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ORIGINAL ARTICLE

Physical Activity and Depression: Nationwide Evaluation of Depression and Physical Activity in South Korea

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PURPOSE: The relationship between depression and physical activity levels in adults in Korea was determined using data from the National Health and Nutrition Survey (K-NAESE).

METHODS: Data collected from K-NAESE between 2014 and 2020, comprising 29,716 (male: 13,416, female: 16,300) participants, were analyzed using a complex sample statistical analysis by applying differential weight to the variables to analyze the relationship between depression and physical activity levels in an estimated South Korean population (50,881,242). Demographic factors were used as control variables while constructing an independent variable-by-variable fit model for the zero-inflated Poison Regression analysis of PHQ-9 depression scores, and a meaningfully interpretable fit model was used in the final model.

RESULTS: A significant relationship was observed between the total PHQ-9 score and commute physical activity (OR=1.042; SE, 0.006; $p<.001$) and moderate-intensity leisure and physical activity time (OR=1.116; SE, 0.008; $p<.001$). A significant association was found between the PHQ-9 scores and physical factors (grip strength; OR=0.985; SE, 0.001; $p<.001$). Using Binomial Logistic Model for Depression Classification, a significant association was observed for classification as low/high-risk depression in individuals without moderate-intensity physical activity (OR=1.190; SE, 0.046; $p<.001$). Furthermore, individuals with a high grip strength were classified as low/high-risk depression compared to a normal grip strength (OR=0.980; SE, 0.004; $p<.001$).

CONCLUSIONS: These findings indicate that a negative association exists between depression and the availability of moderate-intensity leisure and structured physical activity. Furthermore, a negative association was also found between depression and grip strength in the general population of South Korea aged in individuals over the age of 18.

Key words: Physical activity, Depression, Patient health questionnaire-9, National Health and Nutrition Survey

INTRODUCTION

Depression is characterized as a chronic mental disorder with a high prevalence and mortality rate [1]. According to WHO, patients with depression have a lower life expectancy compared to other mental disabilities and substance abuse and neurological disorders [2]. Although the mechanism for depression development is not fully understood, monoamine hypothesis has been previously reported that the biochemical imbalance of monoamine and serotonin, norepinephrine, and dopamine in the central nervous system synapse contributes to depression development [3]. Especially, serotonin receptor, HTR1A, is known to regulate serotonin signaling in the central nervous system and is reported to have a critical role in depression by reducing serotonin secretion and activation [4]. As such, selective serotonin reuptake inhibitors have been widely used in clinical practice for anti-depression medicine [5].

On the other hand, it was shown that physical activity is known to be associated with the prevalence of depression as well as the degree of depression [6], however, more research needs to be investigated for the “mechanisms” by which structured exercise influences depression. Yet, exercise is proposed as an effective non-pharmaceutical anti-depression

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intervention [7]. Skeletal muscle contraction during exercise elicits central and peripheral nerve protection [8], while increasing myokine secretions [9]. Further, myokines can increase peroxisome proliferator-activated receptor gamma coactivator-1α (PGC1-α) activation and reduce pro-inflammation cytokines. Moreover, chronic exercise can directly regulate neuronal factor levels, especially Brain-derived Neurotropic Factor (BDNF) to maintain neurons and synaptic plasticity [10].

Clinically, a sub-analysis of results from the National Social Life, Health and Aging Project in the United States of America demonstrated an inverse relationship between physical activity levels and depression symptoms [11]. Cochrane Review also reported that supervised strength exercise intervention reduces depression compared to rest in 12,109 financially active people [12], demonstrating an association between depression and physical activity levels and physical factors. Moreover, a recent systematic review and meta-analysis reported that exercise reduces depressive symptoms in adults with depression similar to the pharmacological interventions [13], demonstrating the positive role of exercise in depression.

It is shown that physical activity level and function are related to depression and its symptoms mechanistically and clinically; increased physical activity levels and physical function are highly recommended to patients with depression and to reduce the prevalence [14]. Therefore, studies that can recognize the importance of exercise through comprehensive analysis of factors affecting depression using large-scale extensive surveys such as physical activity and muscle strength and analysis of relevance based on physical activity-related variables should be continuously supported. As such, by using the data collected from a nationwide-large-scale investigation, the Korean National Health and Nutrition Examination Survey (K-NHAESE), we evaluated the association between depression and physical factors for the general population of South Korea.

METHODS

1. Data collection

For this study, the data collected from the K-NHAESE between 2014 and 2020 was used. The survey was conducted annually from Korean adults ages 18 to 64 years of age randomly selected by interviews and self-administered questionnaires. The survey included health status questions, such as disease availability, injuries, medical service availability, physical activity levels, physical activity restrictions, quality of life, obesity, and safety awareness. Height, weight, hand grip strength, and blood markers (e.g., glucose level and lipid profile) were also collected from the participants. Furthermore, as depression status was only collected bi-annually using the Patients Health Questionnaire-9 (PHQ-9), data from the years 2014, 2016, 2018, and 2020 were used for analysis. For depression assessment, we used the Korean version of PHQ-9, and normal (PHQ-9 score 0-4), low-risk (score 5-9), and high-risk (Score ≥10) depression was classified according to Park and colleagues in 2010 [15].

2. Data characteristics and statistical analysis

The bi-annual K-NHANES data between 2014 and 2020 was used for the current evaluation. Furthermore, the data collected in these years did not contain the data with the same identification code for individual participants, as such we used complex sampling analysis to treat the obtained data as cross-sectional data to represent the South Korean population using differential weights on the variables. In addition, before we construct a statistical model for depression considering complex sampling analysis, we examined the distribution of PHQ-9 Scores. The result of the PHQ-9 questionnaire is a continuous variable with a range of scores from 0 to 27. However, as we expected, the score "0" is 39.6% among the total responses, a general form of linear regression that assumes the normality of data distribution may result in inaccurate coefficients and standard error estimates; we used Zero-inflated Poisson Model [16] and the formulas are follows:

$$\Pr(y_i = 0) = \pi + (1-\pi)e^{(-\lambda)} \text{ (Zero model)}$$

$$\Pr(y_i = n) = (1-\pi)\frac{\lambda^n e^{(-\lambda)}}{n!} s.t\ n \geq 1 \text{ (Count model)}$$

The differential weights for the individual variables were provided by the Korea Disease Control and Prevention Agency with original data and the R Software (Version 4.3.1), survey, srvyr, and svyVAM, were used for data analysis and significance level of all tests were defined as a *p*-value less than .05.

As a result, data from 29,716 (male: 13,416, female: 16,300) participants out of 34,135 participants were secured, and complex sample statistical analysis was conducted on 50,881,242 people (estimated South Korean population in 2022) by applying the differential weight on the variables. The demographic factors (e.g., average family income, age, and gender) were used as control variables while constructing the fit models for each independent variable (e.g., physical activity, body composition, and blood measures) for Zero-inflated Poisson regression of PHQ-9 depression score and the fit model with meaningful interpretations were used for

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the final model.

RESULTS

1. The statistical description of the population

The statistical description of the population (n=50,881,242) after applying differential weight to collected data (n=29,716) is presented in Table 1. Briefly, the average age was 39.81±20.203 in males and 42.06±21.144 in females, and weight was 67.35±18.72 and 54.77±13.89 in males and females, respectively. Grip strength was 37.68±3.21 kg in males and 22.21±5.41 in females. The average total PHQ-9 Score was 3.04±3.95 in females and 2.56±3.63 in males. Moreover, the classification of depression showed that 11.1% of males classified as low-risk depression and 3.7 % were classified as high-risk. In females, the low-risk and high-risk populations were 17.2% and 7.1%, respectively. Fifty-six percent answered "Yes" for commute physical activity, and average commute physical activity days per week and minutes per day were 4.73±1.87 days and 43.00 ±33.30 minutes, respectively. For moderate-intensity physical activity, 27.3% answered "Yes" and the average days per week was 3.44±1.69 days with 51.00±38.10 minutes per day. Thirteen-point two percent answered "Yes" for high-intensity physical activity, and the average days per week for high-intensity physical activity was 3.13±1.65 days with 55.90±47.60 minutes per day. Finally, mean HDL was 47.68±1.96 mg/dL in males and 54.82±12.42 in females while fasting glucose levels in males and females were 101.74±1.96 and 97.10±20.68 mg/dL, respectively.

2. Physical activity and PHQ-9 Score

Table 2 shows the association between PHQ-9 Scores and demographic factors as well as physical activity types. We used the Count data model (subjects with PHQ-9 Scores equal to and higher than 1) and also the Bernoulli distribution model (subjects with PHQ-9 Scores=0 vs. ≥1), The odds ratio for PHQ-9 Scores compared to average family income and age was 0.999 and 0.998, respectively, in Count data model. The odds ratio of total PHQ-9 for gender, females showed a higher odds ratio

Table 1. Weighted characteristics of study population

Variables	Omission rate (%)	Response and unit	Male	Female	Total
Gender (Number [%])	0		25,480 (50.1)	25,400 (49.9)	50,880 (100)
Age (Mean [SD])	0		39.81 (20.203)	42.06 (21.144)	40.93 (20.709)
Family income (Mean [SD])	0.4	Monthly income in 10,000 ₩ (~$9)	466.37(314.34)	440.42 (315.19)	453.42 (315.03)
Sleep time (Mean [SD])	7.0	Hours per day	7.01 (1.31)	7.03 (1.40)	7.02 (1.35)
Weight (Mean [SD])	0.2	kg	67.35 (18.72)	54.77 (13.89)	61.07 (17.64)
Waist circumference (Mean [SD])	1.4	cm	83.03 (13.20)	76.03 (12.06)	79.54 (13.12)
Grip strength (Mean [SD])	37.5	kg	37.64 (8.90)	22.21 (5.41)	28.33 (10.36)
PHQ-9 Score (Mean[SD])	26.0	Score (range: 0-27)	2.07 (3.21)	3.05 (3.96)	2.56 (3.64)
PHQ-9 classification of depression (Number [%])	26.0	Normal* (in thousands) Low-risk** (in thousands) High-risk*** (in thousands)	16,320 (85.2) 2,130 (11.1) 710 (3.7)	14,780 (75.7) 3,360 (17.2) 1,380 (7.1)	31,120 (80.4) 5,490 (14.2) 2,090 (2.4)
Commute physical activity (Number [%])	21.8	Yes (in thousands) No (thousands)	10,880 (53.5) 9,450 (46.5)	12,370 (59.8) 8,300 (40.2)	23,250 (56.7) 17,760 (43.3)
Commute physical activity (Mean [SD])	57.0	Days per week	4.90 (1.84)	4.59 (1.89)	4.73 (1.87)
Commute physical activity (Mean [SD])	62.6	Minutes per day	45.43 (37.47)	41.37 (29.90)	43.00 (33.30)
Moderate-intensity physical activity (Number [%])	21.8	Yes (thousands) No (thousands)	6,490 (32.0) 13,790 (68.0)	4,690 (22.7) 15,920 (77.3)	11,180 (27.3) 29,720 (72.7)
Moderate-intensity physical activity (Mean [SD])	57.0	Days per week	3.40 (1.76)	3.50 (1.58)	3.44 (1.69)
Moderate-intensity physical activity (Mean [SD])	62.6	Minutes per day	54.73 (42.39)	46.95 (32.42)	51.00 (38.10)
High-intensity physical activity (Number [%])	21.9	Yes (thousands) No (thousands)	3,780 (18.6) 16,500 (81.4)	1,630 (7.9) 18,980 (92.1)	5,410 (13.2) 35,490 (86.8)
High-intensity physical activity (Mean [SD])	91.5	Days per week	3.04 (1.71)	3.33 (1.51)	3.13 (1.65)
High-intensity physical activity (Mean [SD])	92.6	Minutes per day	62.11 (52.71)	44.72 (33.76)	55.90 (47.60)
HDL (Mean [SD])	15.8	mg/dL	47.68 (1.96)	54.82 (12.42)	51.22 (12.24)
Fasting glucose (Mean [SD])	15.8	mg/dL	101.74 (23.54)	97.10 (20.68)	99.44 (22.29)
HbA1c percent (Mean [SD])	16.0	%	5.7 (0.8)	5.5 (0.7)	5.7 (0.8)

PHQ-9 classification: 0-4, normal; 5-9, low-risk; over 10, high-risk.

(OR = 1.213; SE, 0.009; $p < .001$) in the Count data model. Importantly, a significant association between PHQ-9 total score and commute physical activity (OR = 1.042; SE, 0.006; $p < .001$) and Moderate-intensity leisure and structural physical activity (OR = 1.116; SE, 0.008; $p < .001$) were shown in the Count data model. However, in the Bernoulli distribution, only the demographic factors (average family income, age, and gender) were associated with a PHQ-9 Score of 0.

3. Physical factors and PHQ-9 Score

Table 3 shows the association between PHQ-9 Scores and demographic factors as well as physical factors and blood measures. We used the Count data model (subjects with PHQ-9 Scores equal to and higher than 1) and also the Bernoulli distribution model (subjects with PHQ-9 Scores = 0 vs. ≥ 1). In the Count data model, the odds ratio for PHQ-9 Scores compared to average family income and age was 0.999 and 0.997. In contrast, the association was not shown in the Count data model between total PHQ-9 Scores and gender. Further, an association between the PHQ-9 Scores and physical factors, including weight and waist circumference, was not shown; however, a significant association between the total PHQ-9 Scores and hand-grip strength was observed in the Count data model (OR = 0.985; SE, 0.001; $p < .001$). In the Bernoulli distribution model, demographic factors, including average family income (OR = 1.000; SE, 0.000; $p < .001$), age (OR = 1.022; SE, 0.002; $p < .001$), and gender (female: OR = 0.721; SE, 0.059; $p < .001$) were associated with a PHQ-9 Score of 0. However, physical factors, hand-grip strength, weight, and waist circumference were not associated with a PHQ-9 Score of 0. Lastly, blood measures, HDL (OR = 1.004; SE, 0.002; $p < .05$), fasting glucose (OR = 1.004; SE, 0.001; $p < .01$), and glycated hemoglobin (OR = 0.889; SE, 0.038; $p < .01$) were associated with a PHQ-9 Score of 0.

Table 2. Association between PHQ-9 Scores and physical activity

		Odds ratio	Standard error	Z-score	*p*-value
Count data model (PHQ-9 Score equal to and higher than 1)	Average family income	0.999	0.000	39.487	< .001
	Age	0.998	0.000	8.858	< .001
	Gender: female	1.213	0.009	20.581	< .001
	Commute physical activity (NO)	1.042	0.006	6.514	< .001
Leisure and structure physical activity	Moderate-intensity (NO)	1.116	0.008	13.049	< .001
	High-intensity (NO)	1.009	0.012	0.734	.463
Bernoulli distribution (PHQ-9 Score "= 0" vs. "≥ 1")	Average family income	1.000	0.000	7.530	< .001
	Age	1.022	0.001	21.743	< .001
	Gender: female	0.633	0.030	15.347	< .001
	Commute physical activity (NO)	0.979	0.021	1.006	.315
Leisure and structure physical activity	Moderate-intensity (NO)	0.976	0.021	-0.614	.521
	High-intensity (NO)	0.971	0.026	1.117	.264

Table 3. Association between PHQ-9 Score and physical factors

		Odds ratio	Standard error	Z-score	*p*-value
Count data model (PHQ-9 Score equal to and higher than 1)	Average family income	0.999	0.000	31.933	< .001
	Age	0.997	0.000	7.076	< .001
	Gender: female	1.022	0.018	1.162	.245
	Hand-grip strength	0.985	0.001	15.588	< .001
	HDL-C	1.000	0.000	1.014	.311
	Fasting glucose	1.001	0.000	3.392	< .001
	Glycated hemoglobin	1.000	0.011	-0.036	.971
Bernoulli distribution (PHQ-9 Score "= 0" vs. "> 1")	Average family income	1.000	0.000	4.511	< .001
	Age	1.022	0.002	14.420	< .001
	Gender: female	0.721	0.059	5.568	< .001
	Hand-grip strength	1.006	0.003	1.868	< .001
	HDL-C	1.004	0.002	2.293	< .050
	Fasting glucose	1.004	0.001	3.029	< .010
	Glycated hemoglobin	0.889	0.038	3.061	< .010

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Table 4. Association between depression classification and physical activity/physical factors: Binominal Logistic regression

		Odds ratio	Standard error	Z-score	*p*-value
Normal vs. low/high-risk	Average family income	0.999	0.000	8.838	<.001
	Age	0.981	0.002	10.883	<.001
	Gender: female	1.380	0.084	3.815	<.001
	Commute physical activity (NO)	1.045	0.037	1.195	.233
	Moderate-intensity physical activity (NO)	1.190	0.046	3.777	<.001
	Fasting glucose	1.000	0.002	0.063	.950
	Hand-grip strength	0.980	0.004	4.629	<.001
	Glycated hemoglobin	1.062	0.055	1.077	.282
Normal vs. high risk	Average family income	0.998	0.000	8.285	<.001
	Age	0.981	0.000	7.148	<.001
	Gender: female	1.428	0.145	2.459	<.001
	Commute physical activity (NO)	1.085	0.065	1.262	.207
	Moderate-intensity physical activity (NO)	1.302	0.090	2.930	<.010
	Fasting glucose	1.006	0.003	1.797	.073
	Hand-grip strength	0.969	0.008	4.005	<.001
	Glycated hemoglobin	0.957	0.096	0.457	.648

4. Binomial logistic model for depression classification

In the Binominal Logistic Regression for Normal (PHQ-9 Score ≤4) vs. low/high-risk (PHQ-9 Scores >5) depression, a significant association was shown for being classified as low/high-risk depression in people without moderate-intensity physical activity (OR=1.190; SE, 0.046; $p<.001$), and the people with higher hand grip strength were in lower risk for classified as low/high-risk depression compared to Normal (OR=0.980; SE, 0.004; $p<.001$). Similarly, the Binominal Logistic Regression for Normal vs. high-risk depression showed a significant association of being classified as high-risk depression with an answer "NO" for moderate-intensity physical activity (OR=1.302; SE, 0.090; $p<.001$). In addition, hand grip strength was significantly associated with high-risk depression classification (OR=0.969; SE, 0.008; $p<.001$) (Table 4).

DISCUSSION

The study aimed to evaluate the relationship between depression and physical activity levels for the South Korean population. As such, we used data from the nationwide investigation (K-NHAESE), which collected data randomly from individuals over 18 years old every year to investigate the health status of South Koreans. It was shown that the PHQ-9 Scores were associated with the availability of moderate-intensity physical activity and hand grip strength. Similarly, our data also demonstrated a significant association between being classified as depressed and the availability of moderate-intensity physical activity as well as hand grip strength in the South Korean Population.

Based on previous research, physical activity and depression are known to have a bi-directional relationship, where people with depression are likely to have reduced physical activity, and lower physical activity can increase the risk of depression [17]. In addition, a meta-analysis by Schuch and colleagues in 2018 demonstrated a 17% reduced risk of depression in individuals with high physical activity compared to low physical activity [18]. Another meta-analysis by the same group in 2017 involving 2,901 patients with depression showed a substantial reduction in physical activity levels and increased sedentary time per day, suggesting an association between physical activity and depression [19]. Nevertheless, depression is also highly associated with other socioeconomic factors [20]; a comprehensive understanding of the population is required to provide insight into public health. As such, we used a database for a nationwide investigation of the health of South Koreans between 2014-2020, to provide a comprehensive understanding of a single nation population sharing similar cultural values and socio-economic environment.

First, we sought to evaluate the association between depression and physical activity (e.g., the availability of different types of physical activity) in a single nation population that is suitable for South Koreans. We observed a significant reduction in PHQ-9 Scores by 4.2% and 11.6% in those without commute physical activity and moderate-intensity leisure and structure physical activity, respectively, in the Count data model (PHQ-9 Score ">0"). However, no statistically significant difference was found in the Bernoulli distribution model, and as previously described, when the response variable follows the zero-inflated Poisson distribution, the zero-inflated probability and Poisson mean are expressed as linear functions of covariates, which are judged to be the result of the Zero-inflated Poisson Model. To provide more clinical implications, we conducted a Binominal Logistic Regression analysis for the PHQ-9 Score classification of depression in the South Korean Population based on Park et al [21] and Kim et al [22]. In contrast with Count data analysis, only no moderate-intensity leisure and structured physical activity was positively associated with being classified as a low/high-risk depression (19% increase), and high-risk depression (30.2% increase) compared to being classified as Normal, respectively. These results extend and confirm the results from previous studies demonstrating an association between physical activities and depression [23]. However, what is indicated for our analysis is that commute physical activity can improve some symptoms of depression but is not associated with depression classification, and the availability of moderate-intensity exercise (leisure and structured physical activity) is associated with depression classification in the South Korean population.

We also evaluate the association between PHQ-9 Scores and the physical factors, including body composition hand-grip strength, and blood profile. Previously, a longitudinal cohort study by Smith et al. [24] and a cross-sectional study by Brooks et al. [25] showed an association between greater hand-grip strength and a lower risk of the onset of depression symptoms and also demonstrated hand-grip strength as an independent factor negatively associated with depression symptoms in the United States. In our analysis of the South Korean population, a 1.5% reduction of PHQ-9 Scores was observed with a 1 kg of hand-grip strength increase in the Count data model, and hand-grip strength was negatively associated with being classified as low/high-risk depression and high-risk depression compared to Normal.

In contrast, our analysis showed no association between body composition and depression symptoms and classification, which is in contrast with traditional knowledge of this association [26]. For example, a recent study by Zimmermann et al. [27], demonstrated a positive association between body composition (e.g., waist circumference and body fat) in 130 participants. This inconsistency might occur due to socio-demographic variables and cultural differences (e.g., diet and social norms) specific to Koreans [20], and this is the reason for the need for a single-nation evaluation to develop a public health intervention for individual countries. Further, as this is the first study covering the entire Korean adult population, the wide range of age among the participants potentially diminishes the association between body composition and depression. As such further analysis by dividing age groups and gender as well as other social factors would be required to evaluate the associations between physical activity types/levels and depression in detail. However, the association between the PHQ-9 Scores and blood factors related to body composition, such as HDL, fasting glucose levels, and glycated hemoglobin, was similarly observed in our analysis, suggesting that engaging in physical activities to improve body composition is important to prevent or reduce depression symptoms.

The current study has a few strengths and limitations. The key strength of this study is that we used a database for K-NHAESE and were able to secure a large number of cases (a total of 34,135 cases) to represent the general South Korean population. As such, the implications generated from this study can be used to develop nationwide interventions to improve public health in South Korean Society. However, due to the nature of the cross-sectional analysis, this study was not able to deduce the causal effects of physical activity and factors on depression. Furthermore, although the PHQ-9 questionnaire is known to be a gold-standard survey for large population-based studies, the results were evaluated solely based on self-reported questionnaires, which might have influenced the objectivity of the study.

CONCLUSION

In summary, our findings indicated 1) a negative association between depression and the availability of moderate-intensity leisure and structured physical activity and 2) a negative association between depression and hand-grip strength in the general population of South Korea aged over 18 years old. In addition, the association between depression and body composition (waist circumference) was not shown, suggesting culture and socio-demographic-specific differences influencing depression risk factors for South Korea compared to the Western population. Thus, outcomes from this study will provide important implications for the governing body of South Korea to plan and execute intervention programs for enhancing public health, and also alert other countries to perform and evaluate a single-nation study for depression.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

AUTHOR CONTRIBUTIONS

Conceptualization: DH Yoon, KJ Kim; Methodology: DH Yoon, JS Kim; Software: DH Yoon; Formal analysis: DH Yoon, JS Kim; Writing – original draft: DH Yoon, JS Kim, KJ Kim; Writing – review & editing: DH Yoon, JS Kim, KJ Kim; Supervision: KJ Kim, DH Yoon.

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