Lian and Luo *Lipids in Health and Disease* (2024) 23:336
https://doi.org/10.1186/s12944-024-02278-8

Lipids in Health and Disease

RESEARCH

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The association between different leisure-time physical activity patterns and the non-high-density lipoprotein cholesterol to high-density lipoprotein cholesterol ratio in adults: national health and nutrition examination survey 2007–2018

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Abstract

Background Despite the potential superiority of the non-high-density lipoprotein cholesterol to high-density lipoprotein cholesterol ratio (NHHR) as a diagnostic and predictive marker, no study has investigated the link between different leisure-time physical activity (LTPA) patterns and the NHHR. This study aims to explore this relationship.

Methods Data was extracted from the National Health and Nutrition Examination Survey (NHANES) cycles spanning from 2007 to 2008 to 2017–2018. Participants (*N* = 14,211) were classified into four groups based on their LTPA patterns: (1) inactive (LTPA = 0 min/week); (2) insufficiently active (LTPA < 150 min/week); (3) weekend warrior (LTPA ≥ 150 min/week within 1 or 2 sessions); and (4) regularly active (LTPA ≥ 150 min/week in more than 2 sessions). Weighted multiple linear regression analysis was employed twice, using inactive and regular active groups as reference groups, respectively. Weighted stratification analyses and interaction tests were performed by demographics.

Results Compared to the inactive group, each additional unit of LTPA time was associated with a significant 0.23-unit greater decrease in the NHHR in the regularly active group [-0.23 (-0.29; -0.16)]. However, no significant decrease was observed in the "Weekend Warrior" [-0.11 (-0.22; 0.008)] or insufficiently active groups [-0.03 (-0.11; 0.04)]. Moreover, compared to the regularly active group, the insufficiently active [0.21 (0.13; 0.29)], "Weekend Warrior" [0.13 (0.004; 0.25)], and inactive [0.26 (0.20; 0.32)] groups had significantly higher NHHR. The associations between the NHHR and various LTPA patterns did not significantly differ by demographic factors, except for race.

Conclusion The regularly active pattern is significantly associated with a lower NHHR, but no significant difference in the NHHR was detected between the insufficiently active and "Weekend Warriors" patterns. The study suggests that

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frequency and regularity of PA are crucial for optimal lipid management, supporting clinical recommendations to meet or exceed 150 min of PA in more than two sessions per week.

Introduction

Non-high-density lipoprotein cholesterol (non-HDL-C) to high-density lipoprotein cholesterol (HDL-C) ratio (NHHR) is a recently established composite measure of atherogenic lipids [1, 2]. It could be used to evaluate the risk of diseases across multiple body systems, such as those of the cardiovascular [3], digestive [4, 5], and urinary systems [6]. Moreover, since it can encompass all information on not only atherogenic but also anti-atherogenic lipid particles [1, 2], it may possess greater advantages in diagnosis and prediction than conventional lipid parameters. According to Kim et al. (2013), the NHHR is superior for identifying impaired glucose metabolism and metabolic dysregulation compared to the ratio of apolipoprotein B to apolipoprotein A1 [7]. An observational study showed that in patients with type II diabetes, the NHHR could serve as a more reliable risk marker for coronary heart disease than low-density lipoprotein cholesterol (LDL-C) alone, [8]. Additionally, an increasing number of studies have revealed the association and predictive value of the NHHR for multiple diseases, such as periodontitis [9], depression [10], abdominal aortic aneurysm [11], and diabetes [1].

According to previous studies, the NHHR may be associated with numerous factors. In addition to demographic factors such as age, gender, race, marital status, education level, alcohol consumption, smoking, and body mass index (BMI) [9, 12], it is also related to a history of hypertension, diabetes, and certain cardiovascular diseases [12]. Furthermore, regular engagement in physical activity (PA) has been reported to induce favorable alterations in plasma lipid levels. A cross-sectional study revealed a positive association between self-reported leisure time-related PA (LTPA) and HDL-C levels, but an inverse relationship was observed with LDL-C levels [13]. This finding is corroborated by a literature review of intervention trials over the past three decades, which concluded that moderate- to vigorous-intensity PA can increase HDL-C levels while also reducing total cholesterol (TC) and LDL-C levels [14]. The influence of PA on HDL-C and TG levels appears independent of changes in body weight or diet [15]. It is believed that PA enhances the activity of lipoprotein lipase and lecithin cholesterol acyltransferase while reducing hepatic lipase and cholesterol esterified transfer protein activity, which are crucial for reverse cholesterol transport [16].

The World Health Organization (WHO) characterizes PA as any kind of body movement involving the musculoskeletal system that causes energy consumption [17]. It includes not only LTPA, but also transportation-related PA (TPA), and occupational PA (OPA) [17]. OPA refers to physical exertion related to job duties, typically occurring within the duration of a standard work period, such as an 8-hour shift [18]. TPA includes health-promoting active travel behaviors, such as walking or cycling to and from work, and is therefore also referred to as active commuting [19]. LTPA applies to all PAs undertaken during discretionary time. Sports and exercises specifically aimed at consciously improving physical fitness are the concrete forms and core areas of LTPA [20]. However, there is no clear boundary between LTPA and daily activities, which may depend on individual circumstances and subjective perception [20].

Most guidelines advocate that adults should participate in ≥150 min of moderate-intensity, or ≥75 min of vigorous-intensity aerobic PA, or a combination of both each week, to maintain health [21, 22]. Although evidence indicates that these levels offer significant health advantages for most individuals [23], a majority of the population fails to meet these recommendations. These individuals are referred to as insufficiently active, and a significant barrier to adherence is the constraint of time [24]. Therefore, some individuals have to extend the duration of each session but concentrate their activity into one or two days a week, such as only on weekends, to meet this recommendation, and these individuals are referred to as "weekend warriors" [24]. Recent studies have reported that, compared to an inactive PA pattern (no physical activity), the weekend warrior and regularly active patterns (i.e., distributed across more than two sessions to follow the recommended guidelines) may produce similar effects. Both patterns significantly reduced CVD, cancer, and all-cause mortality risks [25], as well as were associated with reduced symptoms of depression [26].

Despite the potential superiority of the NHHR as a diagnostic and predictive marker compared to conventional lipid parameters, no studies have yet investigated the link between different LTPA patterns and the NHHR. This study aims to explore this relationship. The hypothesis is that achieving the recommended level of weekly PA (≥150 min), irrespective of the frequency, is associated with a lower NHHR. By identifying the possible connections between different LTPA patterns and the NHHR, this research not only addresses existing knowledge gaps but also provides practical insights for health professionals to guide patients on effective PA strategies for improving lipid profiles from a novel perspective.

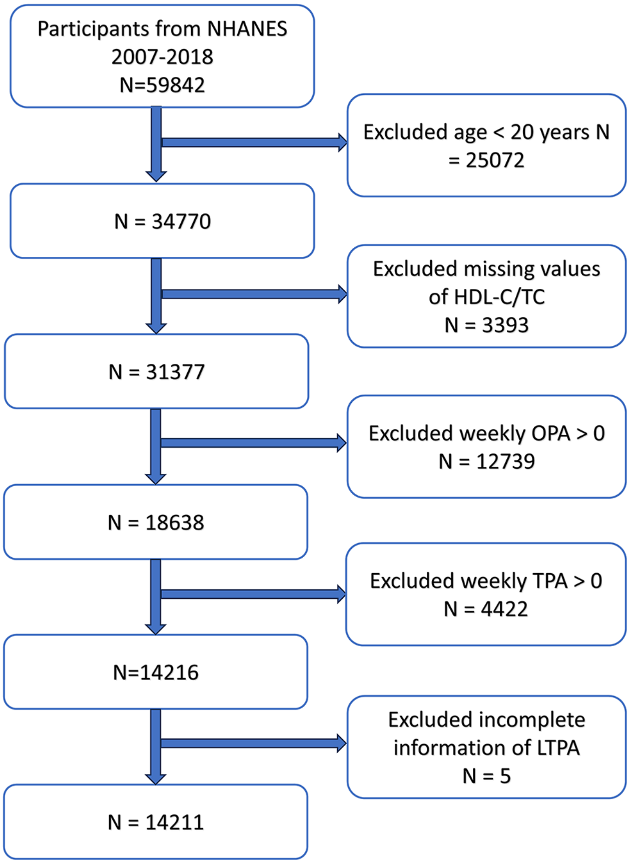

Fig. 1 The flowchart of participant selection and exclusion criteria

Method

Study population

The National Health and Nutrition Examination Survey (NHANES) (https://www.cdc.gov/nchs/nhanes/) data from cycles spanning 2007–2008 to 2017–2018 was accessed on May 20th, 2024 (Fig. 1). The NHANES was a survey administered by the National Center for Health Statistics (NCHS) and could serve as a representative tool for reflecting the health status of United States civilians. This study included individuals ≥ 20 years old who had complete laboratory measurements of both HDL-C and TC, as well as responses to the Global Physical Activity Questionnaire. To eliminate potential interference from the OPA and TPA, participants with an OPA or TPA > 0 were excluded. Consequently, a cohort of 14,211 individuals were included. The survey was approved by the NCHS Research Ethics Review Board (ERB) and signed consent forms were received from all participants. The present study is secondary research, so no additional ethical approval was needed.

NHHR

As described in previous studies, the NHHR indicates the non-HDL-C to HDL-C ratio [9, 27]. HDL-C was directly obtained from laboratory data in the NHANES is referred to as "HDL-C. Data", while non-HDL-C was the difference obtained by subtracting HDL-C from TC utilizing the dataset labeled "TCHOL. Data".

Table 1 LTPA patterns and criteria

LTPA Patterns	Criteria
Inactive	weekly LTPA = 0 min
Insufficiently active	weekly LTPA not achieved the minimum recommended level, i.e. < 150 min per week
Weekend warrior	weekly LTPA meeting the minimum recommended level within 1 or 2 sessions
Regularly active	weekly LTPA achieved the minimum recommended level in more than 2 sessions

PA patterns

Data on LTPA was collected using the Global Physical Activity Questionnaire, assessing the frequency (sessions per week) and duration (minutes per session) of PA during a typical week. The intensity of LTPA was categorized as moderate or vigorous. In accordance with guidelines from health authorities, for simplicity in calculation, one minute of vigorous-intensity PA can be converted to two minutes of moderate-intensity PA [28, 29]. Therefore, total LTPA was calculated using the equation: Total LTPA = Minutes of Moderate-Intensity LTPA + (2 × Minutes of Vigorous-Intensity LTPA) [21]. As previously described [30, 31], participants were classified into four groups based on their LTPA patterns (Table 1).

Covariates

Based on previous studies [9, 10, 12], potential confounders including demographic information, lifestyle factors, and related chronic noncommunicable diseases, were adjusted to evaluate the independent associations between different LTPA patterns and the NHHR. Demographics included age, gender, marital status, race, income level, and education level. Lifestyle factor data consisted of BMI, alcohol consumption, smoking status, and total dietary cholesterol intake, which were estimated using the mean values derived from two dietary recall interviews, as documented in the "Total Nutrient Intake" files. Related chronic non-communicable diseases, which were diagnosed according to the questionnaires, included coronary heart disease, hypertension, angina, stroke, heart attack, diabetes, and congestive heart failure. Hypertension was diagnosed if participants were taking prescribed medication to lower blood pressure or were told that they had high blood pressure more than twice by doctors, while diabetes was diagnosed if participants were told they had diabetes or were prescribed insulin and/or diabetic pills to lower blood sugar levels by doctors. The diagnosis of other included chronic non-communicable diseases was based on the questionnaire documented in the "Medical Conditions" files.

Statistical analysis

Possible differences among the groups with different LTPA patterns and NHHR quartiles were analyzed using a weighted chi-square test for categorical variables or a weighted linear regression model for continuous variables. The results were presented as frequencies (%) for categorical variables or means ± standard deviations (SDs) for continuous variables. To thoroughly examine and validate the relationship between the NHHR and various LTPA patterns, a dual approach was employed. Weighted multiple linear regression analysis was performed twice, using two reference groups: the most sedentary population (inactive group) and the population following the most recommended PA pattern (regularly active group) [32], respectively. In both analyses, three models were incorporated: Model I represented an unadjusted, crude model; Model II was adjusted for demographic and lifestyle variables; Model III underwent further adjustments for related chronic non-communicable diseases. Weighted stratification analyses and interaction tests were performed to assess whether the association of various LTPA patterns with the NHHR could be affected by demographic variables. For all the statistical analyses performed in the present study, $P<0.05$ was considered to indicate statistical significance. R (http://www.r-project.org, accessed on the 12th of August 2024) and EmpowerStats (http://www.empowerstats.com, accessed on the 12th of August 2024) were used for all analyses.

Results

The mean age of the 14,211 participants included was 53.33 (17.75) years (Table 2). Among the four groups categorized by NHHR quartiles, participants with an inactive pattern consistently had the highest percentage, which increased with higher NHHR quartiles. In contrast, the percentage of participants with an active pattern decreased with higher NHHR quartiles. The percentages of those with insufficiently active and weekend warrior patterns fluctuated. Significant differences in age, BMI, gender, race, marital status, income level, education ($P<0.0001$), smoking status ($P=0.0042$), alcohol consumption ($P=0.0489$), diet cholesterol ($P<0.0001$), and history of diabetes ($P=0.033$) were observed among the four NHHR quartiles. Compared with the Quartile 1 group, the proportion of participants who were male, aged 40–59 years, had a BMI ≥ 25 kg/m², identified as Mexican American or other races, were married, had a poverty income ratio (PIR) ≤ 1.3, had an education level lower than 9th grade or high school graduate or equivalent, and smoked on some days consistently increased with higher NHHR quartiles. As for the groups with different LTPA patterns (See Supplementary Table 1, Additional File 1), they demonstrated significant variations in all demographic factors ($P<0.0001$) and lifestyle factors ($P<0.0001$), except for dietary cholesterol ($P=0.295$). Significant differences were also observed in the history of all included noncommunicable diseases ($P<0.0001$), except for hypertension ($P=0.251$). Additionally, the four groups with different LTPA patterns had significantly different NHHR values ($P<0.0001$), with higher values in the inactive (2.98 ± 1.45), insufficiently active (2.86 ± 1.35), and weekend warrior (2.97 ± 1.47) groups compared to the regularly active group (2.69 ± 1.43).

Figure 2 shows the results of multiple linear regression analysis, presented as β (95% CI). The three models showed similar results. In Model III, compared to the inactive pattern, each additional unit of LTPA time was associated with a statistically significant 0.23-unit greater decrease in the NHHR in the regularly active group [-0.23 (-0.29; -0.16)]. However, a significant decrease in the NHHR was not observed for the "Weekend Warrior" pattern [-0.11 (-0.22; 0.008)] or insufficiently active pattern [-0.03 (-0.11; 0.04)], compared to the inactive pattern. Moreover, compared to the regularly active group, all insufficiently active [0.21 (0.13; 0.29)], "Weekend Warrior" [0.13 (0.004; 0.25)], and inactive [0.26 (0.20; 0.32)] patterns had significantly greater NHHR (See Supplementary Tables 2 and Supplementary Fig. 1, Additional File 1).

The robustness of the relationship between the LTPA patterns and the NHHR was evaluated via stratification analyses and interaction tests (Fig. 3). The association between being 'insufficiently active' and the NHHR was not significant in any subgroup, except for individuals aged 60 and older, female, with a PIR ≤ 1.3, and an education level less than 9th grade. Similarly, the "weekend warrior" pattern was not significantly related to a lower NHHR in any subgroup, except for individuals aged 40 and older, female, and with a PIR ≤ 1.3. Conversely, the associations between being "regularly active" and the NHHR were significant across all subgroups, with the exception of individuals aged 20–59, Non-Hispanic Black individuals, Mexican American individuals, and those with a high school diploma or lower education ((See Supplementary Table 3, Additional File 1)). Furthermore, the results of the interaction tests showed that the associations between various LTPA patterns and the NHHR did not exhibit significant differences by demographics, except for race ($P=0.003$).

Discussion

This study aimed to evaluate the relationship between the NHHR and different LTPA patterns, considering both PA duration (0 min, < 150 min, ≥ 150 min) and frequency (1–2 days per week or more than 2 days per week). By extracting data from the nationally representative database and adjusting for covariates, the study revealed that being regularly active (achieving the recommended

Table 2 Profile of study participants across NHHR quartiles

NHHR quartile	Overall	Quartile 1 (0.20–1.91)	Quartile 2 (1.91–2.62)	Quartile 3 (2.62–3.58)	Quartile 4 (3.59–27)	*P*-value
N	14,211	3552	3549	3554	3556	
Age (years)	53.33 ± 17.75	53.75 ± 19.39	54.08 ± 18.27	53.33 ± 17.04	52.15 ± 16.08	< 0.0001
20–39	3698 (26.02%)	1030 (29.00%)	919 (25.89%)	856 (24.09%)	893 (25.11%)	
40–59	4564 (32.12%)	917 (25.82%)	1037 (29.22%)	1246 (35.06%)	1364 (38.36%)	
60+	5949 (41.86%)	1605 (45.19%)	1593 (44.89%)	1452 (40.86%)	1299 (36.53%)	
BMI (kg/m2)	29.53 ± 7.15	27.06 ± 6.80	29.22 ± 7.28	30.44 ± 7.02	31.41 ± 6.74	< 0.0001
< 18.5	218 (1.53%)	131 (3.69%)	54 (1.52%)	21 (0.59%)	12 (0.34%)	
18.5–24.9	3576 (25.16%)	1434 (40.37%)	994 (28.01%)	705 (19.84%)	443 (12.46%)	
25-29.9	4884 (34.37%)	1099 (30.94%)	1209 (34.07%)	1275 (35.88%)	1301 (36.59%)	
30 and above	5533 (38.93%)	888 (25.00%)	1292 (36.40%)	1553 (43.70%)	1800 (50.62%)	
Gender						< 0.0001
Male	5897 (41.50%)	1036 (29.17%)	1280 (36.07%)	1590 (44.74%)	1991 (55.99%)	
Female	8314 (58.50%)	2516 (70.83%)	2269 (63.93%)	1964 (55.26%)	1565 (44.01%)	
Race						< 0.0001
Mexican American	2100 (14.78%)	394 (11.09%)	470 (13.24%)	597 (16.80%)	639 (17.97%)	
Non-Hispanic White	5670 (39.90%)	1417 (39.89%)	1419 (39.98%)	1363 (38.35%)	1471 (41.37%)	
Non-Hispanic Black	3024 (21.28%)	974 (27.42%)	825 (23.25%)	691 (19.44%)	534 (15.02%)	
Other races	3417 (24.04%)	767 (21.59%)	835 (23.53%)	903 (25.41%)	912 (25.65%)	
Marital Status, N (%)						< 0.0001
Accompanied	8475 (59.64%)	1921 (54.08%)	2089 (58.86%)	2217 (62.38%)	2248 (63.22%)	
Alone	5736 (40.36%)	1631 (45.92%)	1460 (41.14%)	1337 (37.62%)	1308 (36.78%)	
Income level, N (%)						< 0.0001
PIR ≤ 1.3	3954 (27.82%)	876 (24.66%)	936 (26.37%)	993 (27.94%)	1149 (32.31%)	
1.3 < PIR < 3.5	6200 (43.63%)	1527 (42.99%)	1549 (43.65%)	1571 (44.20%)	1553 (43.67%)	
PIR ≥ 3.5	4057 (28.55%)	1149 (32.35%)	1064 (29.98%)	990 (27.86%)	854 (24.02%)	
Education, level, N (%)						< 0.0001
Lower than 9th grade	1728 (12.16%)	312 (8.78%)	403 (11.36%)	491 (13.82%)	522 (14.68%)	
The 9th or higher grade to lower than the 12th grade	1976 (13.90%)	470 (13.23%)	451 (12.71%)	483 (13.59%)	572 (16.09%)	
High school graduate or equivalent	3055 (21.50%)	702 (19.76%)	751 (21.16%)	786 (22.12%)	816 (22.95%)	
Some college or equivalent	3866 (27.20%)	1023 (28.80%)	989 (27.87%)	922 (25.94%)	932 (26.21%)	
College graduate or above	3586 (25.23%)	1045 (29.42%)	955 (26.91%)	872 (24.54%)	714 (20.08%)	
Alcohol consumption, N (%)						0.0489

Table 2 (continued)

NHHR quartile	Overall	Quartile 1 (0.20–1.91)	Quartile 2 (1.91–2.62)	Quartile 3 (2.62–3.58)	Quartile 4 (3.59–27)	*P*-value
Yes	9141 (64.32%)	2310 (65.03%)	2209 (62.24%)	2271 (63.90%)	2351 (66.11%)	
No	5070 (35.68%)	1242 (34.97%)	1340 (37.76%)	1283 (36.10%)	1205 (33.89%)	
Smoking status, **N (%)**						0.0042
In every day	4696 (33.04%)	1172 (33.00%)	1052 (29.64%)	1177 (33.12%)	1295 (36.42%)	
In some days	1046 (7.36%)	258 (7.26%)	265 (7.47%)	245 (6.89%)	278 (7.82%)	
Not at all	8469 (59.59%)	2122 (59.74%)	2232 (62.89%)	2132 (59.99%)	1983 (55.76%)	
Hypertension, **N (%)**						0.474
Yes	13,574 (95.52%)	3405 (95.86%)	3386 (95.41%)	3396 (95.55%)	3387 (95.25%)	
No	637 (4.48%)	147 (4.14%)	163 (4.59%)	158 (4.45%)	169 (4.75%)	
Diabetes, **N (%)**						0.033
Yes	2523 (17.75%)	600 (16.89%)	611 (17.22%)	660 (18.57%)	652 (18.34%)	
No	11,418 (80.35%)	2895 (81.50%)	2865 (80.73%)	2822 (79.40%)	2836 (79.75%)	
Borderline	270 (1.90%)	57 (1.60%)	73 (2.06%)	72 (2.03%)	68 (1.91%)	
Angina, **N (%)**						0.085
Yes	439 (3.09%)	112 (3.15%)	112 (3.16%)	98 (2.76%)	117 (3.29%)	
No	13,772 (96.91%)	3440 (96.85%)	3437 (96.84%)	3456 (97.24%)	3439 (96.71%)	
Congestive heart failure, **N (%)**						0.514
Yes	633 (4.45%)	191 (5.38%)	140 (3.94%)	143 (4.02%)	159 (4.47%)	
No	13,578 (95.55%)	3361 (94.62%)	3409 (96.06%)	3411 (95.98%)	3397 (95.53%)	
Coronary heart disease, **N (%)**						0.689
Yes	725 (5.10%)	216 (6.08%)	165 (4.65%)	169 (4.76%)	175 (4.92%)	
No	13,486 (94.90%)	3336 (93.92%)	3384 (95.35%)	3385 (95.24%)	3381 (95.08%)	
Stroke, **N (%)**						0.119
Yes	755 (5.31%)	229 (6.45%)	171 (4.82%)	176 (4.95%)	179 (5.03%)	
No	13,456 (94.69%)	3323 (93.55%)	3378 (95.18%)	3378 (95.05%)	3377 (94.97%)	
Heart attack, **N (%)**						0.232
Yes	771 (5.43%)	228 (6.42%)	171 (4.82%)	169 (4.76%)	203 (5.71%)	
No	13,440 (94.57%)	3324 (93.58%)	3378 (95.18%)	3385 (95.24%)	3353 (94.29%)	
LTPA patterns, **n (%)**						< 0.0001
Inactive	8432 (59.33%)	1940 (54.62%)	2037 (57.40%)	2185 (61.48%)	2270 (63.84%)	
Insufficiently active	2055 (14.46%)	505 (14.22%)	541 (15.24%)	496 (13.96%)	513 (14.43%)	
Weekend Warrior	535 (3.76%)	131 (3.69%)	116 (3.27%)	149 (4.19%)	139 (3.91%)	

Table 2 (continued)

NHHR quartile	Overall	Quartile 1 (0.20–1.91)	Quartile 2 (1.91–2.62)	Quartile 3 (2.62–3.58)	Quartile 4 (3.59–27)	*P*-value
Regularly active	3189 (22.44%)	976 (27.48%)	855 (24.09%)	724 (20.37%)	634 (17.83%)	
HDL-C (mg/dl)	53.23 ± 16.22	69.68 ± 16.65	56.07 ± 11.09	48.02 ± 9.02	39.15 ± 8.17	< 0.0001
TC (mg/dl)	192.10 ± 42.20	170.27 ± 35.71	182.59 ± 35.00	194.32 ± 35.63	221.15 ± 44.02	< 0.0001
Diet cholesterol (mg)	264.46 ± 160.74	252.65 ± 147.80	262.17 ± 151.89	266.80 ± 170.83	276.21 ± 170.23	< 0.0001

Abbreviation: BMI, body mass index; PIR, poverty income ratio; LTPA, leisure-time physical activity; HDL-C, high-density lipoprotein cholesterol; TC, total cholesterol. *P*-value was by weighted linear regression for continuous variables, while *P*-value was by weighted Chi-square test for categorical variables

weekly PA level in 3 or more sessions) could be related to significantly a lower NHHR, but this relationship was not found for those who were insufficiently active (not achieving the recommended weekly PA level) or who were "weekend warriors" (achieving the recommended weekly PA level in 1 or 2 sessions). In other words, the association between PA and the NHHR is affected not only by weekly total PA duration but also by PA frequency. The "Weekend Warrior" PA pattern is a convenient option, especially for those who lack time to engage in regular PA [33]. The "Weekend Warrior" PA pattern has been reported to reduce all-cause mortality [24] and is associated with lower cardiovascular disease and cancer-related mortality [34] as well as a lower risk of depression [30]. However, this PA pattern may not be related to with a lower NHHR in individuals who do not engage in OPA and TPA. These findings suggest that it is important for these individuals not only to meet the recommended weekly amount of PA but also to engage in LTPA more than twice weekly to improve their NHHR.

Furthermore, the association between the PA patterns and the NHHR was not altered by other demographic variables, except for race, as indicated by the results of the interaction tests. This could show the stability of the conclusion. An interesting finding was that the association between the regularly active pattern and a lower NHHR was not significant in populations with less than a college education but was significant in populations with some college education or above. Lara and Amigo (2018) reported that the associations between education level and lipid parameters were inconsistent in different genders [35]. Their study showed that lower education was related to worse lipid profiles in females but was related to better lipid profiles in males [35]. In fact, the possible effect of social inequality on dyslipidemia is less known [36]. An explanation could be that the prevention and intervention of dyslipidemia may occur earlier in higher-educated individuals [36].

Some studies have evaluated the relationship between lipid profiles and LTPA, primarily focusing on the association between conventional lipid parameters and PA duration. A previous cross-sectional study reported that LTPA ≥ 150 min was associated with lower triglycerides (TG) and higher HDL-C levels [37]. Another study examining the relationship between mean daily PA duration and lipid profiles demonstrated that intense PA duration (0.5–1 h of mean daily PA) was associated with higher HDL-C and lower TG levels although not with TC or LDL-C levels [38]. However, moderate PA duration (less than 0.5 h of mean daily PA) did not demonstrate a significant association with any of the lipid profiles examined in the study [38]. These might suggest that PA may need to reach a certain duration threshold to effect changes in specific lipid parameters. Furthermore, a randomized controlled trial in patients with coronary heart disease found that while exercise intensity based on heart rate had little effect on lipid profiles, exercise frequency was significantly associated with increased HDL-C levels, decreased ratio of LDL-C to HDL-C, and reduced ratio of TC to HDL-C [39]. This supports the findings of this study that not only PA duration but also frequency are important factors in influencing lipid profiles. By integrating these insights into clinical practice, healthcare professionals can better guide patients towards effective lifestyle interventions for lipid management.

Strengths and limitations

This is likely to be the first study to explore the possible relationship between the LTPA patterns and the NHHR, a newly developed indicator of atherogenic lipids. The sample size was large ($N = 14211$) due to the use of NHANES data. In addition, the inactive and regularly active groups were used as the reference groups separately for multiple linear regression, and the results of the two analyses were consistent, indicating the reliability of the results of this study. Given the incorporation of survey weights, this result can be generalized to the entire non-institutionalized civilian population in the United States. However, several limitations inherent to the present study warrant discussion. First, due to the design of this study, the causal relationship between the LTPA patterns and the NHHR could not be identified. Consequently, further prospective cohort studies may be necessary to substantiate these findings. It is also important to note that PA frequency and duration were self-reported by participants, potentially reflecting only a typical week at a single time point. This method of data collection may introduce recall bias and does not account for variations

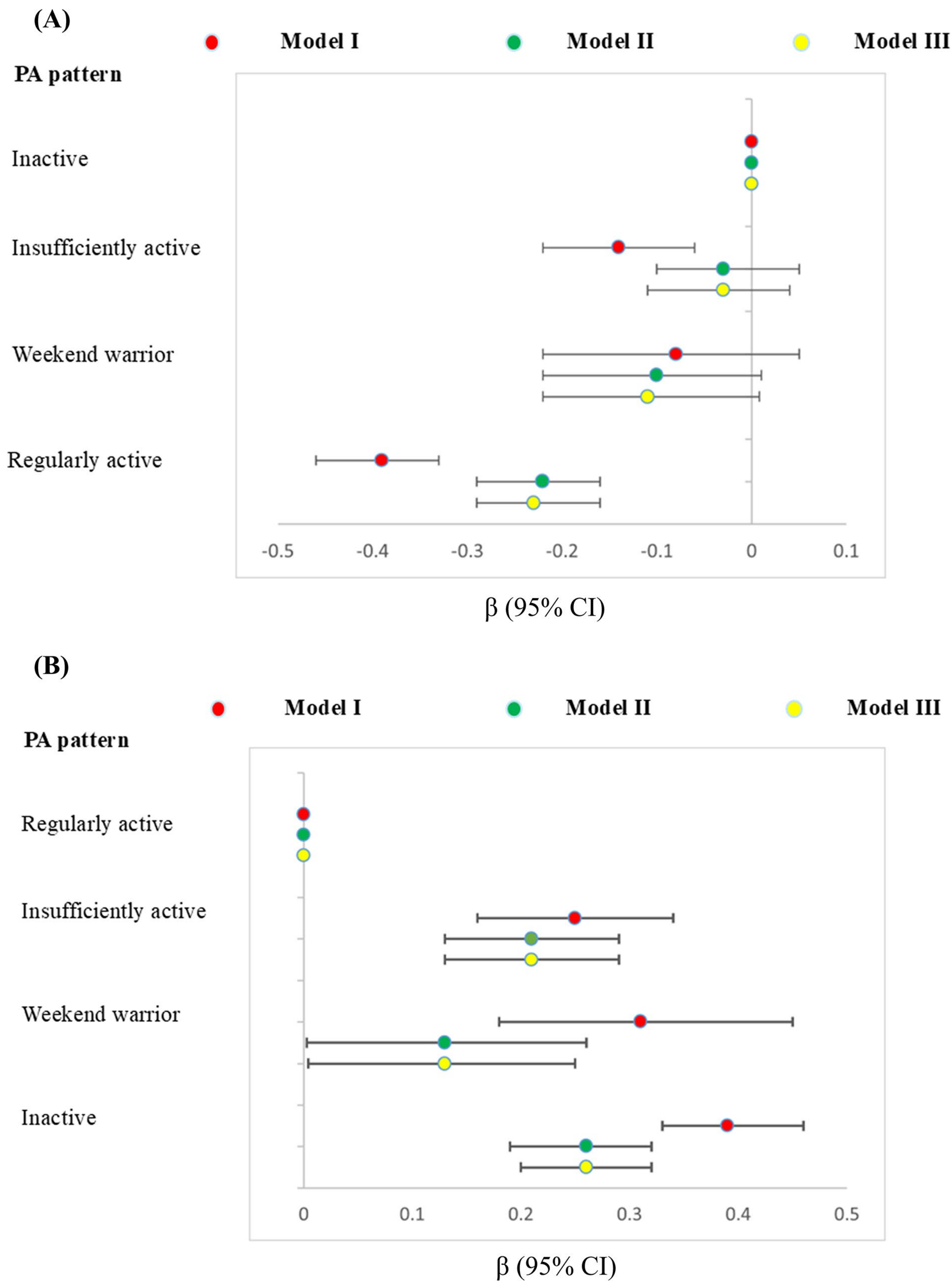

Fig. 2 The association between the LTPA patterns and the NHHR. **(A)** Using the inactive active pattern as the reference, and **(B)** Using the regular active pattern as the reference. Model I: unadjusted and crude; Model II: adjusted for demographic and behavioral factors; Model III: further adjusted for chronic noncommunicable disease

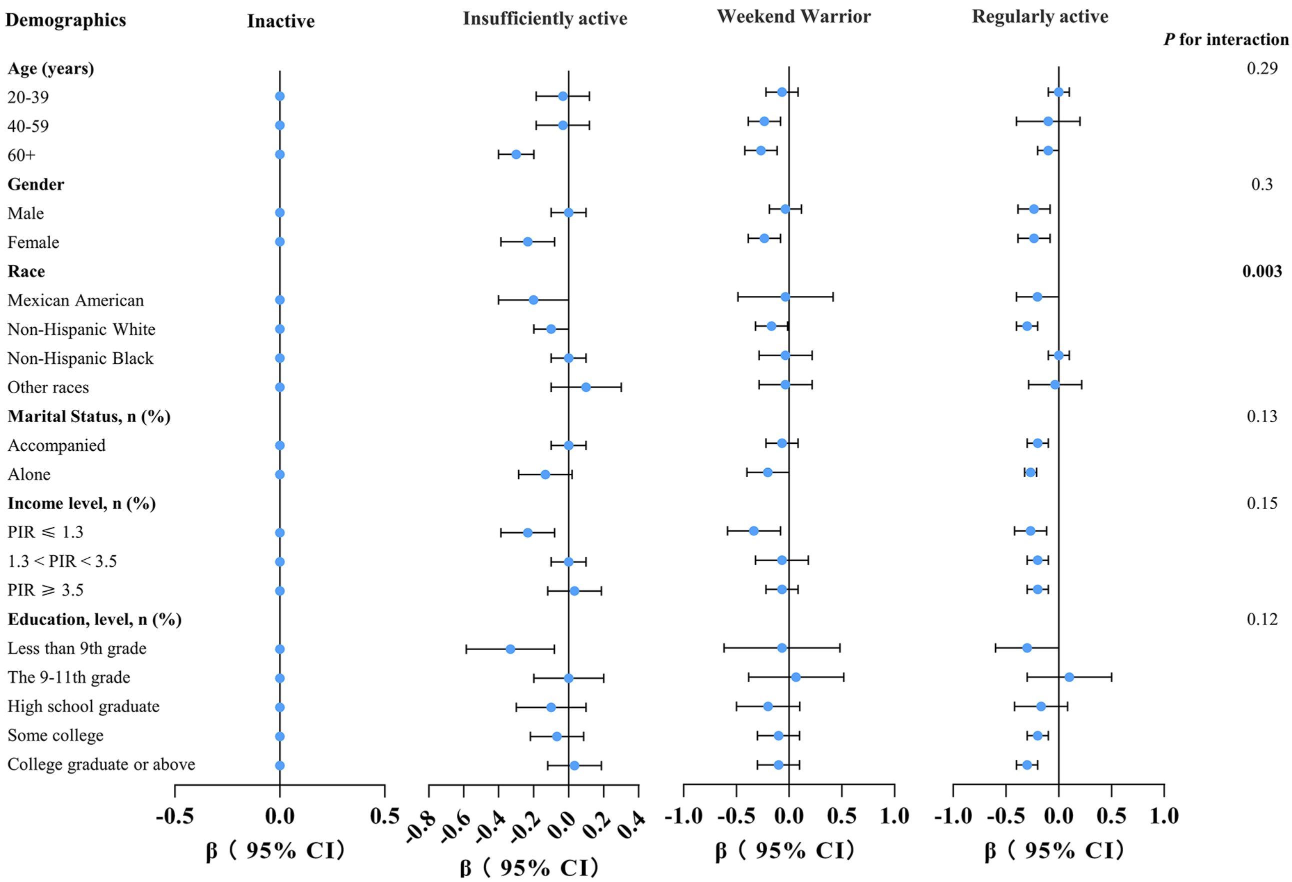

Fig. 3 Weighted stratification analyses assessing the association between various LTPA patterns and the NHHR by demographics

in PA over different periods. To minimize this bias, future studies should incorporate objective measures of PA, such as accelerometers or pedometers, to enhance the accuracy of activity assessment. Additionally, potential confounding variables may have influenced the observed associations, and their impact cannot be entirely ruled out. Therefore, it is recommended to control for a comprehensive range of potential confounders, including dietary habits, stress levels, genetic factors, and medication use, to isolate the effects of PA on the NHHR more effectively. Moreover, the setting of exclusion criterion (excluding individuals with OPA or TPA > 0) may limit the generalizability of the findings to populations where OPA or TPA are significant contributors to overall physical activity, and only 3.76% of participants were categorized into the "weekend warrior" group. Future research should explore the effects of different domains of physical activity (OPA, TPA, and LTPA) on lipid profiles and consider evaluating the effects of LTPA patterns on a broader population. Finally, investigating variations in PA across different seasons and life stages would provide a more comprehensive perspective of the relationship between PA patterns and lipid profiles.

Conclusion

In conclusion, the study revealed that compared with the inactive pattern, the regularly active pattern is significantly associated with a lower NHHR, underscoring the beneficial impact of consistent PA on lipid profiles. Interestingly, no significant difference in the NHHR was detected between the insufficiently active and "Weekend Warriors" patterns, showing that the frequency of PA throughout the week may be as crucial as meeting the recommended PA duration in terms of improving lipid profiles. These findings highlight the importance of maintaining regular PA routines for physical health, encouraging individuals to incorporate consistent PA into their daily lives rather than concentrating efforts solely on meeting PA guidelines in sporadic sessions. This also provides a basis for clinical recommendations, suggesting that it is crucial to encourage individuals to meet or exceed the recommended PA levels (150 min) in more than 2 sessions per week to achieve optimal lipid management.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12944-024-02278-8.

Supplementary Material 1

Author contributions
Both YXL and PCL designed the study, collected and analyzed data. Both authors interpreted the results, wrote the first draft, and reviewed the manuscript. Yanxue Lian and Pincheng Luo are co-first authors.

Funding
This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Data availability
Data can be found by visiting the National Health and Nutrition Examination Survey (NHANES) (https://www.cdc.gov/nchs/nhanes/).

Declarations

Ethics approval and consent to participate
The survey was approved by the NCHS Research Ethics Review Board (ERB) and signed consent forms were received from all participants.

Competing interests
The authors declare no competing interests.

Conflict of interest
The authors declare no conflicts of interest.

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Received: 13 June 2024 / Accepted: 29 August 2024
Published online: 15 October 2024

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