Journal of Adolescent Health ■■ (2017) ■■–■■

ELSEVIER

JOURNAL OF ADOLESCENT HEALTH

www.jahonline.org

Original article

Clustering of Health Behaviors and Cardiorespiratory Fitness Among U.S. Adolescents

Jacob Hartz, M.D., M.P.H. [a], Leah Yingling [b], Colby Ayers, M.S. [c], Joel Adu-Brimpong [b], Joshua Rivers, M.S. [b], Chaarushi Ahuja [b], and Tiffany M. Powell-Wiley, M.D., M.P.H. [d,*]

[a] *Division of Cardiology, Children's National Medical Center, Washington, District of Columbia*
[b] *Office of Intramural Training and Education, Office of Intramural Research, Office of the Director, National Institutes of Health, Bethesda, Maryland*
[c] *Department of Clinical Science, University of Texas—Southwestern, Austin, Texas*
[d] *Cardiology Branch, Division of Intramural Research, National Heart, Lung, and Blood Institute, Bethesda, Maryland*

Article history: Received June 10, 2017; Accepted November 20, 2017
Keywords: Cluster analysis; Nutritional status; Cardiorespiratory fitness; Sedentary lifestyles

A B S T R A C T

Purpose: Decreased cardiorespiratory fitness (CRF) is associated with an increased risk of cardiovascular disease. However, little is known how the interaction of diet, physical activity (PA), and sedentary time (ST) affects CRF among adolescents. By using a nationally representative sample of U.S. adolescents, we used cluster analysis to investigate the interactions of these behaviors with CRF. We hypothesized that distinct clustering patterns exist and that less healthy clusters are associated with lower CRF.
Methods: We used 2003–2004 National Health and Nutrition Examination Survey data for persons aged 12–19 years (N = 1,225). PA and ST were measured objectively by an accelerometer, and the American Heart Association Healthy Diet Score quantified diet quality. Maximal oxygen consumption ($\dot{V}O_2max$) was measured by submaximal treadmill exercise test. We performed cluster analysis to identify sex-specific clustering of diet, PA, and ST. Adjusting for accelerometer wear time, age, body mass index, race/ethnicity, and the poverty-to-income ratio, we performed sex-stratified linear regression analysis to evaluate the association of cluster with $\dot{V}O_2max$.
Results: Three clusters were identified for girls and boys. For girls, there was no difference across clusters for age ($p = .1$), weight ($p = .3$), and BMI ($p = .5$), and no relationship between clusters and $\dot{V}O_2max$. For boys, the youngest cluster ($p < .01$) had three healthy behaviors, weighed less, and was associated with a higher $\dot{V}O_2max$ compared with the two older clusters.
Conclusions: We observed clustering of diet, PA, and ST in U.S. adolescents. Specific patterns were associated with lower $\dot{V}O_2max$ for boys, suggesting that our clusters may help identify adolescent boys most in need of interventions.

Published by Elsevier Inc. on behalf of Society for Adolescent Health and Medicine.

IMPLICATIONS AND CONTRIBUTION

Diet, physical activity, and sedentary time affect cardiorespiratory fitness independently and in concert. The present study uses objective measurements of these variables in cluster analysis of a nationally representative cohort of adolescents. Clusters contained both healthy and unhealthy behaviors and are predictive of cardiorespiratory fitness.

Conflicts of Interest: The authors have no conflicts of interest to disclose.
Authors' Contributions: Jacob Hartz, Leah Yingling, Colby Ayers, Joel Adu-Brimpong, Joshua Rivers, Chaarushi Ahuja, and Tiffany Powell-Wiley made substantial contributions to conception and design, acquisition of data, analysis and interpretation of data, drafting the article and revising it critically for important intellectual content. They gave final approval of the version to be published, and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

* Address correspondence to: Tiffany Powell-Wiley, M.D., M.P.H., Cardiovascular Branch, Division of Intramural Research, National Heart, Lung, and Blood Institute, National Institutes of Health, Building 10, 5-3330, 10 Center Drive, Bethesda, MD 20892.
E-mail address: tiffany.powell-wiley@nih.gov (T. Powell-Wiley).

1054-139X/Published by Elsevier Inc. on behalf of Society for Adolescent Health and Medicine.
https://doi.org/10.1016/j.jadohealth.2017.11.298

Approximately one in five adolescents in the United States is obese (body mass index ≥95th percentile, for age and sex) [1]. Obesity often occurs simultaneously with low cardiorespiratory fitness (CRF). A low CRF in adolescence is associated with an abnormal lipid profile, increased risk of metabolic syndrome, and increased arterial stiffness [2,3]. Although a number of nonmodifiable factors influence CRF, it can be improved with a healthful diet, more physical activity (PA), and less sedentary time (ST) [4]. Unfortunately, poor diet quality [5], inadequate PA [6], and excessive ST [7] are well-documented among U.S. adolescents.

Although each of these health behaviors is an independent risk factor for low CRF [3,4] and cardiovascular disease [8], co-occurrence of more than one of these risk factors may increase cardiovascular risk (as measured by CRF) than any of the factors alone [9–12]. Further, the effects of one health behavior may be influenced by another [10,11]. One method to better understand the interplay of diet, PA, and ST is cluster analysis. Cluster analysis does not predefine groups, but rather identifies groups based on shared characteristics from the available data [13]. Understanding how these health behaviors cluster can help identify populations at the greatest risk of cardiovascular disease and who would benefit most from targeted interventions.

Previous studies evaluating the clustering of different health behaviors in adolescents have been limited by a small sample size [9,12], reliance on self-report [11,14], or focus on populations outside the United States [11,14]. Objective measures of PA and ST are important because they are more predictive of cardiovascular disease risk than self-reported data [15,16].

In the present study, we use the 2003–2004 National Health and Nutrition Examination Survey (NHANES) as it includes a diverse population of 12–19 year olds that are representative of adolescents in the United States. Further, NHANES provides objective measurements of PA and ST using an accelerometer and an objective measure of CRF using a submaximal stress test, which is a validated predictor of maximal oxygen consumption ($\dot{V}o_2max$)[1] in adolescents [17,18]. We hypothesized that cluster analysis would allow U.S. adolescents to be grouped in a meaningful and reliable manner that would help identify subpopulations with elevated cardiovascular risk. We also hypothesized that clusters based on diet quality, PA, and ST would be associated with CRF.

Methods

We used data from the 2003–2004 NHANES cohort [19]. NHANES is an ongoing series of studies conducted by the National Center for Health Statistics that provides a representative sample of the U.S. civilian, noninstitutionalized population. The selection of participants is through a complex, multistage probability design. The specifics of NHANES have been described [20]. The study was conducted according to the guidelines in the Declaration of Helsinki, and all procedures involving human subjects were approved by the National Center for Health Statistics Institutional Review Board. Written informed consent was obtained from all participants 18 years of age and older. The NHANES protocol was developed and reviewed to be in compliance with the Health and Human Services Policy for Protection of Human Research Subjects (45 CFR part 46).

Dietary intake and quality data

Dietary quality was obtained using NHANES 24-hour dietary recall data. NHANES participants underwent two 24-hour dietary recalls; the first consisted of an in-person interview on day 1 at the mobile examination center, whereas the second occurred via a telephone interview conducted 3–10 days following day 1. We only include those who completed the 24-hour recall on day 1 as a majority of participants completed day 1 testing at the mobile examination center examination, and the setting was consistent for all participants.

Each reported food or beverage is recorded based on a specific food code from the U.S. Department of Agriculture Food and Nutrient Database for Dietary Studies. For the 2003–2004 survey, FNDDS 2.0 was used [21].

A healthy eating score was then calculated to assess diet quality, as previously described by Lloyd-Jones et al., and consistent with the current Dietary Guidelines for Americans and American Heart Association recommendations [22,23]. The healthy diet score sets the ideal criteria for five constituents of dietary intake: fruits and vegetables (≥4.5 cups/d), fish (two or more 3.5-oz servings/wk), fiber-rich whole grains (three or more 1-oz equivalent servings/d), sodium (<1,500 mg/d), and sugar-sweetened beverages (≤450 kcal [36 oz]/wk). The highest possible diet score is 5 (meeting all five components of the healthy diet criteria), and lower scores represent lower diet quality. This score was then used in the subsequent cluster analysis. The healthy eating score was then converted to a standardized *z*-score.

Measurement of accelerometer-based activity level and wear time

NHANES adolescents wore an ActiGraph model 7,164 accelerometer (ActiGraph, LLC; Ft. Walton Beach, FL) over the right hip on an elastic belt for 7 days while awake. The accelerometer was to be removed only for swimming or bathing. The uniaxial ActiGraph accelerometer measures and records vertical acceleration as "counts," which reflect the intensity of PA associated with locomotion. Data were recorded in 1-minute epochs for up to 7 days. Details of the accelerometer protocol are available [24].

Consistent with previous research, only those with at least four valid days of wear time were included in our analysis [20]. A valid day was defined as ≥10 hours of "wear time." Wear time was determined by subtracting nonwear time from 24 hours. Nonwear time was defined as any interval of zero intensity counts that lasted for at least 60 consecutive minutes with allowance for 1–3 consecutive minutes of counts between 0 and 100. Wear time was categorized and three of the intensity levels were used for analysis: (1) ST, (2) moderate-intensity PA, and (3) vigorous-intensity PA. A composite variable, moderate-to-vigorous physical activity (MVPA), was defined as an activity greater than or equal to the threshold for moderate activity. Intensity thresholds have previously been determined for those ≥18 years, with moderate-intensity PA having ≥2,020 counts/min and vigorous activity having ≥5,999. For adolescents aged 12–17 years, different thresholds were used for each age group to adjust for differences in resting metabolic rates and are provided in Supplementary Table S1 [25]. A bout of exercise was defined as having >8–10 minutes above the prespecified count thresholds and then

[1] $\dot{V}o_2max$ (mL/kg/min) is a continuous variable that represents the maximal oxygen uptake during intense exercise and was estimated from a submaximal exercise stress test.