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Association of physical activity levels and prevalence of major degenerative diseases: Evidence from the national health and nutrition examination survey (NHANES) 1999–2018

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ABSTRACT

Objectives: Degenerative diseases are associated with lower healthy life expectancy and higher mortality. Physical activity (PA) has demonstrated a fundamental role in the prevention and control of several pathologies associated to the aging process. The aim of this study was to analyze the association of PA with the prevalence of sarcopenia, osteoporosis and osteoarthritis in non-institutionalized American population.
Methods: Cross-sectional study carried out in participants aged ≥50 years from the 1999–2018 National Health and Nutrition Examination Survey (NHANES). Sarcopenia was defined using appendicular lean mass adjusted for body mass index (ALM:BMI; men <0.789 kg/m^2, women <0.512 kg/m^2). Osteoporosis was defined as bone mineral density T-score ≤−2.5 of femur neck. Osteoarthritis and PA were self-reported, and total PA was used to classify participants in groups. The Odds Ratios among the different PA levels for each disease were examined.
Results: Performing at least 150 MET-min/week of PA was associated with reduced odds for sarcopenia; performing >1800 MET-min/week was associated with reduced odds for osteoporosis; and performing 150–1800 MET-min/week of PA was associated with reduced odds for osteoarthritis after adjust the results by several confounders.
Conclusions: The benefits of PA in sarcopenia, osteoporosis, and osteoarthritis prevention are evident among Americans aged ≥50 years.

1. Introduction

The aging population, which is increasing exponentially, is currently a new demographic reality and a source of concern for health systems. Life expectancy in developed countries has significantly increased over recent decades (Oeppen and Vaupel, 2002; Kochanek et al., 2019), although this is not always consistent with the healthy life expectancy (GBD 2017 DALYs and HALE Collaborators, 2018), defined as the number of years a person can be expected to live with complete health (WHO, 2009). In the United States the life expectancy for 65 year old men and women is 17.7 and 20.3 years respectively, while the healthy life expectancy for men and women at this age is 12.9 and 14.8 respectively (CDC, 2013).

Major degenerative diseases that impair quality of life are commonly associated with aging, and frequently closely linked with each other. Sarcopenia, is a progressive and generalized disorder defined as the loss of skeletal muscle mass and strength, and therefore functional capacity (Studenski et al., 2014). Osteoporosis, is defined as a skeletal disorder characterized by decreased density of normally mineralized bone and microarchitectural deterioration of bone tissue, making it more

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vulnerable to fracture due to overload (Glaser and Kaplan, 1997). Moreover, osteoarthritis is the most common joint disorder, characterized by the degeneration of articular cartilage, and also frequently associated with significant functional impairment (Martel-Pelletier et al., 2016). These disorders have been associated with changes in body composition (Martel-Pelletier et al., 2016; Greco et al., 2019), and also with negative health outcomes, including loss of functional capacity, frailty, fractures, falls, pain, and even an increased risk of death (Studenski et al., 2014; Glaser and Kaplan, 1997; Martel-Pelletier et al., 2016; Greco et al., 2019; Batsis et al., 2014; Johnston and Dagar, 2020).

It is known that lifestyle plays a key role in increasing and preserving healthy life expectancy (Mehta and Myrskylä, 2017). In this regard, physical activity (PA) has demonstrated a fundamental role in the improvement of quality of life through the prevention or treatment of degenerative diseases associated with the aging process (Roos and Arden, 2016; Fransen et al., 2015; Beaudart et al., 2017; Pedersen and Saltin, 2015). Moreover, PA is a useful way to reduce the most common negative health outcomes associated with sarcopenia, osteoporosis, and osteoarthritis (Fransen et al., 2015; Beaudart et al., 2017; Pedersen and Saltin, 2015; Varahra et al., 2018).

Prevalence of degenerative diseases among the general population has been analyzed in many studies (Looker et al., 2017; Batsis et al., 2016; Batsis et al., 2015; Vina and Kwoh, 2018), however, few of them have analyze this prevalence among different PA levels in a representative sample of a country. This could be of interest in order to add more information in terms of exercise prescription purposes, or exploring a possible dose-response effect. Therefore, the objective of this study was to analyze the association of PA with the prevalence that these degenerative diseases have in non-institutionalized American population.

2. Material and methods

2.1. Study design and population

The present study was carried out with data from the 1999–2018 National Health and Nutrition Examination Surveys (NHANES), conducted annually by the National Center for Health Statistics (NCHS) with the aim to assess the health and nutritional status of a representative sample of non-institutionalized United States population. The survey uses a multistage, complex, stratified probability sampling design that oversamples minorities and older adults, providing excellent external validity. Only participants aged ≥50 years old were included in the study. We excluded participants with lacked data in any of the analyzed variables, so the final sarcopenia dataset (data from 1999 to 2004) included 4505 participants, the osteoporosis dataset (data from 2007 to 2018) included 7210 participants, and the osteoarthritis dataset (data from 2011 to 2018) included 8820. The selection of the survey periods to analyze each disease is based on the availability of data obtained throughout the same methodology assessment.

All participants provided written informed consent, and The Ethics Review Board of the NCHS approved measurement procedures and data collection and posting of the data online for public use.

2.2. Sarcopenia, osteoporosis, and arthritis definition

Sarcopenia was defined following the Foundation for the National Institutes of Health (FNIH) definition using the appendicular lean mass (ALM) and body mass index ratio (ALM:BMI). ALM was defined as the sum of the lean mass of all limbs expressed in kilograms. To assess the lean mass a dual energy x-ray absorptiometry (DXA) QDR-4500 Hologic scanner (Bedford, MA) was used. The cut points for sarcopenia were <0.789 kg/m^2 and <0.512 kg/m^2 for men and women respectively (Studenski et al., 2014).

Osteoporosis was defined as bone mineral density (BMD) ≤ -2.5 standard deviation (SD) (T-score ≤ -2.5 SD) at femur neck (Shuhart et al., 2019). BMD of the femur neck was obtained with Hologic QDR-4500 and Hologic Discovery DXA scanners (Bedford, MA). APEX™ version 4.0 and Discovery 12.4 software were used to analyze femur scans in the different period data, but results showed no differences in mean BMD at femur neck between both software's (Looker et al., 2017), details of the DXA examination protocol have been published elsewhere (Centers for Disease Control, 2007). T-scores were calculated as (BMD participant – BMD reference group)/SD reference group. As recommended by the International Society for Clinical Densitometry (ISCD), the reference group for calculation T-scores for the femur neck consisted of 20–29 year-old non-Hispanic white females from NHANES III (Shuhart et al., 2019).

The osteoarthritis diagnosis was self-reported through the following question "Has a doctor or other health professional ever told you that you have arthritis?". For this study, only participants with osteoarthritis were included.

2.3. Assessment of physical activity

Physical activity was assessed by interview using a questionnaire. For the period 1999–2004 PA of the last 30 days was evaluated by means of a questionnaire taking into account PA at work/domestic, in transport/travel, and in leisure time. Each of the activities were awarded an energy expenditure on METs using the criteria established by Ainsworth (Ainsworth et al., 2011). The MET-min per week of each activity was calculated by multiplying the standard MET value of each activity by the total number of minutes per week of each activity, then the total MET-min per week was calculated as the sum of MET-min per week of each activity. This physical activity quantification method was identical to that in previous studies (Steeves et al., 2016; Fowler et al., 2020).

For the period 2007–2018 PA was evaluate through the Global Physical Activity Questionnaire (GPAQ) created by WHO (Armstrong and Bull, 2006). This questionnaire analyze the usual PA performed by participants in a typical week in 3 different fields (PA at work/domestic, PA in transport/travel, and PA in leisure time) as long as it has been carried out in continuous periods of 10 min. The questionnaire also takes into account the intensity at which it has been performed (moderate or vigorous). The total MET-min per week was calculated following the GPAQ protocol (World Health Organization, n.d.).

Finally and based in previous cut-points (Ekelund et al., 2016), the subjects were classified into different groups based on their PA level. The groups were defined as Very Low PA (VLPA) (<150 MET-min/week), Low PA (LPA) (150–960 MET-min/week), Medium PA (MPA) (961–1800 MET-min/week) and High PA (HPA) (>1800 MET-min/week).

2.4. Assessment of additional covariates

Age, sex, race/ethnicity, annual household income, educational level, smoking status, alcohol consumption, and BMI were assessed. Age was classified in periods of 10 years from the aged of 50 years (50–59; 60–69; 70–79; ≥80). Race/ethnicity variable difference among Mexican American, Other Hispanic, Non-Hispanic Withe, Non-Hispanic Black, and Other (including Multi-Racial). Annual household income variable classifies the participants in four groups (0–19,999 $; 20,000–44,999 $; 45,000–74,999 $ and ≥75,000 $). Educational level groups were less 9th grade, 9th–12th grade with no diploma, high school graduate or equivalent, college or Associate's degree, and college graduate or above. Finally, participants were classified by alcohol consumption in the last 12 months (0 drinks/day, <2 drinks/day, and ≥2 drinks/day), smoking status (never smoking, former smoker, and smokers), and obesity status (obesity was defined as BMI ≥30 kg/m^2).

2.5. Statistical analysis

According to the NHANES analytical guidelines, all data was downloaded, merged, and analyzed incorporating appropriated

Table 1
Baseline characteristics of study participants according to levels of PA[a].

	Overall	VLPA	LPA	MPA	HPA	*P* value for interaction
Sarcopenia dataset						
N, %	100 (4505)	36.9 (1924)	31.1 (1330)	15.2 (579)	16.8 (672)	<0.001
Sarcopenia, %	16.9 (1021.4)	24.6 (563.6)	14.8 (272.4)	11.2 (96.4)	9.1 (89)	<0.001
Age, %						
50–59	46.0 (1317)	41.1 (498)	46.7 (403)	53.0 (198)	49.4 (218)	<0.001
60–69	26.7 (1463)	26.5 (617)	27.9 (440)	24.3 (183)	27.2 (223)	
70–79	19.0 (1066)	20.4 (463)	18.3 (306)	16.9 (132)	19.0 (165)	
>80	8.3 (659)	12.0 (346)	7.2 (181)	5.8 (66)	4.4 (66)	
Male, %	51.3 (2517)	44.4 (992)	53.3 (746)	53.1 (338)	61.1 (441)	<0.001
ALM, kg	21.28 (0.11)	20.42 (0.18)	21.51 (0.21)	21.68 (0.33)	22.35 (0.21)	
Race/Ethnicity, %						
Mexican American	3.4 (830)	4.5 (426)	3.3 (237)	1.9 (375)	2.5 (92)	<0.001
Other Hispanic	4.2 (155)	5.7 (84)	3.5 (37)	2.2 (12)	3.8 (22)	
Non-Hispanic Withe	81.7 (2721)	75.3 (993)	83.0 (847)	87.9 (406)	87.4 (475)	
Non-Hispanic Black	7.7 (695)	10.9 (378)	6.6 (171)	5.4 (72)	4.8 (74)	
Other	3.1 (104)	3.5 (43)	3.6 (38)	2.7 (14)	1.5 (9)	
Obese, %	32.7 (1461)	37.8 (684)	32.9 (433)	29.2 (176)	24.2 (168)	<0.001
Annual Household income, %						
0–19,999 $	20.2 (1292)	29.9 (715)	16.8 (343)	12.9 (113)	11.6 (121)	<0.001
20,000–44,999 $	32.4 (1569)	37.5 (719)	31.3 (463)	26.9 (181)	28.1 (206)	
45,000–74,999 $	22.9 (856)	18.2 (285)	25.8 (273)	27.0 (137)	24.3 (161)	
≥75,000 $	24.6 (788)	14.4 (205)	26.2 (251)	33.1 (148)	36.1 (184)	
Educational level, %						
Less 9th Grade	8.7 (873)	13.8 (516)	7.7 (227)	4.4 (63)	3.1 (67)	<0.001
9th–12th Grade No diploma	13.1 (699)	19.7 (397)	9.6 (160)	9.5 (71)	8.4 (71)	
High School Graduate	26.0 (1033)	28.2 (435)	25.5 (308)	25.2 (141)	22.9 (149)	
College or AA degree	27.3 (1037)	24.5 (371)	30.4 (347)	27.5 (145)	27.4 (174)	
College Graduate or above	24.9 (863)	13.8 (205)	26.8 (288)	33.4 (159)	38.3 (211)	
Alcohol consumers, %						
0 drinks/day	30.8 (1573)	40.7 (827)	27.8 (414)	24.8 (169)	20.0 (163)	<0.001
<2 drinks/day	61.5 (2613)	52.1 (969)	65.1 (831)	66.7 (366)	70.5 (447)	
≥2 drinks/day	7.7 (319)	7.1 (128)	7.1 (85)	8.5 (44)	9.5 (62)	
Smoking status, %						
Never	37.9 (1730)	34.9 (700)	40.0 (535)	42.2 (246)	36.7 (249)	<0.001
Former	43.5 (1995)	41.2 (814)	42.8 (580)	44.8 (272)	48.9 (329)	
Smoker	18.6 (780)	23.9 (410)	17.2 (215)	12.9 (61)	14.4 (94)	
Osteoporosis dataset						
N, %	100 (7210)	28.5 (2393)	22.9 (1631)	11.7 (816)	36.9 (2370)	<0.001
Osteoporosis, %	4.9 (372)	8.0 (188)	4.9 (82)	4.4 (36)	2.7 (66)	<0.001
Age, %						
50–59	43.7 (2427)	34.5 (625)	42.1 (530)	40.7 (252)	52.8 (1020)	<0.001
60–69	31.9 (2549)	32.7 (846)	32.4 (583)	33.8 (307)	30.4 (813)	
70–79	16.9 (1480)	20.2 (554)	17.7 (350)	19.0 (182)	13.3 (394)	
>80	7.5 (754)	12.7 (368)	7.9 (168)	6.5 (75)	3.5 (143)	
Male, %	51.6 (4039)	42.8 (1179)	44.5 (826)	52.1 (450)	62.6 (1584)	<0.001
BMC, g/cm^2	4.11 (0.02)	3.98 (0.02)	4.00 (0.03)	4.10 (0.05)	4.29 (0.03)	
Race/Ethnicity, %						
Mexican American	4.7 (912)	5.6 (332)	4.2 (173)	3.7 (90)	4.7 (317)	0.002
Other Hispanic	3.7 (663)	3.9 (216)	3.6 (149)	3.3 (69)	3.8 (229)	
Non-Hispanic Withe	77.6 (3652)	74.1 (1165)	78.1 (826)	78.3 (428)	79.8 (1233)	
Non-Hispanic Black	8.8 (1461)	11.0 (547)	8.9 (340)	7.7 (147)	7.3 (427)	
Other	5.2 (522)	5.3 (133)	5.2 (143)	7.0 (82)	4.4 (164)	
Obese, %	37.2 (2634)	44.7 (976)	33.3 (558)	36.7 (281)	33.9 (819)	<0.001
Annual Household income, %						
0–19,999 $	12.9 (1540)	17.1 (612)	13.6 (350)	10.3 (151)	10.0 (427)	<0.001
20,000–44,999 $	28.2 (2424)	32.5 (861)	27.7 (528)	28.3 (276)	25.2 (759)	
45,000–74,999 $	20.8 (1387)	20.4 (431)	19.4 (309)	20.3 (154)	22.1 (493)	
≥75,000 $	38.1 (1859)	30.0 (489)	39.3 (444)	41.1 (235)	42.7 (691)	
Educational level, %						
Less 9th Grade	4.6 (785)	7.5 (342)	4.2 (160)	2.9 (70)	3.2 (213)	<0.001
9th–12th Grade No diploma	9.8 (1002)	14.3 (441)	7.9 (190)	5.9 (72)	8.8 (299)	
High School Graduate	25.2 (1722)	27.0 (583)	22.7 (379)	22.9 (189)	25.9 (571)	
College or AA degree	29.2 (1994)	29.9 (627)	29.2 (460)	27.3 (225)	29.4 (682)	
College Graduate or above	31.1 (1707)	21.3 (400)	36.0 (442)	40.9 (260)	32.7 (605)	
Alcohol consumers, %						
0 drinks/day	24.4 (2191)	32.8 (901)	21.5 (444)	20.2 (216)	21.0 (630)	<0.001
<2 drinks/day	67.6 (4476)	61.2 (1353)	71.7 (1075)	73.0 (543)	68.4 (1505)	
≥2 drinks/day	8.1 (543)	6.1 (139)	7.0 (112)	6.9 (57)	10.6 (235)	
Smoking status, %						
Never	47.2 (3173)	43.0 (1005)	51.0 (755)	52.0 (382)	46.5 (1031)	<0.001
Former	36.8 (2750)	38.1 (908)	36.0 (614)	36.9 (322)	36.2 (906)	
Smoker	16.0 (1287)	18.9 (480)	13.0 (262)	11.2 (112)	17.3 (433)	
Osteoarthritis dataset						

(*continued on next page*)

Table 1 (*continued*)

	Overall	VLPA	LPA	MPA	HPA	*P* value for interaction
N, %	100 (8820)	28.2 (2898)	22.4 (1978)	12.1 (1002)	37.3 (2942)	<0.001
Osteoarthritis, %	29.1 (2212)	35.1 (871)	27.0 (460)	25.3 (225)	26.9 (656)	<0.001
Age, %						
50–59	44.1 (3161)	35.7 (825)	41.5 (694)	45.3 (344)	51.7 (1298)	<0.001
60–69	31.6 (2986)	31.5 (969)	33.4 (686)	29.8 (355)	31.0 (976)	
70–79	16.7 (1737)	20.3 (655)	16.8 (387)	18.2 (209)	13.5 (486)	
>80	7.6 (936)	12.5 (449)	8.3 (211)	6.7 (94)	3.7 (182)	
Male, %	50.4 (4894)	43.2 (1437)	44.4 (998)	47.2 (532)	60.4 (1927)	<0.001
Race/Ethnicity, %						
Mexican American	4.4 (1081)	5.3 (399)	3.7 (200)	3.0 (97)	4.5 (385)	<0.001
Other Hispanic	3.6 (872)	4.2 (297)	3.5 (189)	3.1 (96)	3.5 (290)	
Non-Hispanic Withe	78.4 (4327)	75.4 (1383)	77.9 (949)	79.9 (510)	80.6 (1485)	
Non-Hispanic Black	8.0 (1750)	9.4 (603)	8.6 (412)	7.3 (190)	6.8 (545)	
Other	5.6 (790)	5.7 (216)	6.3 (228)	6.8 (109)	4.6 (237)	
Obese, %	37.9 (3321)	47.8 (1265)	35.9 (717)	37.3 (356)	31.9 (983)	<0.001
Annual Household income, %						
0–19,999 $	12.0 (1810)	16.0 (721)	12.4 (396)	9.9 (179)	9.3 (514)	<0.001
20,000–44,999 $	27.3 (2922)	33.9 (1052)	26.0 (639)	26.7 (324)	23.3 (907)	
45,000–74,999 $	21.0 (1686)	19.7 (512)	20.9 (378)	18.5 (180)	22.7 (616)	
≥75,000 $	39.8 (2402)	30.4 (613)	40.6 (565)	44.9 (319)	44.7 (905)	
Educational level, %						
Less 9th Grade	4.2 (912)	6.9 (395)	3.4 (177)	2.7 (81)	3.0 (259)	<0.001
9th–12th Grade No diploma	8.8 (1140)	13.7 (511)	6.8 (203)	5.9 (97)	7.1 (329)	
High School Graduate	23.1 (2000)	26.0 (705)	21.1 (432)	19.5 (198)	23.3 (665)	
College or AA degree	29.7 (2479)	29.5 (763)	30.9 (579)	26.9 (278)	29.9 (859)	
College Graduate or above	34.3 (2289)	24.0 (524)	37.8 (587)	44.9 (348)	36.6 (830)	
Alcohol consumers, %						
0 drinks/day	22.8 (2584)	31.9 (1080)	20.9 (538)	17.2 (241)	18.9 (725)	<0.001
<2 drinks/day	68.7 (5579)	62.0 (1657)	71.5 (1302)	76.2 (702)	69.6 (1918)	
≥2 drinks/day	8.5 (657)	6.1 (161)	7.6 (138)	6.5 (59)	11.6 (299)	
Smoking status, %						
Never	47.4 (3990)	44.0 (1248)	49.7 (935)	55.6 (499)	45.9 (1308)	<0.001
Former	36.9 (3272)	38.0 (1089)	37.0 (730)	35.8 (381)	36.3 (1072)	
Smoker	15.7 (1558)	18.0 (561)	13.3 (313)	8.6 (122)	17.8 (562)	

VLPA: Very Light Physical Activity (<150 MET-min/week); LPA: Light Physical Activity (150–960 MET-min/week); MPA: Medium Physical Activity (961–1800 MET-min/week); HPA: High Physical Activity (>1800 MET-min/week); Other: Other race including Multi-Racial; AA degree: Associate's degree.

[a] Data are expressed as weighted percentages and unweighted number of participants for categorical variables, and as weighted mean (standard error) for continuous variables.

combined weights, primary sampling unit, and strata provided by NHANES (National center for health statistics, n.d.). Categorical variables were expressed as frequency (%), and continuous variables are presented as mean and standard error (SE). Descriptive analyses were carried out for the overall samples and divided by PA level groups. Weighted logistic regressions models were also carried out for each degenerative disease analyzed according to the PA levels of the participants to examine the adjusted odds ratios (OR). Regression models were adjusted for the following variables: age-adjusted, adjusted by age, sex, race/ethnicity, annual household income, and educational level (Model 1), and additionally adjusted by smoking status, alcohol consumption, and obesity (Model 2). A two-sided *p*-value of 0.05 was considered statistically significant. Statistical analysis was performed using SPSS statistical software ver. 24.0 (IBM Corp., Armonk, NY, USA).

3. Results

3.1. Prevalence of major degenerative diseases in Americans

The prevalence of sarcopenia, osteoporosis, and osteoarthritis in ≥50 years old non-institutionalized Americans were 16.9%, 4.9%, and 29.1% respectively. The prevalence of sarcopenia, osteoporosis and osteoarthritis in VLPA, LPA, MPA and HPA groups were 24.6%, 14.8%, 11.2% and 9.1% respectively for sarcopenia; 8.0%, 4.9%, 4.4% and 2.7% respectively for osteoporosis; and 35.1%, 27.0%, 25.3% and 26.9% respectively for osteoarthritis (Table 1).

The prevalence for each degenerative disease according to sex and PA level group can be seen in the Supplementary Table 1, and according to sex and race/ethnicity in the Supplementary Table 2. The prevalence presented in both supplementary tables is also representative of non-institutionalized US-population.

3.2. Association of physical activity levels and degenerative diseases

Data from 4505 participants were used to study the association between sarcopenia and PA levels. The baseline characteristics of participants according to PA level group and overall can be seen in Table 1. The weighted odds for having sarcopenia were 0.60 (95%CI: 0.47, 0.76, $p < 0.05$) for LPA group, 0.49 (95%CI: 0.35, 0.69, $p < 0.05$) for MPA group, and 0.39 (95%CI: 0.29, 0.52, $p < 0.05$) for the HPA group compared to VLPA group after adjusting the results by confounders included in regression model 2 (Fig. 1 and Table 2).

Data from 7210 participants were used to study the association between osteoporosis and PA levels. Table 1 shown the baseline characteristics of participants according to PA level group and overall. As can be seen in Table 2 and Fig. 1, the weighted odds for having osteoporosis were not significant for LPA and MPA group compared with VLPA, 0.68 (95%CI: 0.46, 1.01, $p > 0.05$) for LPA group, and 0.71 (95%CI: 0.43, 1.18, $p > 0.05$) for MPA group. However, the HPA had 0.57 (95%CI: 0.42, 0.76, $p < 0.05$) lower odds for having osteoporosis than VLPA after adjusting the results by confounders included in regression model 2.

Data from 8820 participants were used to study the association between osteoarthritis and PA levels. The baseline characteristics of participants according to PA level group and overall can be seen in Table 1. The weighted odds for having osteoarthritis were 0.75 (95%CI: 0.62, 0.92, $p < 0.05$) for LPA group, 0.73 (95%CI: 0.55, 0.95, $p < 0.05$) for MPA group, and 0.97 (95%CI: 0.81, 1.16, $p > 0.05$) for the HPA group compared to VLPA group after adjusting the results by confounders included in regression model 2 (Fig. 1 and Table 2).

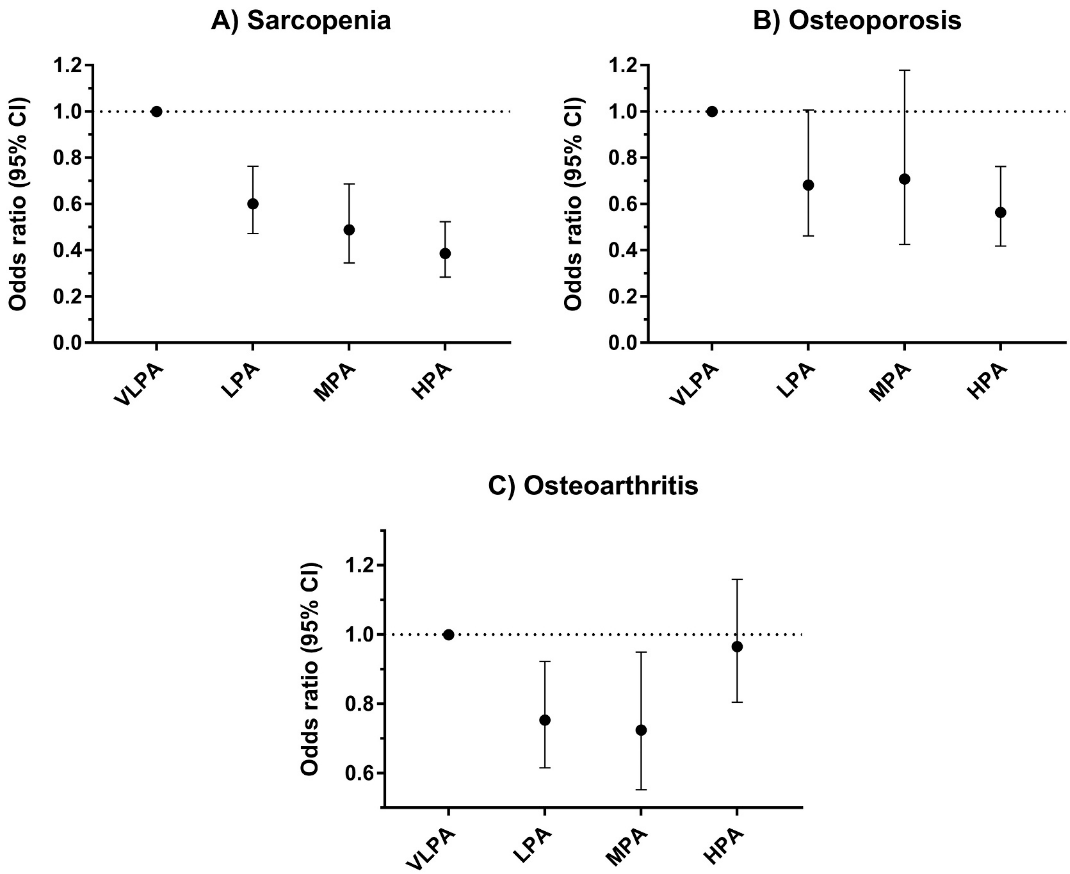

Fig. 1. Odds Ratio (95%CI) for major degenerative diseases according to physical activity level group. Data are representative of non-institutionalized American population.
A) Odds ratio for Sarcopenia B) Odds ratio for Osteoporosis C) Odds ratio for Osteoarthritis.
VLPA: Very Light Physical Activity (<150 MET-min/week); LPA: Light Physical Activity (150–960 MET-min/week); MPA: Medium Physical Activity (961–1800 MET-min/week); HPA: High Physical Activity (>1800 MET-min/week).
All odds ratio were adjusted by age, sex, race/ethnicity, annual household income, educational level, smoking status, alcohol consumption and obesity.

4. Discussion

In this study, we demonstrate that American adults who perform at least 150 MET-min/week of PA presented reduced odds for sarcopenia, those who perform 150–1800 MET-min/week had reduced odds for osteoarthritis, and those who perform more than 1800 MET-min/week had reduced odds for osteoporosis. It seems to be indicating that performing around 1800 MET-min/week (i.e. 64 min/day of moderate PA) is an effective method to prevent some diseases that affect quality of life in a large part of the population over 50 years.

The results observed in our study about the association between sarcopenia and PA levels are in accordance with the main literature findings in this field collected in a recent meta-analysis, which proves that PA protects against sarcopenia and reduces the odds of acquiring it in later life OR = 0.45 (95%CI: 0.37, 0.55, $p < 0.05$) (Steffl et al., 2017). Several previous investigations have focus on if people performed or not PA, but few have stratified their results by PA levels based in frequencies of activity per week/month or METs (Ryu et al., 2013; Beavers et al., 2009; Murphy et al., 2014). The present study shows a possible dose-response relationship, results that agree with a study in Koreans conducted by Ryu et al., which manifested that high levels of PA (≥3000 MET-min/week) are better than moderate (>600 MET-min/week) or low (<600 MET-min/week) levels of PA to prevent sarcopenia in men, although not significant results were reported in women (Ryu et al., 2013). On the other hand, according with reports by Beavers et al., and Murphy et al., PA protects against sarcopenia and reduces the odds of acquiring it in later life, but it is not clear if a dose-response relationship exists (Beavers et al., 2009; Murphy et al., 2014). Previous studies suggest that among others, mitochondrial dysfunction is critical on the sarcopenia pathogenesis (Yoo et al., 2018). Overall, PA appears to ameliorate the mitochondrial-related problems associated with sarcopenia, and consequently, PA has a direct impact on muscle mass quality and quantity, increasing muscle strength and muscle mass in older adults (Yoo et al., 2018; Fragala et al., 2015).

In our study, only the most active group (>1800 MET-min/week) is protected against osteoporosis. These results are similar to those obtained by several previous studies, which demonstrates that only the more active participants were protected against osteoporosis and fracture risk (Kim et al., 2019; Morseth et al., 2012). Kim et al., showed that compared to no activity group, the odds for having osteoporosis were 0.40 (95%CI: 0.16, 0.99, $p < 0.05$) and 0.35 (95%CI: 0.14, 0.90, p < 0.05) times lower among those men who performed moderate and vigorous PA respectively, but no differences were found between those walking (low level of PA) and no activity group (Kim et al., 2019). Morseth et al., concluded that compared with those who did not perform PA, only the most active men and women, (those who performed either light or hard PA at least 3 h/week), had respectively 40% (HR = 0.60, 95%CI: 0.41, 0.90) and 26% (HR = 0.74, 95%CI: 0.58, 0.94) reduced fracture risk in the hip (Morseth et al., 2012). On the other hand, some studies reported no differences in the protective effect among different PA levels (Mackey et al., 2011). These literature discrepancies could be explained through differences in the sample (race, sex, age…), differences in the methodology used to assess the PA, and mainly through differences in the type of PA that people usually performed, because of

Table 2
Odds ratio (95%CI) for degenerative diseases according to physical activity levels. Data are representative of non-institutionalized American population.

	Physical activity levels (MET-min/week)			
	VLPA (<150)	LPA (150–960)	MPA (961–1800)	HPA (>1800)
Sarcopenia				
Age-adjusted	1.00 (ref)[abc]	0.57 (0.45, 0.71)	0.43 (0.31, 0.60)	0.33 (0.25, 0.45)
Multivariable-adjusted 1	1.00 (ref)[abc]	0.58 (0.46, 0.73)	0.46 (0.34, 0.63)	0.34 (0.25, 0.46)
Multivariable-adjusted 2	1.00 (ref)[abc]	0.60 (0.47, 0.76)	0.49 (0.35, 0.69)	0.39 (0.29, 0.52)
Osteoporosis				
Age-adjusted	1.00 (ref)[abc]	0.68 (0.48, 0.96)	0.62 (0.39, 0.99)	0.46 (0.34, 0.62)
Multivariable-adjusted 1	1.00 (ref)[c]	0.70 (0.48, 1.01)	0.71 (0.43, 1.17)	0.60 (0.44, 0.81)
Multivariable-adjusted 2	1.00 (ref)[c]	0.68 (0.46, 1.01)	0.71 (0.43, 1.18)	0.57 (0.42, 0.76)
Osteoarthritis				
Age-adjusted	1.00 (ref)[abc]	0.72 (0.60, 0.87)	0.68 (0.52, 0.88)	0.79 (0.67, 0.94)
Multivariable-adjusted 1	1.00 (ref)[ab]	0.69 (0.57, 0.84)	0.66 (0.50, 0.86)	0.86 (0.72, 1.03)
Multivariable-adjusted 2	1.00 (ref)[ab]	0.75 (0.62, 0.92)	0.73 (0.55, 0.95)	0.97 (0.81, 1.16)

VLPA: Very Low Physical Activity; LPA: Low Physical Activity; MPA: Medium Physical Activity; HPA: High Physical Activity.
Model 1 Adjusted by age, sex, race/ethnicity, annual household income and educational level.
Model 2 Additionally adjusted by smoking status, alcohol consumption and obesity.
[a] Significative differences between Very Low and Low physical activity levels.
[b] Significative differences between Very Low and Medium physical activity levels.
[c] Significative differences between Very Low and High physical activity levels.

the potential preventive effect of PA against osteoporosis depends of the biomechanical impact of the activity (Gomez-Bruton et al., 2017). Maybe one possible reason to explain why in our study only the most active group is protected against osteoporosis, is that persons who belong to this group probably perform more impact loading activities other than walking, putting under high mechanical load the bone tissue than the experienced in daily activities (mainly walking). As a previous theory suppose, the mechanical loads induce stimuli in the bone tissue, resulting in bone mass preservation at sites of mechanical stress (Turner, 2006).

The results provided in our study related to the association of PA and osteoarthritis show a beneficial effect of low and medium level of PA (150–1800 MET-min/week), but this association is not present in the most active group (>1800 MET-min/week). Other authors however, demonstrated a protective effect of vigorous intensity PA on knee osteoarthritis (Racunica et al., 2007), but intensity is not the same as dose (combination of PA intensity and amount). Vigorous activities (such as running or jumping) usually implies a contact stress between the adjacent cartilages surfaces of the joint in the range of 4–9 Nm^2, but at least a 25 Nm^2 contact stress is needed to cause an acute disruption in articular cartilage (Vuori, 2001). However, chronic or repetitive stresses less than 25 Nm^2 may cause articular damage or degeneration (Vuori, 2001). This fact suggests that the main problem is in the amount and not in the intensity of PA, so taking into account the results of our study, low to medium levels of PA seems to be more beneficial than nothing or too much PA in this case.

The three major degenerative diseases analyzed in this study that affect a large part of the population over 50 years old, are not only related with functional disability and so with an impairment in the quality of life (Martel-Pelletier et al., 2016; Greco et al., 2019). In addition, several studies related these diseases with mortality (Martel-Pelletier et al., 2016; Batsis et al., 2014; Johnston and Dagar, 2020). Moreover, the economic burden in the United States due to these diseases are \$18.5 billion for sarcopenia, \$17–25 billion for osteoporosis, and \$193.9 billion for osteoarthritis (Janssen et al., 2004; Burge et al., 2007; Zhao et al., 2019). Therefore, PA can improve both, life expectancy and quality of life. Furthermore, the beneficial effect associated to PA would have an expected impact on the national economic burden that these diseases have.

This study has the strength of the excellent external validity provided by the complex sample design of NHANES, the use of multiple survey periods for each disease, and the use of high-quality data collection methods to assess body composition variables. However, several limitations should be acknowledged in our study. First, the cross-sectional analysis does not allow us to establish a causal temporal link between PA level and the major degenerative diseases analyzed. Second, PA was analyzed taking into account the amount and the intensity, but without taking into account the type of activity performed, and as mention above, this could be a relevant aspect in some degenerative diseases. Third, although data collection about osteoarthritis and PA have been carried out by trained interviewers, the use of self-reported information could be subject to bias. Fourth, only non-institutionalized adults are included in this analysis, so the results can only be applied to this population.

5. Conclusions

The results of the study sustain that PA is associated with lower odds for sarcopenia, osteoporosis and osteoarthritis, three of the major degenerative diseases that affect a large part of the population over 50 years in the United States. Although different doses of PA seem to be more beneficial to prevent each disease, none of the doses analyzed are associated with harmful effects. Overall, PA is effective to prevent these diseases, but the most beneficial dose will depend on conditions of each individual. This implies that public health strategies should focus on PA promotion.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.exger.2021.111656.

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