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Jianheng Li Date

Association of Objectively-Measured Physical Activity Patterns with Cardiovascular Risk Factors: a Pooled Analysis of National Health and Nutrition Examination Survey 2003-04 and 2005-06

By

Jianheng Li

Degree to be awarded: MPH

Epidemiology

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Amit Shah

Committee Chair

Association of Objectively-Measured Physical Activity Patterns with Cardiovascular Risk Factors: a Pooled Analysis of National Health and Nutrition Examination Survey 2003-04 and 2005-06

By

Jianheng Li

Bachelor of Medicine

Shanghai University of Traditional Chinese Medicine

2016

Thesis Committee Chair: Amit J. Shah, MD, MSCR

An abstract of

A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University

in partial fulfillment of the requirements for the degree of
Master of Public Health
in Epidemiology

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Abstract

Association of Objectively-Measured Physical Activity Patterns with Cardiovascular Risk Factors: a Pooled Analysis of National Health and Nutrition Examination Survey 2003-04 and 2005-06

By Jianheng Li

BACKGROUND: The 2008 Physical Activity Guidelines for Americans listed detailed physical activity (PA) recommendations for adults to reduce chronic disease risk especially cardiovascular disease (CVD), however, it failed to provide information on how the combination of PA intensity and frequency may affect cardiovascular fitness. Regular physical activity patterns may offer more CVD risk reduction versus longer, infrequent bursts ("weekend warrior"), but few studies have examined this.

PURPOSE: To investigate the associations of objectively measured PA patterns with CVD risk factors, both regarding total activity and the pattern of activity. The primary analysis involved, amongst active participants, comparing regular PA with less frequent bursts.

STUDY DESIGN: Cross-sectional.

METHODS: Data pooled from the 2003-2004 and 2005-2006 National Health and Nutrition Examination Surveys, a total of 6,176 participants who were 30 years of age and older and wore accelerometers for at least ten hours per day on at least one day were included in the study. Five PA patterns (the inactive, insufficiently active, weekend warrior, regularly active and most regularly active) were constructed based on imputed PA intensity minutes and frequency. Weighted generalized linear regression and logistic regression were performed, controlling for potential confounders and imputing missing values.

RESULTS: The mean (SD) age was 51.7 (0.4) years, 46.9% were female, and 74.4% were white. Participants with the highest PA patterns had 65% (95% CI=0.25 to 0.50) less obesity, 49% (95% CI=0.37 to 0.70) less hypertension, 32% (95% CI=0.45 to 1.03) lower total cholesterol, and 59% (95% CI=0.19 to 0.86) less diabetes prevalence. Across higher levels of PA pattern, the weekend warrior was associated with 9.8 mg/dl higher in total cholesterol (Ptrend=0.03) than the most regularly active participants, but otherwise no significant difference was found between activity pattern types in fully adjusted models.

CONCLUSION: There is an inverse association of PA patterns with CVD risk factors such that higher levels of PA patterns are associated with better cardiovascular health; more consistent PA may have a slightly better cholesterol profile compared to episodic PA (weekend warrior).

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Table of Contents

1. INTRODUCTION

Cardiovascular disease (CVD) is the leading cause of death in America (1), and it is estimated that 6.7% of coronary heart disease (CHD) mortality is attributable to physical inactivity alone (2). Substantial evidence from both observational and clinical studies indicate that physical activity (PA) can reduce the risk of CVD (3, 4), through enhancement of the lipid profile, weight loss, reduced blood pressure, and lower systemic inflammation. PA also enhances endothelial function and cardiac function (5).

Although the benefits of physical activity on CVD health are evident, details of how different physical activity patterns may influence cardiovascular risk are less clear. Physical Activity Guidelines for Americans recommends that adults should do at least 150 minutes per week of moderate-intensity PA, 75 minutes per week of vigorous-intensity aerobic PA, or an equivalent combination of moderate and vigorous-intensity physical activity (MVPA). Additionally, they recommend physical activity should be distributed equally throughout the week. Nevertheless, some individuals find it difficult to organize into a regular physical activity pattern of 30 minutes per day on at least five days per week as suggested. An alternative PA pattern arose, called “weekend warrior,” which comprise 1-3% of U.S. adults (6). The weekend warrior is defined as having 150 minutes MVPA from only 1 or 2 sessions per week, (7-9) but despite the high total duration, some debate exists regarding whether the low frequency is sufficient for full benefit. Although studies found that the weekend warrior may be sufficient to reduce all-cause mortality and may exert beneficial effects on CVD risk factors (10-12), many of those studies defined physical activity patterns based on self-reported questionnaires. Because self-report may lead to misclassification and bias towards the null (13), it is unknown whether this particular physical activity directly measured with actigraphy is associated with similar CVD risk reductions as regular PA.

Therefore, the primary objective of this study was to investigate the associations of actigraphy-based physical activity (both frequency and regularity) with CVD risk factors, with the hypothesis that high levels of PA associated with a lower burden of CVD risk factors, regardless of regularity. Furthermore, we also evaluated for potential confounding from various sociodemographic characteristics.

2. METHODS

2.1 Data and sample

Data for this cross-sectional study were pooled from the 2003-2004 and 2005-2006 National Health and Nutrition Examination Surveys (NHANES). The NHANES study used a stratified, multistage probability sampling design to draw a nationally representative sample of US civilian, noninstitutionalized individuals aged six years or more. Enrolled participants were interviewed in their homes and asked to participate in a health examination conducted in a mobile examination center. IRB approval was obtained, and informed consent was performed as previously described (14, 15). The pooled dataset contains 14,631 participants who are six years of age and older and received Actigraph AM-7164 accelerometers (sampling frequency 10Hertz) to wear at home for seven consecutive days. The detailed accelerometer protocol and description were previously reported (14, 15).

2.2 Measures of physical activity patterns

The primary independent variable was physical activity pattern. Objectively measured physical activity data were divided into five different patterns based on intensity level and activity frequency. To define intensity level, we used the established cut points from published calibration studies (16-19), specifically, sedentary activity was defined as recording 0-759 accelerometer intensity counts per minutes (CPM, each vertical acceleration as a "count", providing an indication of the intensity of physical activity associated with locomotion), light intensity activity as recording 760-2019 CPM, and moderate or vigorous activity as recording >2020 CPM. As opposed to other studies which used 10-min bouts as a valid intensity activity period, we calculated total intensity minutes from 1-minute increments on all valid days to maximize statistical power. Previous studies indicate that shorter bouts of MVPA have similar effects on cardiometabolic risk as longer bouts of MVPA (20, 21). A valid day was defined as wearing the monitor for at least 10 hours a day; intensity minutes from non-valid days and monitors that were not in calibration were considered as missing (22). Missing intensity minutes from participants who had at least one valid day were imputed based on the other non-missing data. The expectation maximization algorithm was used to perform multiple imputation for missing data. Previous research has shown that imputation of PA results in more precise and less biased estimates compared to analysis in only participants who wore the monitors for the full seven valid days (23). Activity frequency was assessed amongst those who met the 150 minutes of MVPA guideline; such individuals were categorized into tertiles based on their coefficient of variance (CV) during the week. Since there is no reported criteria to define weekend warrior base on objectively measured data, we considered weekend warrior as the highest tertile of CV to represent the least consistency in physical activity during the week; the middle tertile was considered to be regularly active, and the lowest tertile was considered as the most regularly active. Additionally, the rest of the participants were labeled as inactive if having <10 min/day of MVPA and insufficiently active if having <150 min/wk of MVPA.

2.3 Measures of dependent variables

Health variables were measured from questionnaires and laboratory data. Continuous risk factors include body mass index, waist circumference, triglycerides, total cholesterol, High-density lipoprotein (HDL), Low-density lipoprotein (LDL), systolic blood pressure, diastolic blood pressure, fasting glucose and Framingham CVD risk. Categorical risk factors include obesity, hypertension, high cholesterol, diabetes and impaired glucose tolerance. High cholesterol was defined as total cholesterol ⩾240 mg/dl and/or LDL ⩾240 mg/dl (24, 25) or was told by a doctor to have high cholesterol levels or told to take prescriptions for cholesterol. Hypertension was defined as an average of systolic blood pressure (SBP) ⩾130 mmHg and/or an average of diastolic blood pressure (DBP) ⩾80 mmHg (26), or current use medications for hypertension; diabetes was defined as a fasting glucose ⩾126 mg/dl or current use medications for diabetes; impaired glucose tolerance (IGT) as a fasting glucose 100 to <126 mg/dl. Overweight was defined as body mass index (BMI) ⩾25 kg/m^2 and <30kg/m^2, obesity was defined as BMI ≥30 kg/m^2. The 10-year Framingham CVD risk score was computed for participants who were less than 75 years old using a sex-specific model (27).

2.4 Covariates

Covariates included participants' age, sex, race/ethnicity (self-reported White, Black, Hispanic and other), educational level (less than high school, more than high school, and graduate degree), self-reported health (excellent to good and fair to poor), annual family income (under $20,000, $20,000 to $74,999, and $75,000 and over), current smoker (yes or no), and total minutes of MVPA summed throughout the week.

2.5 Statistical Analysis

All analyses adjusted for the complex sampling design. The weighted mean and standard error of mean were used to describe the distributions of continuous variables, and weighted percentage and standard error of percentage were used to describe categorical variables; the ANOVA test and chi-square test were used to compare the distribution of baseline characteristics between physical activity patterns. Generalized linear regression models and logistic regression models were used to examine the cross-sectional association of physical activity patterns with CVD risk factors, participants with missing covariates were excluded from the analysis. Orthogonal polynomials trend tests were performed to assess the trend across categories of physical activity patterns. A series of sensitivity analyses compared with complete data were also performed, since the results were similar, we used the imputed data to conduct the analysis. All models were adjusted for the following covariates: age, sex, race/ethnicity, education level, self-reported general health, annual family income, and smoking; in addition, total MVPA minutes was also adjusted in a trend test for the association of PA patterns with CVD risk factors amongst the three PA patterns. Imputation was implemented in SAS using the EM algorithm under PROC MI (23). Overall, 22.4% of the total MVPA minutes for each missing segment per day was imputed. Statistical significance was denoted at $P<0.05$. All analyses were conducted using SAS version 9.4 and SUDAAN 11.1.

3. RESULTS

A total of 6,176 participants who were 30 years of age and older and wore the monitor for at least ten hours per day on at least one day were included in the study. Selected characteristics of participants by physical activity patterns are shown in Table 1. In this study population, the overall age was 51.7 (0.4) years, 46.9% were female, and 74.4% were white. A total of 3,101 (50.2%) were classified as inactive; 1,377 (22.3%) as insufficiently active; and 566 (9.2%) were classified as active (weekend warriors, regularly active and most regularly active). Related to the other four groups, participants of the inactive group tended to be older female, to have the highest proportion of current smokers, and were more likely to have a lower level of annual family income, education, and general health. Across each group, most participants were white. Compared to participants with inactive or insufficiently active PA, those in active groups (weekend warrior, regularly active and most regularly active) were similar in age, more likely to be male, and tended to have a higher socioeconomic status (higher proportion of annual family income in the $75,000 and over and graduate school education), a lower proportion of current smokers, and a better general health status. Compared to the regularly active and the most regularly active groups, the weekend warriors were more likely to be current smokers and to be in lower level of a general health condition, but they were similar in other characteristics. With regard to physical activity, on average, less active participants were more likely to have more sedentary minutes per day and to have less light physical activity and moderate to vigorous activity compared to active participants.

Associations of physical activity patterns with CVD risk factors and Framingham Risk Score are shown in Table 2. For continuous risk factors, compared to the physically inactive group, participants from the other four groups had significantly lower BMI, waist circumference, HDL and higher triglycerides (all P for beta coefficients were <0.05). Also, statistically significant trends were found in most risk factors across physical activity patterns except for DBP and LDL. The active group had a 3.7 kg/m^2 lower BMI (P_{trend} <0.0001), 9.9 cm lower in waist circumference (P_{trend} <0.0001), 3.3 mmHg lower in SBP (P_{trend} =0.02), 4.7 mg/dl lower in plasma glucose (P_{trend} =0.04), 6.4 mg/dl lower in HDL (P_{trend} <0.0001), 34.6 mg/dl lower in triglyceride (P_{trend} =0.05), and 4.8 point lower in Framingham Risk Score (P_{trend} <0.0001) for the highest level of physical activity pattern compared to the lowest. For categorical risk factors, significantly lower prevalences of obesity, hypertension, high cholesterol, and diabetes were found across physical activity patterns. Participants with the highest PA patterns had 65% (95% CI=0.25 to 0.50, P_{trend}<0.0001) less obesity, 49% (95% CI=0.37 to 0.70, P_{trend}=0.0001) less hypertension, 32% (95% CI=0.45 to 1.03, P_{trend}=0.01) lower total cholesterol, and 59% (95% CI=0.19 to 0.86, P_{trend}=0.004) less diabetes prevalence compared to those who were physically inactive.

In table 3 shows the association of higher levels of PA patterns with CVD risk factors and Framingham CVD risk, with the most regularly active as the reference group. Statistically significant trends were only found in waist circumference and total cholesterol across the higher levels PA pattern; compared to the highest level of PA pattern (most regularly active), the lowest level (weekend warrior) was associated with 2.0 cm higher in waist circumference (P_{trend} =0.04), 9.8 mg/dl higher in total cholesterol (P_{trend}=0.03), after adjusting for total minutes of MVPA, the association with total cholesterol remained statistically significant (P_{trend}=0.04). Figure 1 and Figure 2 shows the PA level specific associations and the dose-response curves. For risk factors such as obesity and its closely correlated factors (BMI and waist circumference), diabetes, triglyceride, high cholesterol and hypertension, and for Framingham CVD risk, there was a steeper change in beta estimates or odds ratio as the level of PA pattern went higher, as opposed to the relatively flat change from the regularly active to the most regularly active level.

4. DISCUSSION

In this cross-sectional study of a nationally representative U.S. sample, we found that for the middle age and older participants, high PA patterns were associated with better cardiovascular health, including lower BMI, waist circumference, the prevalence of obesity, hypertension, high cholesterol, and diabetes. Therefore, a higher level of physical activity pattern may have a healthier CVD risk factor profile. Comparison among higher levels of PA patterns indicates that people who exercise more consistently may have a slightly better profile of CVD risk factors compared to weekend warriors especially for total cholesterol.

Our findings are consistent with results reported by other studies that have investigated the associations of PA patterns or different components of PA patterns (e.g., MET-minutes and exercise frequency) with cardiometabolic health (28-32). Particularly, in Metzger *et al*. study, they used a latent class analysis method to classify physical activity into five different classes with the definition of weekend warrior as those who accumulated a large portion of their MVPA minutes during the weekend, and the higher PA class as those who accumulated a consistently greater amount of MVPA during weekdays, results showed that four classes of more physically active compared to the most sedentary class, were associated with lower odds of obesity, high blood pressure, high blood glucose, high triglycerides, low HDL and metabolic syndrome. This is overall similar to our findings; furthermore, they did not observe any differences between weekend warriors and other patterns of MVPA. In a study by O'Donovan *et al.* (10), the authors categorized PA patterns based on self-reported frequency, duration, and intensity of PA; they found that all levels of PA patterns were comparable to each other and superior to the physically inactive group for the outcome of CVD mortality.

We found that people who exercise more regularly trended towards having a better CVD risk profile compared to the weekend warrior, which is a new finding compared to other studies (10, 30, 31) that reported no significant impact of exercise pattern. In particular, the average total cholesterol level was 9.8 mg/dl higher in the weekend warrior group and 3.1 mg/dl higher in the regularly active group than in the most regularly active group. The P_{trend}=0.04 in fully adjusted models was significant. Other CVD risk factors also showed slight trends as well that were not statistically significant. Overall these results are mixed, but provide stimulus for further research in this area.

Possible mechanisms behind this finding could be that weekend warrior produces similar strength and performance effects (measured by maximum rate of oxygen consumption) as those who are more active at the same intensity (33). In addition, physical fitness, achieved through regular exercise, may have blunting effects on the hormonal stress-responsive system, such as the hypothalamic-pituitary-adrenal axis and the sympathetic nervous system, which reduces the adverse behavioral and metabolic consequences (e.g., obesity, diabetes and metabolic syndrome) caused by stressful events (34-36). Another mechanism could be that higher level of PA patterns can reduce systematic inflammation which is closely associated with obesity, diabetes, and metabolic syndrome (37, 38). By increasing resilience and maintaining a better inflammatory state through higher levels of PA Patterns and more consistent activity, people may achieve a better profile of CVD risk factor.

Our study is subject to several limitations. The data we used was from a cross-sectional study in which directionality and causation cannot be determined. The results may be confounded by unmeasured factors such as chronic stress, sleep deprivation, and poor eating habits, which are closely associated with physical activity and CVD risk. Because the accelerometer can only record vertical movements and is not water resistant, intensity counts from activities like swimming and cycling cannot be captured, therefore some participants PA levels may be misclassified. This may bias the results towards the null, which may be a significant problem since some of our conclusions are based on null results. And due to the sampling nature of the monitor, PA intensity may be oversimplified because it only measures vertical acceleration counts, and ignores other factors such as velocity, which also contribute to PA intensity. Nonetheless, our data show this method is useful in assessing lower risk individuals, and likely correlate with PA intensity despite this limitation. Additionally, we used custom criteria to categorize physical activity patterns that are not validated as official criteria for PA regularity, which may decrease its clinical relevance.

In conclusion, our findings suggest that higher levels PA patterns are associated with better cardiovascular health; more consistent physical activity patterns may also offer incremental benefit, at least with regards to total cholesterol. Further studies are warranted to validate this finding, which is new compared to previous studies.

5. REFERENCE

1. National Center for Health S. Health, United States. Health, United States, 2016: With Chartbook on Long-term Trends in Health. Hyattsville (MD): National Center for Health Statistics (US); 2017.
2. Lee IM, Shiroma EJ, Lobelo F, Puska P, Blair SN, Katzmarzyk PT. Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. Lancet (London, England). 2012;380(9838):219-29.
3. Eaton CB. Relation of physical activity and cardiovascular fitness to coronary heart disease, Part I: A meta-analysis of the independent relation of physical activity and coronary heart disease. The Journal of the American Board of Family Practice. 1992;5(1):31-42.
4. Shiroma EJ, Lee IM. Physical activity and cardiovascular health: lessons learned from epidemiological studies across age, gender, and race/ethnicity. Circulation. 2010;122(7):743-52.
5. Warburton DER, Nicol CW, Bredin SSD. Health benefits of physical activity: the evidence. CMAJ : Canadian Medical Association Journal. 2006;174(6):801-9.
6. Kruger J, Ham SA, Kohl HW, 3rd. Characteristics of a "weekend warrior": results from two national surveys. Med Sci Sports Exerc. 2007;39(5):796-800.
7. Surgeon General's report on physical activity and health. From the Centers for Disease Control and Prevention. Jama. 1996;276(7):522.
8. Lee IM, Sesso HD, Oguma Y, Paffenbarger RS, Jr. The "weekend warrior" and risk of mortality. American journal of epidemiology. 2004;160(7):636-41.
9. Physical Activity Guidelines Advisory Committee report, 2008. To the Secretary of Health and Human Services. Part A: executive summary. Nutrition reviews. 2009;67(2):114-20.
10. O'Donovan G, Lee IM, Hamer M, Stamatakis E. Association of "Weekend Warrior" and Other Leisure Time Physical Activity Patterns With Risks for All-Cause, Cardiovascular Disease, and Cancer Mortality. JAMA internal medicine. 2017;177(3):335-42.
11. Alaca N, Uslu S, Gulec Suyen G, Ince U, Serteser M, Kurtel H. Effects of different aerobic exercise frequencies on streptozotocin-nicotinamide-induced type 2 diabetic rats: Continuous versus short bouts and weekend warrior exercises. Journal of diabetes. 2017.
12. Hamer M, O'Donovan G, Lee IM, Stamatakis E. The 'weekend warrior' physical activity pattern: how little is enough? British journal of sports medicine. 2017.
13. Atienza AA, Moser RP, Perna F, Dodd K, Ballard-Barbash R, Troiano RP, et al. Self-reported and objectively measured activity related to biomarkers using NHANES. Med Sci Sports Exerc. 2011;43(5):815-21.
14. National Health and Nutrition Examination Survey in 20092011.
15. R: A Language and Environment for Statistical Computing. Vienna, Austria: R Foundation for Statistical Computing; 2009.
16. Brage S, Wedderkopp N, Franks PW, Andersen LB, Froberg K. Reexamination of validity and reliability of the CSA monitor in walking and running. Med Sci Sports Exerc. 2003;35(8):1447-54.
17. Freedson P, Sirard J, Debold E, Pate R, Dowda M, Trost S, et al. Calibration of the computer science and applications, inc.(CSA) Accelerometer 256. Medicine & Science in Sports & Exercise. 1997;29(5):45.
18. Leenders N, Sherman WM, Nagaraja H, Kien CL. Evaluation of methods to assess physical activity in free-living conditions. Medicine and science in sports and exercise. 2001;33(7):1233-40.

19. Yngve A, Nilsson A, Sjostrom M, Ekelund U. Effect of monitor placement and of activity setting on the MTI accelerometer output. Medicine and science in sports and exercise. 2003;35(2):320-6.
20. Strath SJ, Holleman RG, Richardson CR, Ronis DL, Swartz AM. Objective Physical Activity Accumulation in Bouts and Nonbouts and Relation to Markers of Obesity in US Adults. Preventing chronic disease. 2008;5(4):A131.
21. Glazer NL, Lyass A, Esliger DW, Blease SJ, Freedson PS, Massaro JM, et al. Sustained and shorter bouts of physical activity are related to cardiovascular health. Med Sci Sports Exerc. 2013;45(1):109-15.
22. Troiano RP, Berrigan D, Dodd KW, Masse LC, Tilert T, McDowell M. Physical activity in the United States measured by accelerometer. Med Sci Sports Exerc. 2008;40(1):181-8.
23. Catellier DJ, Hannan PJ, Murray DM, Addy CL, Conway TL, Yang S, et al. Imputation of missing data when measuring physical activity by accelerometry. Med Sci Sports Exerc. 2005;37(11 Suppl):S555-62.
24. Executive Summary of The Third Report of The National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, And Treatment of High Blood Cholesterol In Adults (Adult Treatment Panel III). Jama. 2001;285(19):2486-97.
25. Grundy SM, Cleeman JI, Merz CN, Brewer HB, Jr., Clark LT, Hunninghake DB, et al. Implications of recent clinical trials for the National Cholesterol Education Program Adult Treatment Panel III guidelines. Circulation. 2004;110(2):227-39.
26. Whelton PK, Carey RM, Aronow WS, Casey DE, Collins KJ, Dennison Himmelfarb C, et al. 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA Guideline for the Prevention, Detection, Evaluation, and Management of High Blood Pressure in Adults. A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. 2017.
27. Wilson PW, D'Agostino RB, Levy D, Belanger AM, Silbershatz H, Kannel WB. Prediction of coronary heart disease using risk factor categories. Circulation. 1998;97(18):1837-47.
28. Maddison R, Jiang Y, Foley L, Scragg R, Direito A, Olds T. The association between the activity profile and cardiovascular risk. J Sci Med Sport. 2016;19(8):605-10.
29. Peterson MD, Al Snih S, Stoddard J, McClain J, Lee IM. Adiposity and insufficient MVPA predict cardiometabolic abnormalities in adults. Med Sci Sports Exerc. 2014;46(6):1133-9.
30. Metzger JS, Catellier DJ, Evenson KR, Treuth MS, Rosamond WD, Siega-Riz AM. Associations between patterns of objectively measured physical activity and risk factors for the metabolic syndrome. American journal of health promotion : AJHP. 2010;24(3):161-9.
31. Xiao J, Chu M, Shen H, Ren W, Li Z, Hua T, et al. Relationship of "weekend warrior" and regular physical activity patterns with metabolic syndrome and its associated diseases among Chinese rural adults. Journal of sports sciences. 2018:1-9.
32. Liu Y, Wen W, Gao YT, Li HL, Yang G, Xiang YB, et al. Level of moderate-intensity leisure-time physical activity and reduced mortality in middle-aged and elderly Chinese. Journal of epidemiology and community health. 2018;72(1):13-20.
33. Meyer T, Auracher M, Heeg K, Urhausen A, Kindermann W. Does cumulating endurance training at the weekends impair training effectiveness? European journal of cardiovascular prevention and rehabilitation : official journal of the European Society of Cardiology, Working Groups on Epidemiology & Prevention and Cardiac Rehabilitation and Exercise Physiology. 2006;13(4):578-84.
34. Deuster PA, Silverman MN. Physical fitness: a pathway to health and resilience. US Army Medical Department journal. 2013:24-35.

35. Huang CJ, Webb HE, Zourdos MC, Acevedo EO. Cardiovascular reactivity, stress, and physical activity. Frontiers in physiology. 2013;4:314.
36. Li G, He H. Hormesis, allostatic buffering capacity and physiological mechanism of physical activity: a new theoretic framework. Medical romehypotheses. 2009;72(5):527-32.
37. Black PH. The inflammatory response is an integral part of the stress response: Implications for atherosclerosis, insulin resistance, type II diabetes and metabolic syndrome X. Brain, behavior, and immunity. 2003;17(5):350-64.
38. Kiecolt-Glaser JK, Glaser R. Depression and immune function: central pathways to morbidity and mortality. Journal of psychosomatic research. 2002;53(4):873-6.

6. TABLES

Table 1. Baseline characteristics of the study participants by physical activity group, 30 years of age and older; NHANES 2003–2004 and 2005–2006 (N = 6,176)

	Inactive[a] (n=3,101)		Insufficiently Acive[a] (n=1,377)		Weekend Warrior[a] (n=566)		Regularly Active[a] (n=566)		Most Regularly Active[a] (n=566)		P[c]
	N	Measures[b]	N	Measures[b]	N	Measures[b]	N	Measures[b]	N	Measures[b]	
Age (year)	3,101	57.9 (0.5)	1,377	48.6 (0.4)	566	45.3 (0.6)	566	46.5 (0.6)	566	46.1 (0.5)	<.0001
Sex (%)											<.0001
Male	1,206	33.9 (1.0)	674	45.5 (1.2)	364	63.3 (2.4)	382	64.9 (2.4)	396	66.3 (1.8)	
Female	1,895	66.1 (1.0)	703	54.5 (1.2)	202	36.7 (2.4)	184	35.1 (2.4)	170	33.7 (1.8)	
Race/Ethnicity (%)											<.0001
White	1,726	74.6 (2.5)	684	72.5 (2.4)	270	71.5 (3.2)	302	76.9 (2.7)	316	77.9 (2.5)	
Black	690	12.5 (1.5)	282	10.3 (1.4)	120	10.6 (1.6)	99	8.0 (1.6)	87	6.7 (1.1)	
Hispanic	566	7.6 (1.2)	345	10.7 (1.5)	154	13.6 (2.4)	140	10.7 (1.5)	146	12.1 (1.7)	
Other	119	5.3 (0.7)	66	6.6 (0.9)	22	4.3 (1.1)	25	4.4 (1.3)	17	3.3 (0.8)	
Annual family income category (%)											<.0001
Under $20,000	1,040	25.3 (1.7)	289	14.6 (0.9)	136	14.5 (1.6)	84	7.9 (1.2)	79	9.2 (1.8)	
$20,000 to $74,999	1,596	56.9 (1.6)	727	54.3 (2.5)	262	48.2 (2.3)	310	52.5 (2.6)	306	51.8 (3.3)	
$75,000 and Over	374	17.8 (1.7)	325	31.1 (2.3)	159	37.3 (2.8)	157	39.6 (2.8)	174	39.0 (3.1)	
Education (%)											<.0001
Less than high school	1,022	21.9 (1.2)	332	13.6 (1.3)	160	16.2 (2.3)	129	12.7 (1.4)	113	11.7 (1.4)	
More than high school	818	28.9 (0.9)	328	25.9 (1.7)	112	21.4 (2.1)	141	25.2 (2.5)	103	18.0 (1.9)	
Graduate degree	1,255	49.2 (1.7)	717	60.5 (1.7)	294	62.4 (2.9)	296	62.1 (2.4)	349	70.3 (2.0)	
General health condition (%)											<.0001
Good to exellent	1,988	73.3 (1.4)	1,034	86.0 (1.3)	439	88.4 (1.5)	463	93.9 (1.0)	459	90.5 (1.8)	
Fair or poor	925	26.7 (1.4)	240	14.0 (1.3)	98	11.6 (1.5)	67	6.1 (1.0)	72	9.5 (1.8)	
Current Smoker (%)											0.001
Yes	653	45.9 (1.9)	290	45.0 (2.2)	137	51.2 (4.2)	111	41.1 (3.7)	103	32.8 (3.0)	
No	989	54.1 (1.9)	376	55.0 (2.2)	144	48.8 (4.2)	163	58.9 (3.7)	172	67.2 (3.0)	
Body Mass Index (kg/m^2)	3,065	30.1 (0.2)	1,370	28.9 (0.2)	565	27.5 (0.3)	565	27.2 (0.3)	564	26.9 (0.3)	<.0001
Waist Circumference (cm)	2,952	102.1 (0.5)	1,343	98.6 (0.5)	562	96.0 (0.7)	558	95.5 (0.9)	554	94.5 (0.6)	<.0001
SBP (mmHg)	2,914	130 (0.5)	1,313	123 (0.5)	550	121 (0.8)	557	122 (1.1)	546	120 (0.7)	<.0001
DBP (mmHg)	2,914	70 (0.4)	1,313	73 (0.4)	550	73 (0.5)	557	73 (0.7)	546	72 (0.4)	<.0001
Glucose, plasma (mg/dL)	1,420	110.3 (1.2)	620	102.1 (1.3)	269	99.1 (1.4)	282	98.5 (1.1)	258	100.0(1.7)	<.0001
Triglyceride (mg/dL)	1,411	161.8 (6.3)	615	149.8 (4.7)	268	139.4 (8.3)	282	135.9 (7.8)	257	135.6 (6.9)	0.02
Total Cholesterol (mg/dL)	2,953	205.2 (0.9)	1,327	206.8 (1)	554	204.5 (1.7)	553	202.9 (1.7)	548	201.0 (1.5)	0.74
HDL (mg/dL)	2,952	54.6 (0.4)	1,327	54.1 (0.5)	554	55.4 (0.9)	553	54.2 (0.7)	548	56.0 (0.7)	<.0001
LDL (mg/dL)	1,369	119.0 (1.2)	589	121.6 (1.8)	263	121.5 (1.8)	274	117.6 (2.3)	252	118.1 (2.4)	0.59
High cholesterol (%)											<.0001
Yes	1,678	76.2 (1.4)	662	71.3 (2.2)	250	66.6 (2.9)	249	62.0 (2.4)	249	68.5 (2.7)	
No	536	23.8 (1.4)	259	28.7 (2.2)	124	33.4 (2.9)	131	38.0 (2.4)	122	31.5 (2.7)	
Diabetes (%)											<.0001
Yes	623	24.1 (1.2)	133	15.2 (1.5)	29	8.4 (2.4)	29	6.8 (1.7)	32	7.8 (1.5)	
No	1,397	75.9 (1.2)	552	84.8 (1.5)	250	91.6 (2.4)	259	93.2 (1.7)	241	92.2 (1.5)	
IGT (%)											0.52
Yes	474	29.6 (1.8)	212	32.2 (2.5)	80	26.5 (3.7)	90	29.0 (3.5)	76	27.2 (3.8)	
No	1,203	70.4 (1.8)	473	67.8 (2.5)	199	73.5 (3.7)	198	71.0 (3.5)	197	72.8 (3.8)	
Framingham Risk Score (%)	637	18.8 (0.8)	300	12.8 (0.7)	132	9.8 (1.1)	130	9.0 (0.9)	124	9.0 (0.5)	<.0001
Sedentary PA (min/day)	3,101	1,181 (2.5)	1,377	1,109 (2.8)	566	1,086 (5.5)	566	1,037 (5.7)	566	1,023 (5.7)	<.0001
Light PA (min/day)	3,101	256 (2.5)	1,377	317 (2.8)	566	320 (5.1)	566	364 (5.5)	566	374 (5.3)	<.0001
MVPA (min/day)	3,101	4 (0.1)	1,377	15 (0.1)	566	37 (0.9)	566	42 (1)	566	44 (1.2)	<.0001

[a] Inactive: < 10 min/wk of moderate-vigorous physical activity (MVPA); insufficiently active: 30-150 min/wk of MVPA; most regularly active, regularly active and weekend warrior: the first, second and last tertile of coefficient of variation based on the minutes of MVPA across the 7 days.

[b] Continuous variables presented as mean (standard error of mean) and categorical variables as percentage (standard error of percentage).

[c] ANOVA test for continuous variables and Chi-square test for categorical variables.

Table 2. Associations of physical activity patterns with CVD risk factors; NHANES 2003–2004 and 2005–2006 (N = 6,176)

	Inactive[a]	Insufficiently Acive[a] (n=1,377)		Weekend Warrior[a] (n=566)		Regularly Active[a] (n=566)		Most Regularly Active[a] (n=566)		P[d]
	(n=3,101)	Beta (SE)	P[b]	Beta (SE)	P[b]	Beta (SE)	P[b]	Beta (SE)	P[b]	
Body Mass Index (kg/m^2)	ref	-1.4 (0.4)	**0.003**	-2.9 (0.5)	**<.0001**	-3.5 (0.6)	**<.0001**	-3.7 (0.4)	**<.0001**	**<.0001**
Waist Circumference (cm)	ref	-3.4 (0.9)	**<.001**	-7.8 (1.1)	**<.0001**	-9.2 (1.3)	**<.0001**	-9.9 (1.0)	**<.0001**	**<.0001**
SBP (mmHg)	ref	-3.0 (0.8)	**0.001**	-2.1 (1.4)	0.14	-2.8 (1.5)	0.07	-3.3 (1.2)	**0.01**	**0.02**
DBP (mmHg)	ref	0.6 (0.5)	0.22	-0.5 (1.0)	0.58	-0.8 (1.2)	0.47	-0.9 (0.7)	0.21	0.09
Glucose, plasma (mg/dL)	ref	-6.1 (1.9)	**0.002**	-6.1 (2.9)	**0.04**	-7.7 (2.5)	**0.005**	-4.7 (3.4)	0.18	**0.04**
Total Cholesterol (mg/dL)	ref	4.3 (2.1)	**0.05**	3.0 (3.5)	0.39	-3.2 (2.9)	0.28	-6.3 (3.0)	**0.04**	**0.03**
HDL (mg/dL)	ref	2.0 (0.8)	**0.02**	6.7 (1.3)	**<.0001**	4.9 (1.3)	**<.001**	6.4 (1.1)	**<.0001**	**<.0001**
LDL (mg/dL)	ref	5.1 (3.0)	0.10	3.9 (3.9)	0.32	-1.4 (3.7)	0.71	-3.4 (3.4)	0.32	0.26
Triglyceride (mg/dL)	ref	-26.6 (12.4)	**0.04**	-43.6 (18.6)	**0.03**	-42.0 (17.7)	**0.02**	-34.6 (15.5)	**0.03**	**0.005**
Framingham Risk Score (%)	ref	-2.1 (0.7)	**0.006**	-3.6 (0.9)	**<.001**	-4.4 (1.0)	**<.0001**	-4.8 (0.7)	**<.0001**	**<.0001**
		OR (95% CI)	P[c]	OR (95% CI)	P[c]	OR (95% CI)	P[c]	OR (95% CI)	P[c]	
Obesity	ref	0.68 (0.51, 0.92)	**0.01**	0.35 (0.24, 0.50)	**<.0001**	0.36 (0.22, 0.58)	**<.0001**	0.35 (0.25, 0.50)	**<.0001**	**<.0001**
Hypertension	ref	0.71 (0.53, 0.94)	**0.02**	0.59 (0.40, 0.89)	**0.01**	0.54 (0.35, 0.83)	**0.006**	0.51 (0.37, 0.70)	**<.0003**	**0.0001**
High Cholesterol	ref	1.04 (0.78, 1.38)	0.80	0.78 (0.49, 1.25)	0.29	0.63 (0.40, 0.98)	**0.04**	0.68 (0.45, 1.03)	0.07	**0.01**
Diabetes	ref	0.55 (0.32, 0.97)	**0.04**	0.31 (0.13, 0.73)	**0.009**	0.21 (0.07, 0.63)	**0.007**	0.41 (0.19, 0.86)	**0.02**	**0.004**
IGT	ref	1.29 (0.81, 2.05)	0.27	1.28 (0.73, 2.24)	0.38	1.01 (0.64, 1.58)	0.97	0.79 (0.43, 1.45)	0.44	0.42

[a] Inactive: < 10 min/wk of moderate-vigorous physical activity (MVPA); insufficiently active: 30-150 min/wk of MVPA; most regularly active, regularly active and weekend warrior: the first, second and last tertile of coefficient of variation based on minutes of MVPA across the 7 days.

[b] Generalized linear regress model ajust for age, sex, race, education, annual family income, general health condition and smoking.

[c] Logistic regress model ajust for age, sex, race, education, annual family income, general health condition and smoking.

[d] Othorgonal polynomials trend test, ajusted for age, sex, race/ethnicity, education, annual family income, general health condition and smoking.

Table 3. Associations of higher levels of physical activity patterns with CVD risk factors, with the most active group as the reference; NHANES 2003–2004 and 2005–2006

	Most Regularly Active[a] (n=566)	Weekend Warrior[a] (n=566)		Regularly Active[a] (n=566)		P[d]	P[e]
		Beta (SE)	P[b]	Beta (SE)	P[b]		
Body Mass Index (kg/m^2)	ref	0.7 (0.4)	0.08	0.1 (0.5)	0.83	0.07	0.14
Waist Circumference (cm)	ref	2.0 (0.9)	**0.04**	0.4 (1.3)	0.77	**0.04**	0.08
SBP (mmHg)	ref	1.2 (1.8)	0.48	0.7 (1.9)	0.74	0.48	0.52
DBP (mmHg)	ref	0.3 (1.0)	0.75	-0.1 (1.3)	0.95	0.73	0.72
Glucose, plasma (mg/dL)	ref	-0.8 (4.6)	0.86	-3.1 (3.6)	0.39	0.92	0.94
Total Cholesterol (mg/dL)	ref	9.8 (4.3)	**0.03**	3.1 (2.9)	0.28	**0.03**	**0.04**
HDL (mg/dL)	ref	0.4 (1.7)	0.81	-1.2 (1.6)	0.48	0.73	0.61
LDL (mg/dL)	ref	9.0 (5.6)	0.12	4.4 (4.6)	0.36	0.12	0.14
Triglyceride (mg/dL)	ref	-1.5 (20.0)	0.94	-2.0 (19.8)	0.92	0.95	0.87
Framingham Risk Score (%)	ref	1.1 (0.9)	0.23	0.2 (0.9)	0.83	0.22	0.30
		OR (95% CI)	P[c]	OR (95% CI)	P[c]		
Obesity	ref	0.95 (0.56, 1.61)	0.84	0.96 (0.55, 1.67)	0.87	0.85	0.65
Hypertension	ref	1.08 (0.73, 1.60)	0.69	0.99 (0.58, 1.71)	0.97	0.66	0.74
High Cholesterol	ref	1.23 (0.65, 2.34)	0.52	0.96 (0.57, 1.63)	0.88	0.47	0.52
Diabetes	ref	0.69 (0.19, 2.41)	0.54	0.43 (0.18, 1.03)	0.06	0.64	0.64
IGT	ref	2.03 (0.89, 4.59)	0.09	1.61 (0.74, 3.50)	0.22	0.09	0.09

[a] Weekend warrior as >150 minutes of MVPA and in the highest tertile of the CV, regular active as >150min/week of MVPA and in the middle tertile of the CV and most regularly active as >150min/week of MVPA and in the lowest tertile of the CV.
[b] Generalized linear regress model ajust for age, sex, race, education, annual family income, general health condition and smoking.
[c] Logistic regress ajust model for age, sex, race, education, annual family income, general health condition and smoking.
[d] Othorgonal polynomials trend test, ajusted for age, sex, race/ethnicity, education, annual family income, general health condition and smoking.
[e] Othorgonal polynomials trend test, ajusted for age, sex, race/ethnicity, education, annual family income, general health condition, smoking and total MVPA minutes.

7. FIGURES

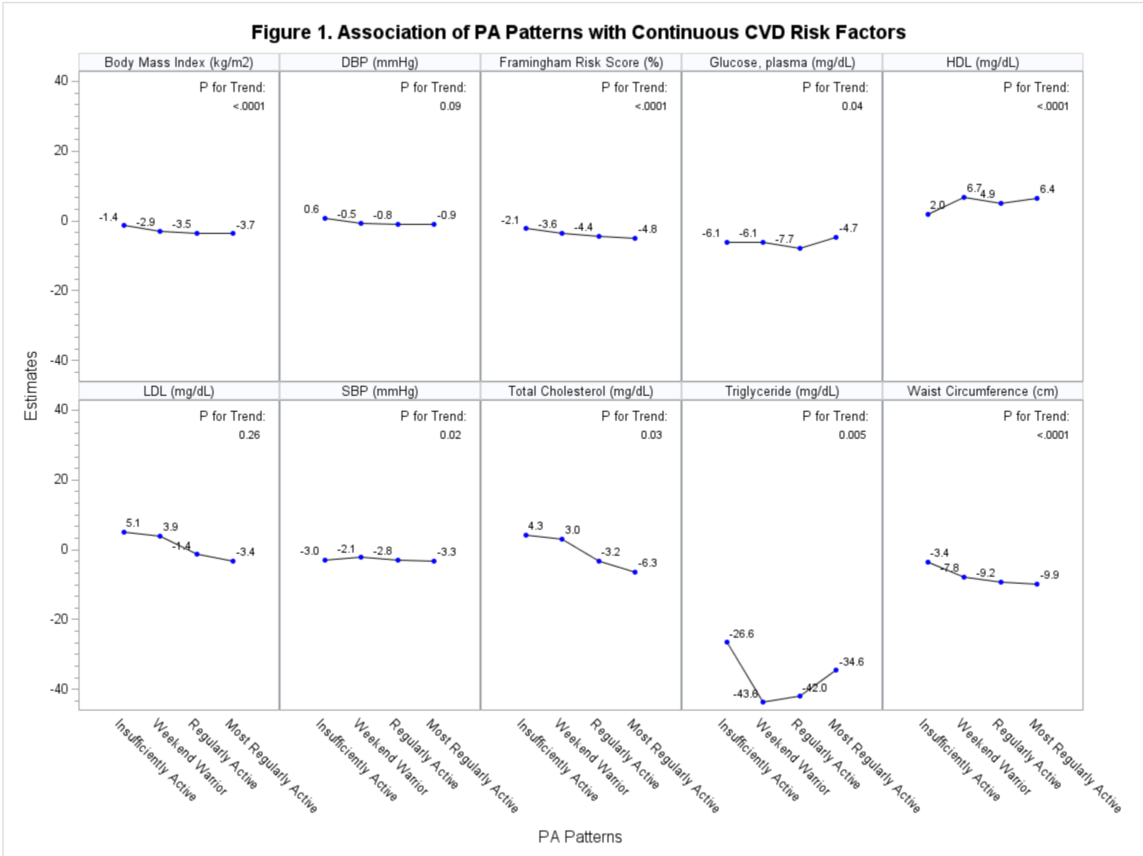

Figure 1. Association of PA Patterns with Continuous CVD Risk Factors (with the inactive as the reference group), generalized linear regression model controlling for age, sex, race/ethnicity, education, annual family income, general health condition and smoking.

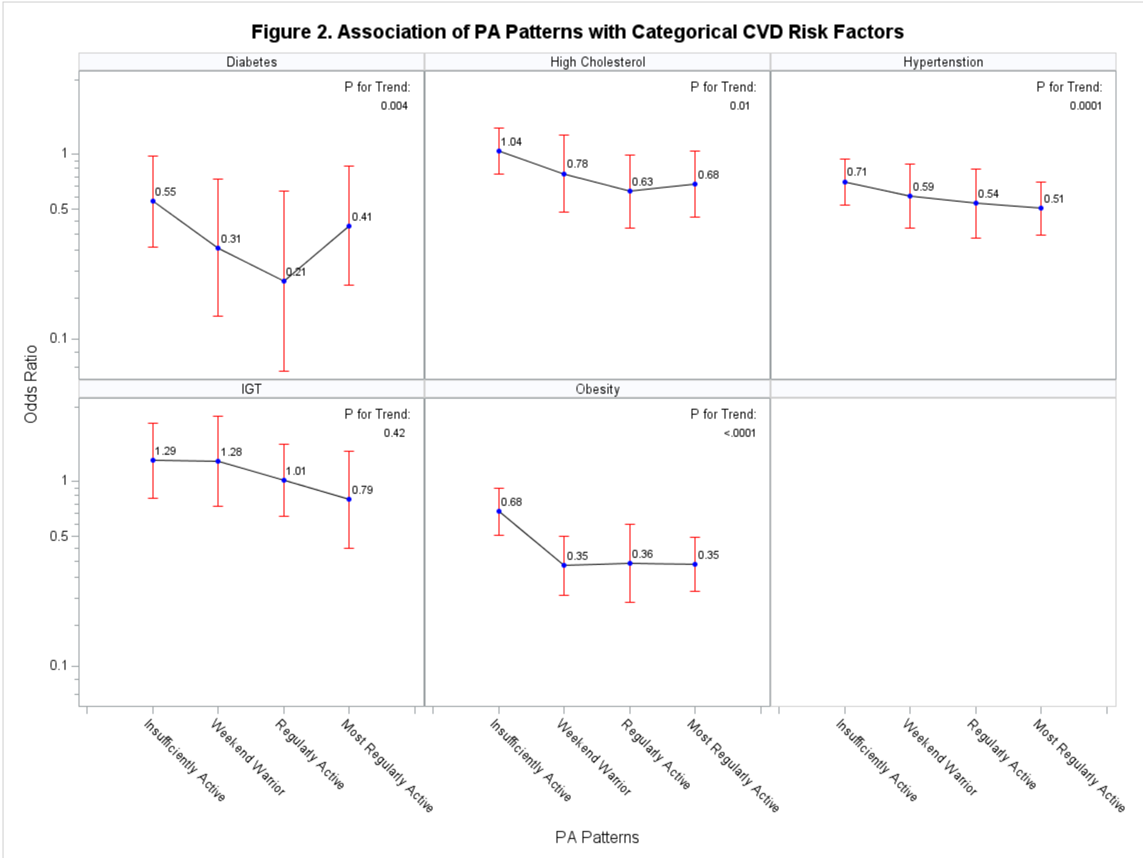

Figure 2. Association of PA Patterns with Categorical CVD Risk Factors (with the inactive as the reference group), logistic regression model controlling for age, sex, race/ethnicity, education, annual family income, general health condition and smoking.