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Correlation analysis of exercise volume and musculoskeletal disorders in people with income level differences: research based on the 2011–2018 NHANES dataset

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Abstract

Objectives Socioeconomic factors significantly impact human health; however, the impact of exercise and income on musculoskeletal system health remains unclear. Our study aims to explore the relationship between exercise and income with musculoskeletal system health in young and middle-aged adults.

Design This cross-sectional study used data from 7,515 adults aged 20–59 years, which were obtained from the US NHANES, 2011–2018. Participants' musculoskeletal system health was evaluated on the basis of them having osteopenia, osteoporosis, or sarcopenia.

Methods Ordinal regression was used to explore the correlation between income level, exercise volume, and musculoskeletal system health. Mediating effect analysis was used to assess whether the exercise volume affected the impact of income levels on musculoskeletal system health. Ordinal regression and restricted cubic spline curve were used to further analyze the relationship between exercise and income level.

Results In the analysis of adjusted all covariates, the probability of having good musculoskeletal system health in high-income participants was higher than that of low- or middle-income participants. The probability of having good musculoskeletal system health in the actively exercising group higher than that of the participants exercised insufficiently or sufficiently. Mediating effect of exercise masked the effect of income on musculoskeletal system health. Participants with low income levels tended to spend more time exercising that those who had high income levels; exercise volume and income level had a significant non-linear relationship.

Conclusion The findings presented will help identify young and middle-aged adults who are most at risk of developing musculoskeletal health problem and will likely benefit from certain lifestyle interventions.

Keywords Income, Physical activity, Musculoskeletal health

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Introduction

Although the economies of many countries and regions have experienced significant growth in recent decades, which has improved overall living standards, a considerable wealth gap still exists in high-income countries such as the United States (US) and the United Kingdom (UK). The differences in income levels between individuals have also led to health inequalities within the population. Thus, analyzing the health status of people across different income levels to devise targeted policies for macro-health regulation are essential measures geared toward solving the problem of health inequality.

The income level has a crucial impact on overall health. For instance, studies have shown that family income is closely related to mental health [1] and can affect the prevalence of some diseases (e.g., human papillomaviral infection) [2]. In addition, socioeconomic status has been shown to affect the incidence of cardiovascular diseases [3]. Prolonged, persistent low income levels has even been linked to an increase in all-cause mortality among middle-aged individuals [4]. Thus, income level is a key factor affecting the overall health of a population.

UK- and US-based cross-sectional studies involving adolescents have shown that those from higher income families participated in more organized sporting activities and spent more time doing recreational exercise than those from low-income families [5]. Although most of the comparative studies have involved adolescents, the relationship between exercise and income likely transcends across the whole of society. For instance, the income level of people who partake in regular physical activity has been shown to be 13.36% higher than that of people who do not exercise regularly [6]. Therefore, the correlation between income level and exercise was one of the themes being explored in this study.

Exercise is closely related to the health of the musculoskeletal system, which comprises bone junctions and skeletal muscle. Conditions such as sarcopenia, which are traditionally associated with aging [7], however, current research results show that sarcopenia begins to appear in adults over the age of 20 due to lifestyle, metabolic level and other factors [8]. Physical activity such as sports participation not only delays muscle aging but also reduces the rate of age-related muscle mass decline, while maintaining muscle strength and regenerative ability [9]. Bone mineral density (BMD) is also an important indicator of musculoskeletal system health. Recently, a large number of clinical studies have confirmed the correlation between BMD and exercise [10, 11].

In summary, based on the close relationship between social factors (income level, etc.) and behavioral factors (exercise level, etc.) and physical health status, our study hypothesize that the impact of income level on health status may be mediated through its influence on physical activity. The present study used data from four rounds of the National Health and Nutrition Examination Survey (NHANES) (from 2011 to 2018) to measure BMD and the skeletal muscle mass index (SMI) as indicators of the health status of the musculoskeletal system to assess the complex relationship between income levels, exercise patterns, and musculoskeletal system health.

Methods

Study design

Our study includes income level as the exposure variable and overall health status of the musculoskeletal system as the outcome variable. The aim is to investigate the impact of income level on musculoskeletal disorders and the role of physical activity in this relationship. Additionally, we explore the nature of the relationship between income level and physical activity. Based on the above research design, we included participants from the NHANES database for the years 2011–2018 as the subjects of this study.

During the 2011–2018 period, the NHANES involved a total of 39,156 participants, among which 14,943 participants were aged between 20 and 59 years. Subsequently, 4,283 participants who lacked whole-body DEXA data, 1,794 participants who lacked exercise-related data, 1,329 participants who lacked household income index data, and 22 participants who lacked other covariates (such as information relating to age, sex, race, education level, body mass index [BMI] [12], hypertension [13], diabetes) were excluded. Thus, a total of 7,515 participants were included in the final study analysis (Fig. 1). We evaluated the participants' musculoskeletal system health on the basis of them having reduced BMD, osteoporosis, or sarcopenia.

Body measurement

The NHANES body measurements dataset (in kg/m^2) was used to calculate the participants' BMI. The participants were subsequently divided into the following three groups according to their BMI: < 25 (normal); 25–30 (overweight) and > 30 (obesity) [14]. The DEXA examination was used to collect the limb muscle mass data, whole body density, and BMD; only non-pregnant individuals aged 20–59 years were examined.

Assessment of musculoskeletal system health

DEXA was used to evaluate BMD and muscle mass. Osteoporosis and osteopenia were diagnosed according to the T-score. The calculation of the T-score included the mean and standard error of the BMD in young people aged 20–29 years for a given NHANES cycle [15]. A T-score ≥-1was defined as normal BMD, a T-score < -1 was defined as osteopenia, and a T-score < -2.5 was defined as osteoporosis. Participants with osteoporosis,

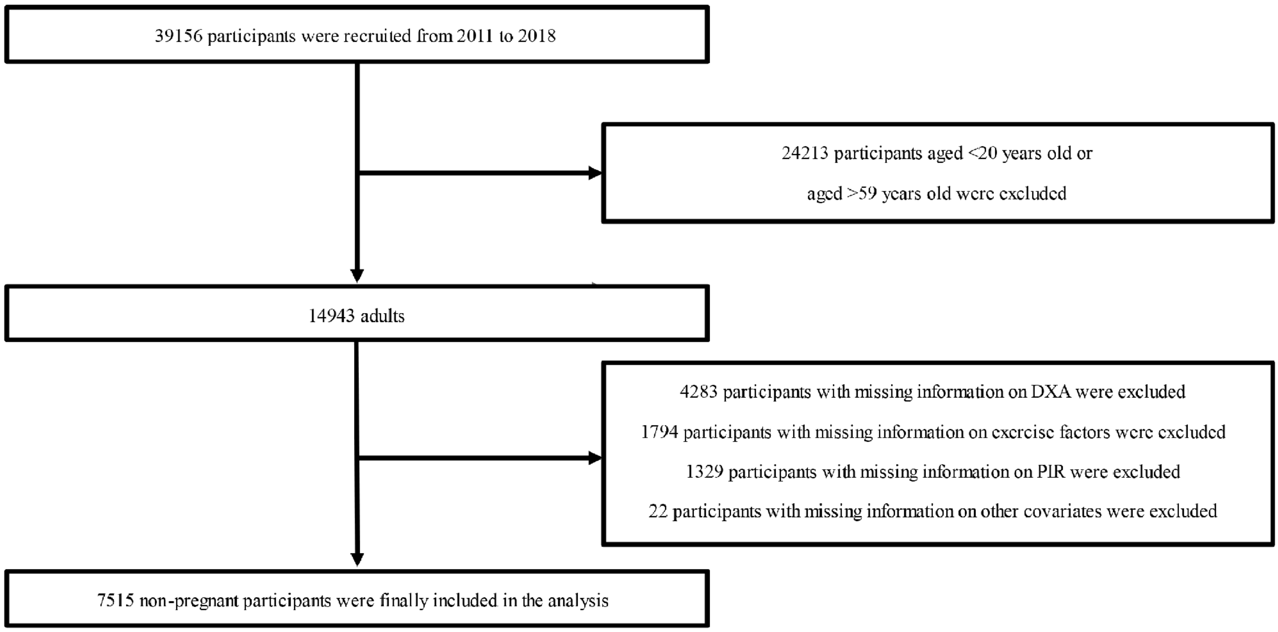

Fig. 1 Flow chart of study participants

osteopenia, and normal BMDs were given musculoskeletal health scores of 0,1, and 2, respectively. SMI was used to evaluate muscle mass. The BMI correction method recommended by the National Institutes of Health was used to calculate SMI by dividing the mass (kg) of the appendix skeletal muscle (ASM) by the BMI (kg/m^2). SMIs < 0.789 (for men) and < 0.512 (for women) [16] were defined as sarcopenia. Considering the overall health of the musculoskeletal system, we have established a scoring system based on the concept of osteosarcopenia [17]. Participants with sarcopenia and normal muscle mass were given musculoskeletal health scores of 0 and 1, respectively. The overall status of an individual's musculoskeletal system was defined based on the combination of their scores. Thus, combined scores of 0–1, 2, or 3 indicated very poor, poor, and good musculoskeletal system health.

Physical activity

The exercise data used in the NHANES study were based on the Global Physical Activity Questionnaire (GPAQ) [18], which is used to collect physical activity data from interviews with participants. The total duration of exercise was calculated by converting the duration of exercise with a given into its equivalent duration of moderate intensity exercise, before summing these values. The conversion was based on the recommended MET score schedule provided by the NHANES database. The participants were then divided into the following three groups on the basis of their total moderate intensity exercise durations: > 300 min per week is actively exercising;150–300 min per week is exercising sufficiently; < 150 min per week is exercising insufficiently [19].

Income levels

Income levels were calculated by family monthly poverty level index (FMMPI), there were three categories of income levels (FMMPI): < 1 is low income; 1–3 is middle income; > 3 is high income.

The FMMPI is an index for the ratio of monthly income to poverty. The 2017 and 2018 Department of Health and Human Services' (HHS) poverty guidelines were used as the poverty measure to calculate this index (HHS 2019). The variable FMMPI was calculated by dividing family income by the poverty guidelines, specific to family size, as well as the appropriate year and state. In summary, it is a variable that perfectly suit for our study.

Covariates

This study included socioeconomic factors, BMI, diabetes, and hypertension as important determinants of musculoskeletal system health. The race parameter was divided into six categories: Mexican American, Non-Hispanic White, Non-Hispanic Black, Other Hispanic, Non-Hispanic Asian, and Other Race. The education level was divided into six categories: < 9th grade, 9–11th grade, High school graduate, Some college or AA degree, College graduate or above.

For hypertension and diabetes, this study adopted a comprehensive diagnosis method. Participants with systolic blood pressure ≥ 140 mmHg or diastolic blood pressure ≥ 90 mmHg for two consecutive blood pressure readings or those who had been diagnosed with hypertension or treated with medication for hypertension were defined as having hypertension (the 'Yes' group), and the rest were defined as not having hypertension (the 'No' group) [20]. Participants who had been diagnosed with diabetes or used insulin or oral hypoglycemic drugs or had fasting blood glucose levels ≥ 7.0 mmol/L or glycosylated hemoglobin A1c (HbA1c) levels ≥ 6.5% were defined as having diabetes (the 'Yes' group), and the rest were defined as not having diabetes (the 'No' group) [21]. The above diagnostic and medication data were collected from questionnaires, the examination data were derived from the body measurement data, and the test data were derived from the laboratory data.

Statistical analysis

In this study, the samples were weighted according to the NHANES year. The statistical significance of differences between groups was determined using the analysis of variance (ANOVA) and chi-squared test; weighted averages were used for continuous data, while weighted percentage frequencies were used for categorical data. Unadjusted, micro-adjusted, or multivariate fully adjusted methods were used to conduct a multi-class ordered logistic regression analysis of the relationship between income level, physical activity level, and the health status of the musculoskeletal system. Age, sex, race, education level, BMI, hypertension, and diabetes were included in the adjusted model.

Our complex multi-stage random sampling technique was based on NHANES dataset. We used "survey" R package in R software (4.3.1) and variables respectively named "Masked variance unit pseudo-stratum variable for variance estimation", "Masked variance unit pseudo-PSU variable for variance estimation" and "Full sample 2 year MEC exam weight" to apply a complex multi-stage random sampling technique.

The unadjusted, micro-adjusted, and multivariate fully adjusted methods were used to conduct a multi-category ordinal logistic regression analysis of the interaction between income level and exercise. Age, sex, race, education level, BMI, hypertension, and diabetes were included in the adjustment model. The restricted cubic spline (RCS) curve was used to describe the distribution of the participants' income levels and physical activity levels, which could then be used to justify the results of the mediating effect analysis.

The chain mediating effect analysis method was used to determine the role of exercise duration and income level on musculoskeletal system health. Taking the income level of the population as the exposure factor, the duration of physical activity as the intermediary variable, and the health status of the musculoskeletal system as the outcome variable, the direct effect, indirect effect and intermediary ratio were calculated.

Statistical analysis was performed using IBM SPSS (version 26.0, https://www.spss.com) and R software (version 4.3.1, https://www.R-project.org). All the tests to determine statistical significance were two-sided. A P-value of < 0.05 was considered as a measure of statistical significance.

Results

Population characteristics

Table 1 shows the demographic baseline characteristics of the 7,515 participants whose data were extracted from the NHANES database for use in this study. As shown in Table 1, the musculoskeletal health status of the participants indicates that 2.19% had very poor health, 18.06% had poor health, and 79.76% had good health. The participants with poor musculoskeletal system health were mostly women (68.1%), Mexican Americans (24.2%), patients with hypertension (33.8%), patients with diabetes (15.0%), and those with a BMI > 30 (59.1%), a FMMPI < 1 (27.2%), and exercising insufficiently (59.0%). Thus, participants with poor musculoskeletal system health were more likely to have the following characteristics: poor general health (hypertension, diabetes), female sex, obesity, older age, low income, and performing insufficient levels of exercise. Meanwhile, participants with good musculoskeletal system health were more likely to be male, perform sufficient levels of exercise, and have a high income.

The correlation between income level, physical activity level, and musculoskeletal system health

In Model 1 (unadjusted), the Odds Ratio (OR) and 95% Confidence Interval (CI) of participants with high income levels having good musculoskeletal system health compare with participants with low or middle-income levels respectively were 1.389 (1.199, 1.622) and 1.251 (1.096, 1.425) (Table 2). That of participants in the actively exercising group compare with participants who were exercising insufficiently and sufficiently respectively was 1.855 (1.626, 2.114) and 1.277 (1.094, 1.493) (Table 2).

After adjusting for age, sex, and race in Model 2, we found that the probability of having good musculoskeletal system health in the group of participants with high-income levels was 1.650 (1.408, 1.934) and 1.403 (1.221, 1.613) times higher than that in the group of participants with low and middle income levels, respectively (Table 2). The probability that actively exercising participants had good musculoskeletal system health was 1.383 (1.200, 1.595) times greater than the insufficiently exercising participants.

After adjusting for all the covariates (age, sex, race, education level, BMI, hypertension, diabetes) in Model 3,

Table 1 Descriptive baseline characteristics of participants based on their musculoskeletal system health

	Musculoskeletal system health				*p* value
	Total (*N* = 93202630)	0–1 (*N* = 2037653)	2 (*N* = 16827793)	3 (*N* = 74338384)	
Gender					< 0.001
Male	52.4%	31.9%	36.6%	56.6%	
Female	47.5%	68.1%	63.4%	43.4%	
Age					
20–29	28.2%	16.1%	25.3%	29.0%	< 0.001
30–39	24.5%	12.2%	17.7%	26.4%	
40–49	24.2%	25.1%	20.4%	25.1%	
50–59	23.1%	46.6%	36.7%	19.5%	
Race					< 0.001
Mexican American	9.3%	24.2%	11.9%	8.4%	
Other Hispanic	6.6%	6.6%	9.2%	6.0%	
Non-Hispanic White	64.4%	56.5%	61.8%	65.3%	
Non-Hispanic Black	10.4%	2.6%	4.8%	11.8%	
Non-Hispanic Asian	5.6%	9.4%	8.1%	4.9%	
Other Race	3.7%	0.7%	4.2%	3.6%	
Education level					< 0.001
Less than 9th grade	2.9%	9.5%	4.3%	2.4%	
9-11th grade	7.9%	12.7%	9.1%	7.5%	
High school graduate	20.7%	24.8%	25.0%	19.6%	
Some college or AA degree	33.9%	30.6%	30.4%	34.7%	
College graduate or above	34.6%	22.5%	31.2%	35.7%	
Hypertension					< 0.001
No	75.8%	66.2%	74.6%	76.4%	
Yes	24.1%	33.8%	25.4%	23.6%	
Diabetes					< 0.001
No	92.7%	85.0%	91.1%	93.2%	
Yes	7.3%	15.0%	8.9%	6.8%	
BMI					< 0.001
Normal	33.1%	16.0%	38.9%	32.2%	
Overweight	33.2%	24.9%	28.4%	34.6%	
Obesity	33.7%	59.1%	32.6%	33.2%	
Income Levels					< 0.001
Low income	17.4%	27.2%	19.3%	16.7%	
Middle income	39.3%	41.9%	41.1%	38.9%	
High income	43.2%	30.9%	39.6%	44.4%	
Moderate intensity exercise duration					< 0.001
Exercising insufficiently	41.2%	59.0%	48.4%	39.2%	
Exercising sufficiently	25.8%	18.7%	26.0%	25.9%	
Actively exercising	33.0%	22.3%	25.6%	34.9%	

BMI, body mass index. Values are presented as weighted percentages, %

we found that the probability of achieving good musculoskeletal system health in the group of participants with high income levels was 1.377 (1.159, 1.639) and 1.259 (1.087, 1.460) times higher than in the groups of participants with low and middle income levels, respectively (Table 2). The probability of having good musculoskeletal system health in the actively exercising population was 1.427 (1.236, 1.647) and 1.178 (1.001, 1.387) times greater than that in the insufficiently and sufficiently exercising groups, respectively. After incorporating all covariates into the adjusted ordinal logistic regression model, we found that the participants who were actively exercising and had higher income levels were more likely to have a healthy musculoskeletal system (Fig. 2).

The mediating effect of exercise on the correlation between income level and musculoskeletal system health

To explore whether the amount of exercise affected how income level impacted musculoskeletal system health, we next analyzed the relationship between these three

Table 2 Association between musculoskeletal system health and income levels with moderate intensity exercise duration

	Model 1			Model 2			Model 3		
	OR	95%CI	*p* value	OR	95%CI	*p* value	OR	95%CI	*p* value
Income Levels									
Low	1(reference)	1(reference)		1(reference)	1(reference)		1(reference)	1(reference)	
Middle	1.111	(0.969,1273)	$p=0.130$	1.138	(0.985,1.313)	$p=0.078$	1.062	(0.918,1.229)	$p=0.424$
High	**1.389**	**(1.199,1.622)**	$p<0.001$	**1.587**	**(1.354,1.861)**	$p<0.001$	**1.338**	**(1.124,1.590)**	$p<0.001$
Moderate intensity exercise duration									
Insufficiently	1(reference)	1(reference)		1(reference)	1(reference)		1(reference)	1(reference)	
Sufficiently	**1.452**	**(1.265,1.669)**	$p=0.002$	**1.246**	**(1.076,1.443)**	$p=0.003$	**1.237**	**(1.068,1.435)**	$p=0.005$
Actively	**1.855**	**(1.626,2.114)**	$p<0.001$	**1.413**	**(1.225,1.629)**	$p<0.001$	**1.452**	**(1.257,1.677)**	$p<0.001$

Model 1: No covariates were adjusted. Model 2: Age, gender, and race were adjusted. Model 3: Age, gender, race, education level, BMI, hypertension and diabetes were adjusted. BMI, body mass index

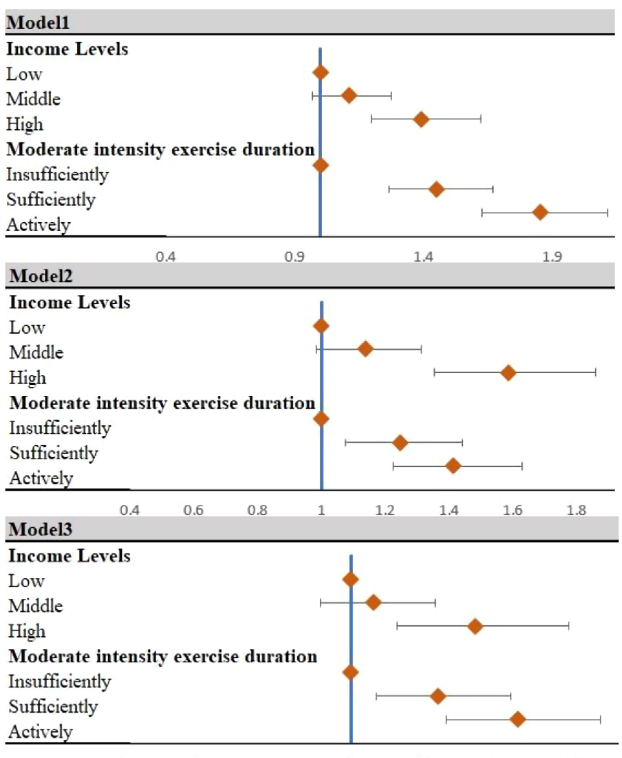

Fig. 2 OR (95% CI) in income levels and moderate intensity exercise duration associated with musculoskeletal system health, weighted. Model1 was unadjusted; Model2 was adjusted for age, gender and race; Model3 was adjusted for age, gender, race, education level, BMI, hypertension and diabetes. BMI, body mass index

factors. To this end, we performed a chain mediating effect analysis in which the amount of exercise was treated as an intermediary variable, the musculoskeletal system health score was treated as a dependent variable, and the income level (FMMPI) was treated as an independent variable.

Under the condition of high income level as a reference, the direct effect (DE) of low income level on the musculoskeletal system health score was −0.0507 (−0.0763, −0.0250). The indirect effect (IE) of low income level on the musculoskeletal system health score through the amount of exercise was 0.0056 (0.0028, 0.0087); of note, the total effect was −0.0450 (−0.0706, −0.0195) and the mediating effect ratio was 12.44% [22], suggesting the presence of a masking effect (Fig. 3a); the direct effect (DE) of middle income level on the musculoskeletal system health score was −0.0744 (−0.1040, −0.0448). The indirect effect (IE) of low income level on the musculoskeletal system health score through the amount of exercise was 0.0061 (0.0030, 0.0094); of note, the total effect was −0.0683 (−0.0978, −0.0389) and the mediating effect ratio was 8.20% [22], suggesting the presence of a masking effect (Fig. 3b). Thus, we found that although musculoskeletal system health correlated positively with the income level and the amount of exercise, the physical activity level exerted a masking effect in the analysis of the mediating effect. The results showed that the income level and the physical activity level did not participate in a simple positive correlation.

Correlation analysis between physical activity level and income level

Our next aim was to explore the causes of the masking effect described above. Taking the level of exercise as the dependent variable and the income level as the independent variable, we next performed an ordered multi-classification logistic regression analysis on the correlation between the two variables. In Model 1 (unadjusted), the participants with low-income levels were 1.603 (1.433, 1.794) and 1.612 (1.462, 1.777) times more likely to be actively exercising than those with high and middle income levels, respectively. After adjusting for age, sex, and race (Model 2), the participants with low income levels were 1.380 (1.226, 1.553) and 1.427 (1.289, 1.580) times more likely to be actively exercising than those with high and middle income levels, respectively (Table 3).

After adjusting for all the covariates (age, sex, race, education level, BMI, hypertension, diabetes), the Model 3 results showed that the participants with middle income levels were 1.221 (1.096, 1.360) times more likely to be actively exercising than those with high income levels (Fig. 4). Our results showed that people with low income

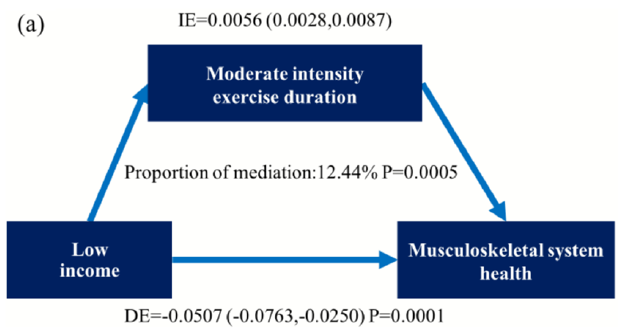

Fig. 3 Weighted estimated proportion of the association between musculoskeletal system health and income levels mediated by moderate intensity exercise duration. IE, estimate of the indirect effect; DE, estimate of the direct effect; the proportion of mediation = IE/DE + IE

Table 3 Association between income levels and moderate intensity exercise duration

	Model 1			Model 2			Model 3		
	OR	95%CI	*p* value	OR	95%CI	*p* value	OR	95%CI	*p* value
Income Levels									
Low	**1.603**	**(1.433,1.794)**	$p<0.001$	**1.38**	**(1.226,1.553)**	$p<0.001$	1.112	(0.976,1.267)	$p=0.106$
Middle	**1.612**	**(1.462,1.777)**	$p<0.001$	**1.427**	**(1.289,1.580)**	$p<0.001$	**1.221**	**(1.096,1.360)**	$p<0.001$
High	1(reference)	1(reference)		1(reference)	1(reference)		1(reference)	1(reference)	

Model 1: No covariates were adjusted. Model 2: Age, gender, and race were adjusted. Model 3: Age, gender, race, education level, BMI, hypertension and diabetes were adjusted. BMI, body mass index

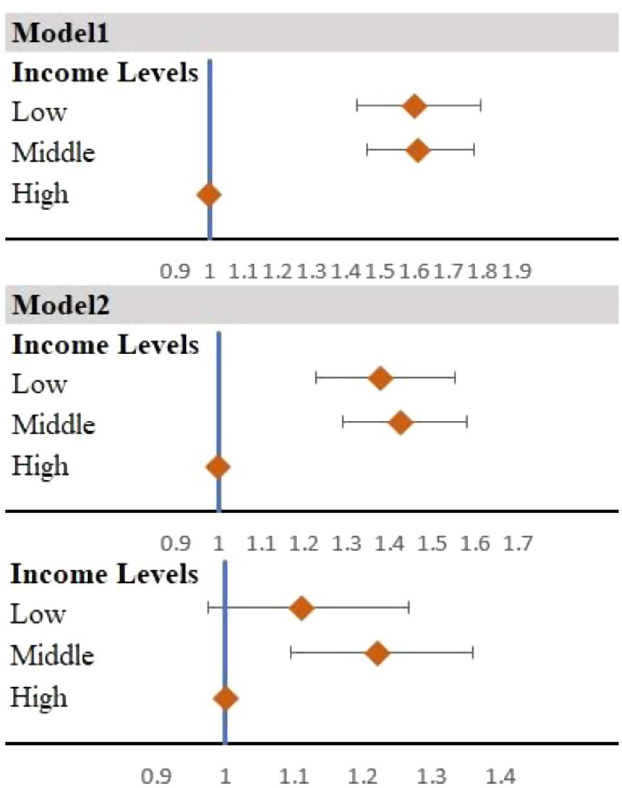

Fig. 4 OR (95% CI) in income levels associated with moderate intensity exercise duration, weighted. Model1 was unadjusted; Model2 was adjusted for age, gender and race; Model3 was adjusted for age, gender, race, education level, BMI, hypertension and diabetes. BMI, body mass index

levels were more likely to be actively exercising than those with high income levels; this finding may explain the masking effect of exercise in the mediating effect of FMMPI on the health of the musculoskeletal system score. Thus, we found that people with low incomes were more likely to exercise than those with high incomes; however, the distribution of physical activity level relative to the FMMPI could not be fully described.

RCS curve analysis of income level and exercise volume

After a preliminary analysis of the relationship between exercise volume and income level, we defined exercise volume as the dependent variable and FMMPI as the independent variable. We performed RCS curve fitting to further analyze the distribution of exercise amount relative to FMMPI. Our results showed that at a FMMPI < 1.0553, the amount of exercise tended to decrease with an increase in FMMPI; however, at a FMMPI ≥ 1.0553, the amount of exercise tended to increase with an increase in FMMPI (Fig. 5a). Therefore, exercise volume masked the mediating effect of FMMPI on the health of the musculoskeletal system.

We next classified exercise volume into two categories, whereby an exercise duration < 150 min was defined as insufficient exercise, while an exercise duration ≥ 150 min was defined as sufficient exercise. The 50th percentile of FMMPI (FMMPI equals 1.9347) was used as the reference point for RCS curve fitting of the odds ratio (OR) value. The results showed that the population with a 0.3266 ≤ FMMPI ≤ 1.9347 exercised sufficiently, while the population with a FMMPI < 0.3266 or > 1.9347 exercised

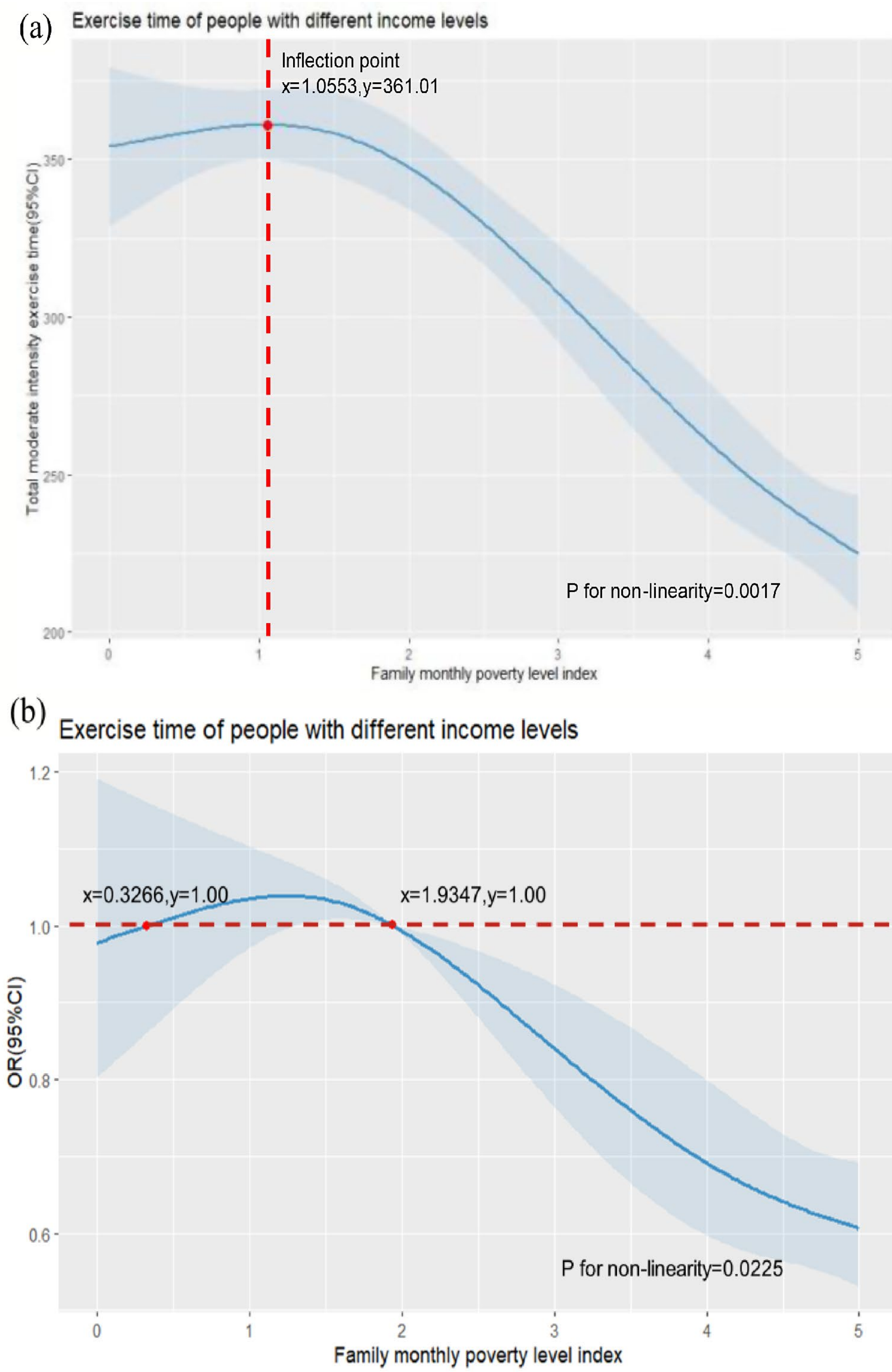

Fig. 5 Association between FMMPI and moderate exercise duration

insufficiently (Fig. 5b). Thus, the results showed that participants with high-income levels were more likely to spend less time exercising than those with low-income levels; this findings may explain the masking effect of exercise in the previous mediating effect analysis.

Discussion

In this cross-sectional study, people who had a high income or were actively exercising had a higher odds ratio for good musculoskeletal system health than those who had a low income and were not doing enough exercise. However, the physical activity level parameter masked the mediating effect of FMMPI on the musculoskeletal system health, which was due to a significant non-linear relationship between physical activity level and income level. From the results of the RCS curve analysis, we concluded that there was a significant non-linear relationship between income level (FMMPI) and exercise volume. We found that at a FMMPI < 1.0553, the amount of exercise decreased with the increase in FMMPI, while at a FMMPI ≥ 1.0553, the amount of exercise increased with the increase in FMMPI. Thus, the participants with a 0.3266 ≤ FMMPI ≤ 1.9347 were deemed as exercising sufficiently, while those with a FMMPI > 1.9347 or < 0.3266 were exercising insufficiently.

Although bones and muscles have the same embryonic origins and together form the human musculoskeletal system, diseases effecting these body building blocks are often discussed separately. Osteoporosis greatly increase the risk of bone fracture [15, 23, 24]. Thus, controlling the occurrence and progression of osteoporosis is an effective measure to prevent bone-related adverse clinical outcomes, including fractures [25, 26]. The occurrence and progression of sarcopenia, which involve muscle and are an area of active research in the field of sports medicine [27, 28], are closely related to factors such as exercise and aging [29, 30]. The recent clinical concept of skeletal muscle reduction provides a further theoretical basis for evaluating the overall health of the musculoskeletal system [31, 32].

Due to the reduction of physical activity in the elderly, this group is more prone to osteoporosis and sarcopenia, and the risk factors of this group have also received widespread attention, especially in people with osteoporosis and sarcopenia aged over 65 years [33, 34]. However, except the influence of aging, the effect of exercise level on the health status of the musculoskeletal system is rarely studied. The sociological and behavioral risk factors associated with musculoskeletal diseases in the younger populations need to be further determined [35, 36]. This helps us to find the risk factors of musculoskeletal disorders in different target groups, and to develop different exercise guidelines and treatment strategies for different populations. Therefore, this study selected young and middle-aged people as the target group.

In recent years, the influence of social and economic factors on human health has become a popular clinical research topic. Low socioeconomic status and income level have been shown to inhibit the development of the nervous system, limit physical function and daily activities, and increase the prevalence of chronic diseases (e.g., liver and kidney diseases, ischemic heart disease, cerebral infarction, and chronic obstructive bronchitis) [37–39]. Income level is an important socioeconomic factor, which has a crucial impact on human health, including the health of the musculoskeletal system.

Income level is closely related to the overall health of an individual, with effects ranging from type of diet to all-cause mortality [4, 40]. Moreover, income level, as a factor that influences lifestyle, has been shown to subtly alter the exercise habits of adolescents [5]. Population-level studies have shown that low-income countries have a higher incidence of underactivity, and that the rate of exercise participation is closely related to all-cause and cardiovascular mortality [41, 42]. Studies have shown that dietary factors (intake of protein and other nutrients) are closely related to the impact of income levels and exercise levels on the health status of the population [43–46]. This also suggests a close relationship between income level, physical activity, and physical health. However, the effect of income level on the exercise pattern and the musculoskeletal system health of working adults aged 20–59 years is uncertain. Our study not only evaluated the link between physical activity level and income level in young and middle-aged people, but also determined the influence of income level and physical activity level on the health of the musculoskeletal system.

We found that physical activity level and income level correlated positively with the health of the musculoskeletal system; however, the income level had a non-linear relationship with the physical activity level, which highlights the importance of considering our changing lifestyles when searching for interdependencies. Our research shows that people with low income levels have a lower risk of insufficient exercise than people with high income levels. This may be due to differences in exercise patterns and jobs, which needs to be further explored. Importantly, our findings imply that increasing physical activity level will improve musculoskeletal health irrespective of income level.

The main strength of this study was that it evaluated the health of the musculoskeletal system as a whole, which meant that the impact of income level and physical activity level on overall health could be more readily assessed. By calculating the T-score, bone loss was also included in the evaluation criteria, which rendered the overall evaluation of musculoskeletal system health from a combined score more innovative and convincing. Second, this study included NHANES data from 7,515 respondents, which constitutes a sufficiently large sample size to support joint and hierarchical analyses with adequately high statistical power. Third, although there are suggestions and studies on the exercise mode of elderly patients with osteoporosis and bone mineral density reduction [26, 47], there are still gaps in the relevant exercise guidelines for young and middle-aged groups with poor musculoskeletal health. The purpose of this study is to provide a theoretical basis for filling the gaps in related fields.

This study also had some limitations. First, as a cross-sectional study, this study could determine the certain relationship between variables, and could only highlight correlations between variables. Second, the 'amount of exercise' parameter was not determined via accelerometer monitoring but was evaluated using a questionnaire. Moreover, the 'total exercise duration' used in this study was not included in the original NHANES dataset but was obtained following secondary data processing by our research team. Third, both lifestyle (exercise) and socioeconomic status (income level) were affected by the disease status of the participants. To comprehensively characterize the physical activity profiles of the population, this study further describes the characteristics of individuals with a weekly physical activity duration > 300 min. The study did not use the typical classification methods based on exercise duration. Although this study included hypertension and diabetes for adjustment, it could not completely eliminate the possibility of residual confusion because the effect of other diseases was not considered. In addition, the covariates considered in this study are limited, some lifestyle factors such as nutritional status are not included in the research model. Furthermore, ecological fallacy related to income levels at the group level may lead to inaccurate representations of individual income situations, obscure significant variability and complexities at the individual level, and potentially affect the accuracy of research conclusions.

Conclusions

In summary, people with better musculoskeletal system health tend to spend more time exercising and have higher incomes. In terms of the correlation between income level and physical activity level, individuals with a low income tend to spend more time exercising but have worse musculoskeletal system health than individuals with a high income. These results may provide baseline characteristic data for determining the populations predisposed to poor musculoskeletal system health and provide a reference for the development of exercise guidelines for people with different income levels. Further research needs to clarify the causal relationship between musculoskeletal system health, physical activity level, and income level.

Practical implications

1. Our study found that individuals with a low income tend to spend more time exercising but have worse musculoskeletal system health than individuals with a high income.
2. We provided baseline characteristic data for determining the populations predisposed to poor musculoskeletal system health and provided a reference for the development of exercise guidelines for people with different income levels.
3. Our study preliminarily identified some of the predilection population of musculoskeletal disorders and could arousing vigilance to musculoskeletal disorders.

Abbreviations

BMI	Body mass index
FMMPI	Family monthly poverty level index
NHANES	National Health and Nutrition Examination Survey
OR	Odds ratios

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Author contributions

X.T. and Y.Q. conceived the study design and are responsible for the overall content. X.P. analyzed and interpreted the data. S.L., B.C. and Z.Y. prepared the manuscript. W.H. edited the manuscript. All authors approved the submitted and final versions.

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Data availability

https://www.cdc.gov/nchs/nhanes/.

Declarations

Ethics approval and consent to participate

The NHANES surveys we used were approved by the relevant institutional review boards and all participants provided written informed consent.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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