance of 16.76 highlight the overdispersion in the data. Table 2 displays statistics of association for numeric study variables across PHQ tertile grouping. All numeric variables were significantly different across PHQ groups, less WBTA and BSI. The table also identifies PSQ, MVWA, and ST as positively associated and MVPA negatively associated with PHQ scores. Table 3 summarizes the performance of each generalized linear model predicting PHQ count scores. The table entries are ranked by χ^2/DF. The negative binomial model was considered the best fitting model. Although the zero-inflated negative binomial presented the smallest AIC statistic, the smaller χ^2/DF along with a simpler interpretation were given heavier weight in the judging process.

Table 4 displays the negative binomial regression analysis predicting PHQ depression scores with WBTA, MVPA, MVWA, ST, and PSQ. This model indicated mean PHQ score changed by 0.89 (0.82 – 0.96) for those with some WBTA (compared to none), by 0.88 (0.81 – 0.94) for those in the lowest tertile of MVWA (compared to the highest tertile), by 0.90 (0.83 – 0.98) and 0.90 (0.83 – 0.97) for those in the lowest and middle tertiles (respectively) of ST (compared to the highest tertile), by 1.30 (1.21 – 1.40) and 1.10 (1.00 – 1.21) for those in the lowest and middle tertiles of MVPA (compared to the highest tertile) and by 1.35 (1.31 – 1.38) for each one point increase in PSQ score.

Table 5 displays the same model adjusted additionally for all covariates. The fully adjusted model indicated mean PHQ score changed by 0.92 (0.85 – 0.99) for those with some WBTA (compared to none), by 0.88 (0.82 – 0.95) for those in the lowest tertile of MVWA (compared to the highest tertile), by 0.83 (0.76 – 0.91) and 0.86 (0.80 – 0.93) for those in the lowest and middle tertiles (respectively) of ST (compared to the highest tertile), by 1.22 (1.13 – 1.31) for those in the lowest tertile of MVPA (compared to the highest tertile) and by 1.36 (1.32 – 1.39) for each one point increase in PSQ score.

Figure 2 displays the predicted PHQ score means overall by ST group and MVPA group. Each panel of the graph indicates a significant indirect linear trend in PHQ means across the MVPA tertile groups. The significant trend in means within each ST tertile provides robust evidence for a PA dose-response on PHQ scores. With a noteworthy difference in PHQ means between the lowest tertile of MVPA in the last ST tertile (Mean = 4.16, 95% CI: 4.00 - 4.31).

Figure 3 displays the same predicted PHQ score graph but for males. A similar dose-response pattern was observed between PA and PHQ scores in males. The most noteworthy difference in this graph, however, is the fact that the PHQ means among the most physically active (i.e., highest MVPA tertile) are close in magnitude across the three ST tertiles. This indicates that ST may not be a strong risk factor for depression symptoms among physically active males. Figure 4 also displays the predicted PHQ score graph but for females. Again, a similar dose-response pattern was observed between PA and PHQ scores in females. However, ST appears to have an added negative affect on depression symptoms in females as observed by the large predicted PHQ mean for the first MVPA tertile in the highest ST tertile.

Figure 5 displays ORs and 95% CIs for the binary modeling of a zero PHQ score. The graph illustrates the odds of zero changed by 1.20 (1.05 – 1.37) for the highest MVPA tertile (compared to lowest tertile), by 1.30 (1.11 – 1.51) and 1.26 (1.10 – 1.45) for the lowest and middle tertiles (respectively) of ST (compared to the highest tertile), by 0.70 (0.60 – 0.83) and 0.85 (0.74 – 0.97) for the middle and highest tertiles (respectively) of MVWA (compared to the lowest tertile) and by 0.64 (0.61 – 0.67) for each one point increase in PSQ score.

Table 1. Sample characteristics by PA and Depression status

		Met PAG (MVPA ≥ 150 min/week)			Depressed (PHQ ≥ 10)		
Characteristic	*N*	No	Yes	*p*	No	Yes	*p*
Overall	6,205	64.0	36.0	<.001	91.8	8.2	<.001
Sex				<.001			<.001
Female	3,129	68.8	31.2		89.8	10.2	
Male	3,076	59.2	40.8		93.8	6.2	
Age Group (yr)				<.001			.019
18 to 24	764	47.3	52.8		90.1	10.0	
25 to 34	974	52.8	47.2		93.4	6.6	
35 to 44	952	64.2	35.8		90.3	9.7	
45 to 54	983	67.0	33.0		91.3	8.8	
55 to 64	1,197	70.7	29.3		91.6	8.4	
65+	1,335	73.5	26.5		93.3	6.7	
p for trend		<.001			.113		
Race				.007			.291
White	2,294	64.5	35.5		91.6	8.4	
Black	1,572	66.6	33.4		91.9	8.1	
Hispanic	1,311	63.2	36.8		90.9	9.1	
Other	1,028	60.0	40.0		93.1	6.9	
Income Quartile				<.001			<.001
1st (low)	1,555	71.9	28.1		87.1	12.9	
2nd (low-middle)	1,545	71.2	28.8		90.9	9.1	
3rd (high-middle)	1,553	61.5	38.5		93.3	6.7	
4th (high)	1,552	51.5	48.5		95.9	4.1	
p for trend		<.001			<.001		
BMI Status				<.001			<.001
Low	2,082	56.2	43.8		93.4	6.6	
Middle	2,059	63.8	36.2		92.9	7.1	
High	2,064	72.1	27.9		89.1	10.9	
p for trend		<.001			<.001		

Note. PAG is physical activity (PA) guidelines. BMI status (low, middle, high) is based on tertiles. p-value columns are for the chi-square (χ^2) test of independence. p for trend is for the Cochran-Armitage trend test.

Table 2. Description of predictor variables and covariates across PHQ groups

	Low PHQ (*N* = 2,076)			Moderate PHQ (*N* = 2,156)			High PHQ (*N* = 1,973)				K-W	J-T
Variable	*Mean*	*Min*	*Max*	*Mean*	*Min*	*Max*	*Mean*	*Min*	*Max*	r_S	*p*	*p*
PHQ	0	0	0	1.86	1.00	3.00	7.86	4.00	27.00	-	-	-
Sex (1=male, 0=female)	0.58	0.00	1.00	0.49	0.00	1.00	0.41	0.00	1.00	-.142	<.001	-
Age (18 to 80 yr)	50.1	18.0	80.0	47.1	18.0	80.0	47.6	18.0	80.0	-.059	<.001	<.001
Income (0 to 5)	2.82	0.00	5.00	2.80	0.00	5.00	2.29	0.00	5.00	-.129	<.001	<.001
PSQ (0 to 6)	1.12	0.00	6.00	1.43	0.00	6.00	2.06	0.00	6.00	.290	<.001	<.001
WBTA (min/week)	69	0	3360	59	0	3780	77	0	3960	ns	.044	.986
MVWA (min/week)	843	0	10800	829	0	11820	890	0	12600	.046	.001	<.001
MVPA (min/week)	262	0	6860	233	0	5220	196	0	4800	-.101	<.001	<.001
ST (min/day)	320	0	1140	341	2	1200	351	2	1200	.056	<.001	<.001
BMI (kg/m^2)	29.0	15.4	62.1	29.7	14.8	66.5	30.9	14.6	82.0	.094	<.001	<.001
BSI (T-score)	49.9	7.4	83.6	49.5	8.4	81.7	50.6	16.2	98.4	ns	.004	.131

Note. *N* = 6,205. PHQ groups (low, moderate, high) are based on tertiles. K-W is the Kruskal-Wallis nonparametric ANOVA. J-T is the Jonckheere-Terpstra test of trend. r_S is Spearman correlation coefficient between each numeric predictor and PHQ group with only significant ($p < .05$) values reported. Income is ratio of family income to poverty threshold ranging from 0 to 5. PSQ is poor sleep quality score ranging from 0 to 6. BMI is body mass index in kg/m^2. BSI is body shape index in T-score units (Mean = 50 and SD = 10). WBTA is walking and biking for transportation activity in min/week. MVWA is moderate-to-vigorous work activity in min/week. MVPA is moderate-to-vigorous-PA in min/week. ST is sedentary time in min/day.

Table 3. Generalized linear model comparisons for PHQ scores as count data ranked by χ2/DF

Model	Distribution	Link	DF	FLL	χ^2	χ^2/DF	AIC
NB	Negative Binomial	Log	6182	-13571.0	6205.4	1.00	27190.1
ZINB w/c	Zero Inflated Negative Binomial	Log	6159	-13409.1	6475.5	1.05	26912.3
ZINB	Zero Inflated Negative Binomial	Log	6181	-13552.5	6532.7	1.06	27155.0
ZIP	Zero Inflated Poisson	Log	6181	-15623.9	11569.5	1.87	31295.8
ZIP w/c	Zero Inflated Poisson	Log	6159	-15356.6	12056.6	1.96	30805.1
POI	Poisson	Log	6182	-18220.9	26409.2	4.27	36487.8
GLM	Normal	Identity	6182	-16981.0	86557.2	14.00	34010.0

Note. *N* = 6,205. Fully adjusted models were compared. Models are ranked by χ^2/DF. ZINB w/c and ZIP w/c are modeling zeros with covariates. FLL is full log likelihood. AIC is Akaike information criterion.

Table 4. Negative binomial regression analysis predicting PHQ depression scores with physical activity (PA) and poor sleep quality (PSQ)

Parameter	*b*	*SE*	*p*	*exp(b)*	*LL*	*UL*
Intercept	0.706	0.026	<.001			
WBTA: 1	-0.108	0.017	<.001	0.89	0.82	0.96
WBTA: 2	ref					
MVPA: 1	0.255	0.017	<.001	1.30	1.21	1.40
MVPA: 2	0.103	0.023	<.001	1.10	1.00	1.21
MVPA: 3	ref					
MVWA: 1	-0.135	0.017	<.001	0.88	0.81	0.94
MVWA: 2	-0.023	0.021	.277	0.98	0.89	1.08
MVWA: 3	ref					
ST: 1	-0.098	0.019	<.001	0.90	0.83	0.98
ST: 2	-0.074	0.017	<.001	0.90	0.83	0.97
ST: 3	ref					
PSQ	0.276	0.005	<.001	1.35	1.31	1.38

Note. *N* = 6,205. WBTA is walking and biking activity. MVPA is moderate-to-vigorous PA. MVWA is moderate-to-vigorous work activity. WBTA grouped (1,2) by median split. MVPA, MVWA, and ST grouped (1,2,3) by tertiles. Model includes only the predictors in the table.

Table 5. Fully adjusted negative binomial regression analysis predicting PHQ depression scores with physical activity (PA) poor sleep quality (PSQ) and body measures

Parameter	*b*	*SE*	*p*	*exp(b)*	*LL*	*UL*
Intercept	-0.381	0.148	.010			
WBTA: None	-0.084	0.039	.032	0.92	0.85	0.99
WBTA: Some	ref					
MVPA: T1	0.197	0.038	<.001	1.22	1.13	1.31
MVPA: T2	0.087	0.050	.082	1.09	0.99	1.20
MVPA: T3	ref					
MVWA: T1	-0.124	0.039	.001	0.88	0.82	0.95
MVWA: T2	-0.005	0.049	.920	1.00	0.90	1.10
MVWA: T3	ref					

Parameter	*b*	*SE*	*p*	*exp(b)*	*LL*	*UL*
ST: T1	-0.184	0.044	<.001	0.83	0.76	0.91
ST: T2	-0.148	0.040	<.001	0.86	0.80	0.93
ST: T3	ref					
PSQ	0.305	0.013	<.001	1.36	1.32	1.39
BMI	0.001	0.002	.633	1.00	1.00	1.01
BSI	0.008	0.002	<.001	1.01	1.00	1.01

Note. *N* = 6,205. WBTA is walking and biking activity. MVPA is moderate-to-vigorous PA. MVWA is moderate-to-vigorous work activity. WBTA grouped (1,2) by median split. MVPA, MVWA, and ST grouped (1,2,3) by tertiles. Model includes the predictors in the table plus age, sex, race, and income.

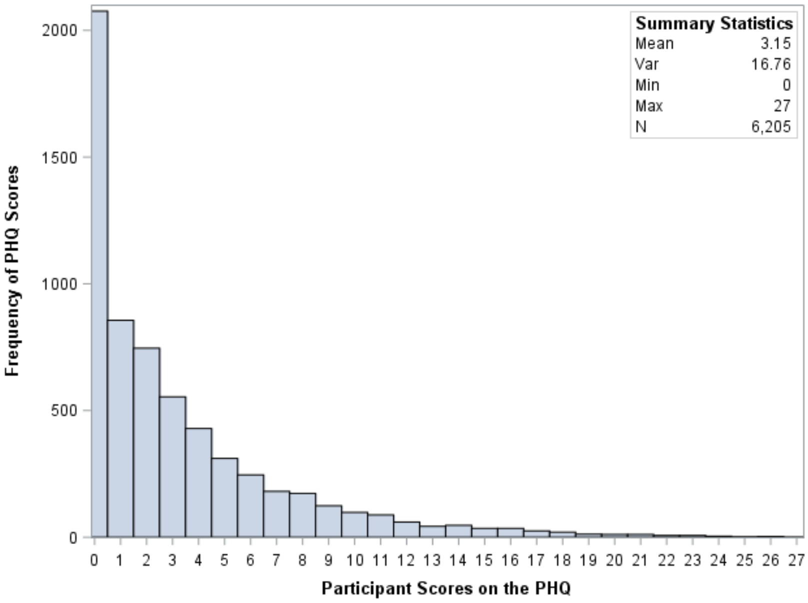

Figure 1. Participant scores from the nine-item Patient Health Questionnaire (PHQ)

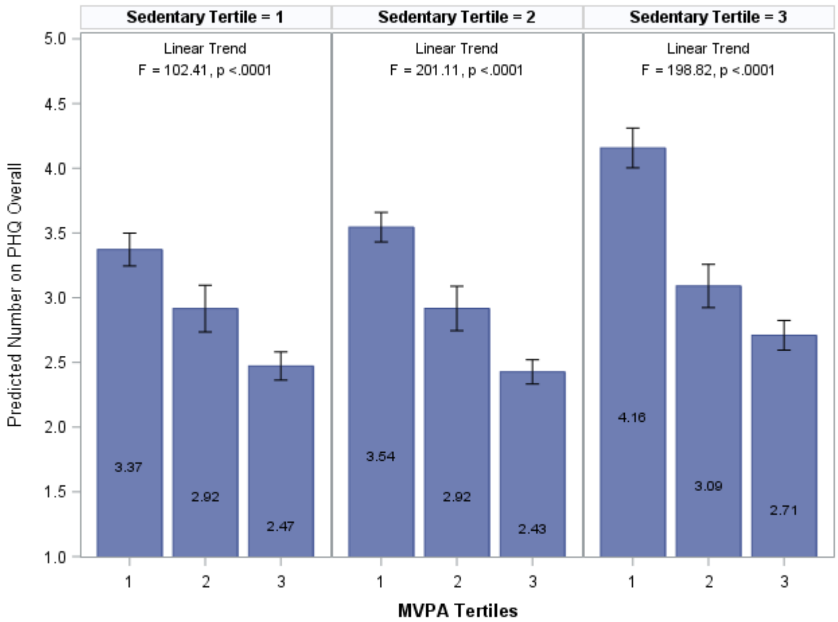

Figure 2. Predicted PHQ score means by ST group and MVPA group – Overall

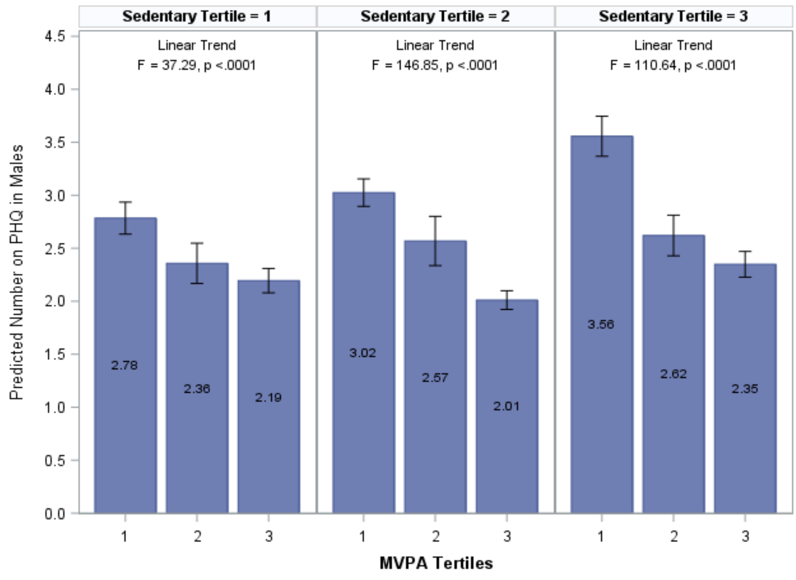

Figure 3. Predicted PHQ score means by ST group and MVPA group – Males

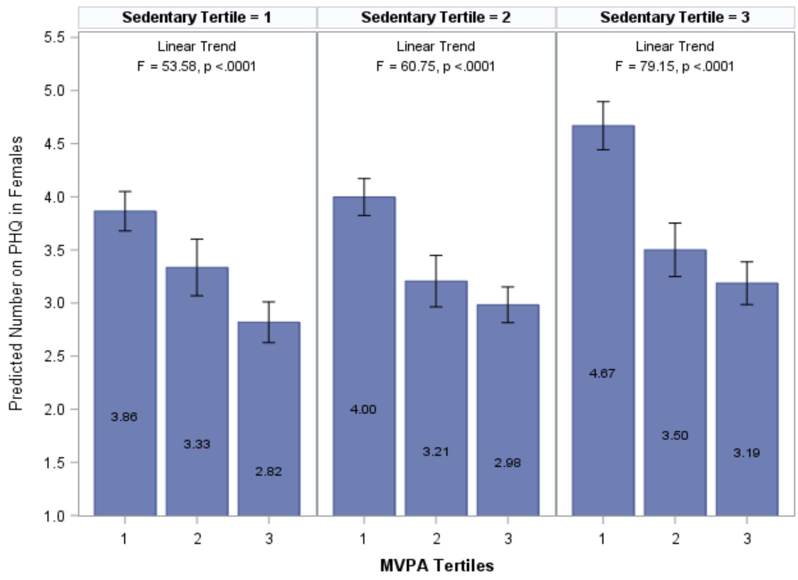

Figure 4. Predicted PHQ score means by ST group and MVPA group – Females

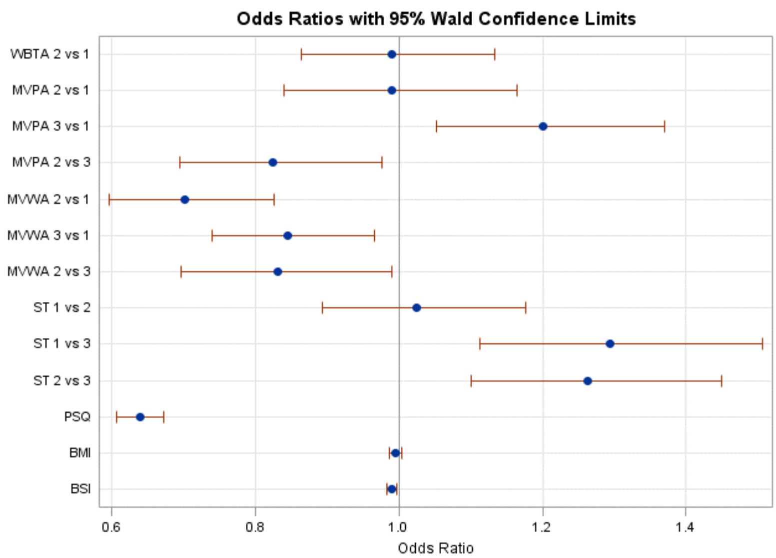

Figure 5. Forest plot for the fully adjusted binary modeling of zero PHQ scores

4. Discussion

The purpose of this study was to examine the ability of SQ and PA to independently predict scores from the PHQ using different modeling approaches. Unadjusted bivariate analyses revealed that PSQ, ST, and MVWA were positively associated with PHQ scores. Conversely, MVPA was negatively associated with PHQ scores. Some of these findings were expected and have been identified by others. For example, a recent study of taxi drivers observed an extraordinarily strong association between depression and sleep disorders with OR statistics for having a sleep disorder at different levels of depression ranging from 3.9 to 35.3 when compared to counterparts without depression [24]. Similar findings have been reported in college student, adult, and elderly populations [25,26,27,28,29]. Studies have also reported positive associations between ST and depression [30,31]. As well, a plethora of research data provide evidence for the negative association between MVPA and depression [32,33,34,35]. The positive association between MVWA and depression symptoms in the current study, however, was an unexpected finding. This finding may also be less established in the research literature. In fact, a large national study of adults specifically found no relationship between PA at work and symptoms of depression [36]. Another study examining different mood indicators, including depression, also found no relationship with work-related PA in adults [37]. A large study of Korean adults, however, did find that high-intensity work-related PA significantly increased depressive symptoms [38]. This study differs from the current findings which assessed both moderate- and vigorous-intensity activity at work in one measure of MVWA. Nevertheless, given these mixed findings, more research may be needed to clarify the association between MVWA and symptoms of depression.

The modeling portion of this study reinforced those revealed in the bivariate analyses and brings to light at least four points worth discussing. The first noteworthy point is the fact that after adjusting for all PA variables, SQ, and the remaining covariates, WBTA became a significant predictor of PHQ. A correlation that was not evident in the bivariate analysis. Active transportation has been linked to better mental health and improved depression in adults by others [39,40]. On the other hand, several studies have shown null findings or mixed findings for walking or biking for transportation and depression symptoms [41,42,43]. It is possible, however, that controlling for SQ and ST in the current study, removed enough variation from PHQ scores to identify a valid association between WBTA and depression symptoms. The second noteworthy point worth mentioning is that the model in the current study was able to identify four PA variables and SQ as independent predictors of PHQ scores while adjusting for confounding body measure and demographic variables. This finding provides novel evidence for the PA and SQ relationship with PHQ scores in adults.

The third noteworthy point worth mentioning concerns the use of the negative binomial model for the modeling of PHQ count scores. It was found that the negative binomial model performed better than the traditional Poisson model and arguably better than the zero-inflated models. The zero-inflated models are generally appropriate in scenarios when a special subpopulation can have no other possible score than a zero (i.e., *structural* zeros) and thus, in this case, is not at risk for any symptoms of depression [44]. A situation that does not seem reasonable considering the PHQ items (i.e., tiredness, poor appetite, feeling bad, etc.) in adult populations. Additionally, the nominal difference in fit (i.e., AIC value) observed in the zero-inflated negative binomial model did not seem to justify the additional complexity in interpreting the zero modeling (i.e., logit modeling) within a zero-inflated model. Therefore, the negative binomial model was deemed the better fitting and more appropriate model for the current data. Finally, the fourth noteworthy point worth mentioning concerns the sex differences observed in model predicted PHQ scores. Considering both sexes, a significant indirect linear trend was noted in predicted PHQ means across MVPA tertile groups in all three ST tertile groups. However, predicted PHQ means were greatest in the most sedentary and least physically active females. In fact, a magnitude of 1 PHQ count greater than their male counterparts. Findings that make sense when considering evidence purporting that depression symptoms are greater in female populations and greater in less active adult populations [45,46].

A secondary purpose of this study was to capitalize on the information obtained from the zero-inflated negative binomial model by explicitly modeling zero PHQ scores using binary logistic regression. That is, since the zero-inflated model fit well, special attention on the zero scores seemed appropriate. Results of which were in-line with the previous in that increased amounts of MVPA, decreased amounts of ST, decreased amounts of MVWA, and decreased amounts of PSQ resulted in increased likelihood (odds) of scoring a PHQ zero. These findings indicate that adults responding with zero scores on the PHQ can be predicted with PA and SQ variables.

When interpreting these findings, it should be noted that they come from cross-sectional data and do not necessarily imply a cause-and-effect relationship between PA, SQ, and depression. Furthermore, this study used a general depression symptom scale, the PHQ, and thus did not assess or generalize to specific depression states associated with factors such as pregnancy, substance use, adverse event, disease, or aging [47]. Finally, results from this study should be interpreted with the understanding that all major predictors were assessed as well as the main outcome variable using self-reported questionnaires. Therefore, certain reporting biases can not be ruled out. Regardless, the scales used in this study are well-established in the research and have acceptable psychometric characteristics [48,49,50].

5. Conclusions

The negative binomial model was considered the better fitting and more appropriate model for the current data. Results found that inadequate sleep, large amounts of work activity, low amounts of recreational activity, and high amounts of sedentary behavior were independent risk factors for depression in adults. Health promotion specialists should incorporate sleep quality strategies into physical activity programming.

References

[1] Lee B, Wang Y, Carlson SA, et al. National, State-Level, and County-Level Prevalence Estimates of Adults Aged ≥18 Years Self-Reporting a Lifetime Diagnosis of Depression - United States, 2020. MMWR Morb Mortal Wkly Rep. 2023; 72(24): 644-650. Published 2023 Jun 16.

[2] US Preventive Services Task Force, Barry MJ, Nicholson WK, et al. Screening for Depression and Suicide Risk in Adults: US Preventive Services Task Force Recommendation Statement. JAMA. 2023; 329(23): 2057-2067.

[3] Puyat JH, Kazanjian A, Wong H, Goldner E. Comorbid Chronic General Health Conditions and Depression Care: A Population-Based Analysis. Psychiatr Serv. 2017; 68(9): 907-915.

[4] Culpepper L. Understanding the burden of depression. J Clin Psychiatry. 2011; 72(6): e19.

[5] US Department of Health and Human Services. Depression. National Institute of Mental Health. Revised 2024.

[6] O'Connor E, Henninger M, Perdue LA, Coppola EL, Thomas R, Gaynes BN. Screening for Depression, Anxiety, and Suicide Risk in Adults: A Systematic Evidence Review for the U.S. Preventive Services Task Force. Rockville (MD): Agency for Healthcare Research and Quality (US); June 2023.

[7] Yu-An Chen A, Sturm R. Depressive Symptoms among US Adults during the Great Recession and Economic Recovery. J Ment Health Policy Econ. 2022; 25(1): 3-10.

[8] Furukawa Y, Nagaoka D, Sato S, et al. Cognitive behavioral therapy for insomnia to treat major depressive disorder with comorbid insomnia: A systematic review and meta-analysis. J Affect Disord. Published online September 4, 2024.

[9] Kroenke K, Spitzer RL, Williams JB. The PHQ-9: validity of a brief depression severity measure. J Gen Intern Med. 2001; 16(9): 606-613.

[10] Zhang H, Xu Y, Xu Y. The value of the platelet/high-density lipoprotein cholesterol ratio in predicting depression and its cardiovascular disease mortality: a population-based observational study. Front Endocrinol (Lausanne). 2024; 15: 1402336. Published 2024 Jul 29.

[11] U.S. Department of Health and Human Services (HHS). Pubmed. NIH National Library of Medicine. Published June 26, 1997. Accessed August 3, 2024. https://pubmed.ncbi.nlm.nih.gov/.

[12] Allison P. Logistic regression using SAS: Theory and application. SAS institute. 2012.

[13] Schober P, Vetter TR. Count Data in Medical Research: Poisson Regression and Negative Binomial Regression. Anesth Analg. 2021; 132(5): 1378-1379.

[14] Meng Y, Ma N, Shi Y, et al. The association of physical activity and sedentary behavior with depression in US adults: NHANES 2007-2018. Front Public Health. 2024; 12: 1404407. Published 2024 Jun 21.

[15] Kim EC, Jeong A, Lee DH, Park DH, Jeon JY. Impact of leisure physical activity and resistance exercise on the prevalence of depressive symptoms in Korean adults: Analysis of the Korean National Health and Nutrition Examination Survey. J Affect Disord. 2024; 356: 329-337.

[16] Pereira-Payo D, Mendoza-Muñoz M, Denche-Zamorano A, Rubio-de la Osa A, Moreno-Quintanilla M, Pastor-Cisneros R. Physical Activity Is Associated with the Incidence of Depression in United States Adults from the NHANES 2013-18: A Cross-Sectional Study. Healthcare (Basel). 2024;12(5):552. Published 2024 Feb 27.

[17] Ormiston CK, Lopez D, Ishino FAM, McNeel TS, Williams F. Acculturation and depression are associated with short and long sleep duration among Mexican Americans in NHANES 2005-2018. Prev Med Rep. 2022; 29: 101918. Published 2022 Jul 21.

[18] Lee MR, Jung SM, Choi SH, Hwang H, Chang Y, Hwangbo Y. Relationship between mid-sleep time and depression, health-related quality of life, and sleep deprivation in the 2018 Korea Community Health Survey. Chronobiol Int. 2024; 41(1): 1-9.

[19] Hart PD. Use of Dietary Supplements to Build Muscle and Physical Activity in US Adults. American Journal of Public Health. 2023; 11(6): 183-8.

[20] Hart, PD. Sleep quality predicts body shape index while adjusting for physical activity. American Journal of Public Health Research. 2024; 12(3), 40-47.

[21] Krakauer NY, Krakauer JC. A new body shape index predicts mortality hazard independently of body mass index. PLoS One. 2012; 7(7): e39504.

[22] Stokes ME, Davis CS, Koch GG. Categorical data analysis using SAS. SAS institute; 2012 Jul 31.

[23] Shreve, Joni N. and Donna Dea Holland. 2018. SAS® Certification Prep Guide: Statistical Business Analysis Using SAS®9. Cary, NC: SAS Institute Inc.

[24] Abedi L, Naghizad MB, Habibpour Z, Shahsavarinia K, Yazdani MB, Saadati M. A closer look at depression and sleep quality relation: A cross-sectional study of taxi drivers in Tabriz metropolis. Health Sci Rep. 2024; 7(9): e70037. Published 2024 Sep 2.

[25] Wen LY, Zhang L, Zhu LJ, et al. Depression and suicidal ideation among Chinese college students during the COVID-19 pandemic: the mediating roles of chronotype and sleep quality. BMC Psychiatry. 2024; 24(1): 583. Published 2024 Aug 27.

[26] Sun M, Zhang Q, Han Y, Liu J. Sleep Quality and Subjective Cognitive Decline among Older Adults: The Mediating Role of Anxiety/Depression and Worries. J Aging Res. 2024; 2024: 4946303. Published 2024 May 7.

[27] Genario R, Gil S, Oliveira-Júnior G, et al. Sleep quality is a predictor of muscle mass, strength, quality of life, anxiety and depression in older adults with obesity. Sci Rep. 2023; 13(1):11256. Published 2023 Jul 12.

[28] Lim JA, Yun JY, Choi SH, Park S, Suk HW, Jang JH. Greater variability in daily sleep efficiency predicts depression and anxiety in young adults: Estimation of depression severity using the two-week sleep quality records of wearable devices. Front Psychiatry. 2022; 13: 1041747. Published 2022 Nov 7.

[29] Benitez A, Gunstad J. Poor sleep quality diminishes cognitive functioning independent of depression and anxiety in healthy young adults. Clin Neuropsychol. 2012; 26(2): 214-223.

[30] Yang Y, Wang Y, Yang L. Association between physical activity and sedentary behavior and depression in US adults with cardiovascular disease: NHANES 2007-2016. J Affect Disord. Published online September 3, 2024.

[31] Jiang Y, Zhang M, Cui J. The relationship between sedentary behavior and depression in older adults: A systematic review and meta-analysis. J Affect Disord. 2024; 362: 723-730.

[32] Gyasi RM, Quansah N, Boateng PA, et al. Meeting the WHO Physical Activity Guidelines is Associated With Lower Odds of Depression in Older Adults: Potential Psychosomatic Mechanisms. Am J Geriatr Psychiatry. 2024; 32(9): 1105-1118.

[33] Yang H, Fu C, Zhang X, Li W. Association between physical activity levels and anxiety or depression among college students in China during the COVID-19 pandemic: A meta-analysis. Medicine (Baltimore). 2023; 102(49): e36524.

[34] Yang H, Fu C, Zhang X, Li W. Association between physical activity levels and anxiety or depression among college students in China during the COVID-19 pandemic: A meta-analysis. Medicine (Baltimore). 2023; 102(49): e36524.

[35] Pearce M, Garcia L, Abbas A, et al. Association Between Physical Activity and Risk of Depression: A Systematic Review and Meta-analysis. JAMA Psychiatry. 2022; 79(6): 550-559.

[36] Boparai JK, Dunnett S, Wu M, et al. The Association Between Depressive Symptoms and the Weekly Duration of Physical Activity Subset by Intensity and Domain: Population-Based, Cross-Sectional Analysis of the National Health and Nutrition Examination Survey From 2007 to 2018. Interact J Med Res. 2024; 13: e48396. Published 2024 Jul 5.

[37] Skurvydas A, Istomina N, Dadeliene R, et al. Mood profile in men and women of all ages is improved by leisure-time physical activity rather than work-related physical activity. BMC Public Health. 2024; 24(1): 546. Published 2024 Feb 21.

[38] Joo MJ, Jang YS, Jang YS, Park EC. Association between work-related physical activity and depressive symptoms in Korean workers: data from the Korea national health and nutrition examination survey 2014, 2016, 2018, and 2020. BMC Public Health. 2023; 23(1): 1752. Published 2023 Sep 8.

[39] Scrivano L, Tessari A, Marcora SM, Manners DN. Active mobility and mental health: A scoping review towards a healthier world. Glob

Ment Health (Camb). 2023; 11: e1. Published 2023 Nov 21.

[40] Knott CS, Panter J, Foley L, Ogilvie D. Changes in the mode of travel to work and the severity of depressive symptoms: a longitudinal analysis of UK Biobank. Prev Med. 2018; 112: 61-69.

[41] Fukai K, Kuwahara K, Chen S, et al. The association of leisure-time physical activity and walking during commuting to work with depressive symptoms among Japanese workers: A cross-sectional study. J Occup Health. 2020; 62(1): e12120.

[42] Marques A, Peralta M, Henriques-Neto D, Frasquilho D, Rubio Gouveira É, Gomez-Baya D. Active Commuting and Depression Symptoms in Adults: A Systematic Review. Int J Environ Res Public Health. 2020; 17(3):1041. Published 2020 Feb 6.

[43] Kuwahara K, Honda T, Nakagawa T, et al. Associations of leisure-time, occupational, and commuting physical activity with risk of depressive symptoms among Japanese workers: a cohort study. Int J Behav Nutr Phys Act. 2015; 12: 119. Published 2015 Sep 18.

[44] Pittman B, Buta E, Krishnan-Sarin S, O'Malley SS, Liss T, Gueorguieva R. Models for analyzing zero-inflated and overdispersed count data: an application to cigarette and marijuana use. Nicotine Tob Res. Published online April 18, 2018.

[45] Bennie JA, De Cocker K, Biddle SJH, Teychenne MJ. Joint and dose-dependent associations between aerobic and muscle-strengthening activity with depression: A cross-sectional study of 1.48 million adults between 2011 and 2017. Depress Anxiety. 2020; 37(2): 166-178.

[46] Pratt LA, Brody DJ. Depression in the U.S. household population, 2009-2012. NCHS Data Brief. 2014; (172): 1-8.

[47] Maurer DM, Raymond TJ, Davis BN. Depression: Screening and Diagnosis. Am Fam Physician. 2018; 98(8): 508-515.

[48] Helmerhorst HJ, Brage S, Warren J, Besson H, Ekelund U. A systematic review of reliability and objective criterion-related validity of physical activity questionnaires. Int J Behav Nutr Phys Act. 2012; 9: 103. Published 2012 Aug 31.

[49] Wang W, Bian Q, Zhao Y, et al. Reliability and validity of the Chinese version of the Patient Health Questionnaire (PHQ-9) in the general population. Gen Hosp Psychiatry. 2014; 36(5): 539-544.

[50] Erdoğan Ş, Üçpunar HK, Tavat BC. Validity and Reliability of the Turkish Version of the Munich Chronotype Questionnaire. Münih Kronotip Anketi Türkçe Formu'nun Geçerlik ve Güvenilirlik Çalışması. Turk Psikiyatri Derg. 2022; 33(4): 274-279.

© The Author(s) 2024. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (http://creativecommons.org/licenses/by/4.0/).