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Short Communication

Favorable association of physical activity on cognitive function among older adult smokers

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ABSTRACT

Background: Emerging work suggests that chronic smoking may have deleterious neurocognitive effects. Physical activity has been shown to maintain or improve cognitive function. Thus, it stands to reason that physical activity may moderate the relationship between smoking and cognitive function among older adults. This has yet to be fully evaluated, which was this study's purpose. **Methods:** Data from the 1999-2002 NHANES were employed (N = 2,144; 60-85 yrs). Cognitive function was assessed from the Digit Symbol Substitution Test. Moderate-to-vigorous physical activity (MVPA) and smoking were assessed via self-report. **Results:** In a multiplicative interaction model, the interaction term of physical activity and smoking on cognitive function was not significant (βadjusted = -0.41; 95% CI: -3.11 to 2.28; P=0.75). However, smokers who were physically active had better cognitive function than smokers who were not physically active. **Conclusion:** Physically active smokers had better cognitive function than their less active smoking counterparts.

KEY WORDS: Epidemiology; Elderly; Executive function; Nhanes; Smoking

INTRODUCTION

Aging, sedentary behavior, and chronic smoking each associate with neurocognitive decline and related loss of working memory, cognitive efficiency, and information processing speed [1-3]. Although specific mechanisms underlying these effects are not fully understood, possibilities include altered brain structure, connectivity, receptor binding, hypoxic events, or alterations in biochemistry and neurotransmission [4-6]. On balance, however, the evidence points toward both greater neurocognitive loss [7, 8] and physical inactivity [2, 9] when older smokers are compared to age-matched nonsmokers. At the same time, an encouraging neurocognitive protective effect of regular physical activity has been reported [10, 11] including increased cognitive function [12], memory[13], information processing speed [14], prefrontal cortex activity during memory tasks [15], and improved cerebral blood flow [16]. Yet it remains unclear if greater than age-related neurocognitive loss persists among chronic tobacco users that are more physically active.

Based in part on the foregoing evidence we recently developed a conceptual model proposing that regular participation in physical activity moderates smoking-induced neurocognitive impairment [8]. In addition, it was speculated that improved cognitive function among more active smokers may plausibly promote a more appropriate mental state to quit smoking [8]. The purpose of this study was to examine the first proposition by looking at whether moderate-to-vigorous physical activity (MVPA) associates with improved cognitive function among older smokers. Also examined was if MVPA-associated cognitive function effects differ between older smokers and nonsmokers.

METHODS

Design and Participants

Data was extracted from the 1999-2002 NHANES. Notably, these cycled were utilized as these are the only current NHANES cycles with assessment of cognitive function. All study procedures were approved by the National Center for Health Statistics committee. Participant consent was obtained before any data collection. The sample included 2,441 adult (60-85 yrs) participants. Additional details on the NHANES study design can be found elsewhere (http://www.cdc.gov/nchs/nhanes.htm).

Measurement of Smoking Status

Smoking status was subjectively evaluated, and defined as current smoker, former smoker and never smoker. Participants were asked, "Have you smoked at least 100 cigarettes in your life?" Response options for this question were, "yes, no." Those who answered "yes" were asked, "Do you now smoke cigarettes?" Responses options included, "every day, some days, or not at all." Current smoker was defined as smoking every day or some days. Former smoker was defined as smoking at least 100 cigarettes in their life, but not currently smoking. Never smoker was defined as not smoking at least 100 cigarettes in their life and not currently smoking. Notably, subjectively-assessed smoking status has demonstrated evidence of convergent validity [17].

Measurement of Cognitive Function

Cognitive function was assessed from the Digit Symbol Substitution Test (DSST) [18]. The DSST is a test of visuospatial and motor speed-of-processing and executive function [19, 20]. Participants 60 years of age and older were asked to copy symbols that were paired with numbers within 2 min. Testing was administered in a quiet setting with minimal distractions, and tests were scored as the number of correct responses identified over the 2 minute period.

Physical Activity

As described elsewhere [18, 21], physical activity was subjectively assessed by asking participants their engagement in 48 different activities. Ultimately, Metabolic Equivalent of Task (MET)-min-month was calculated by multiplying the number of days, by the mean duration, by the respective MET level (MET-min-month = days*duration*MET level). As noted previously [21], this subjective assessment of physical activity displays evidence of convergent validity.

Measurement of Covariates

Covariates included: *age*; *gender*; *race-ethnicity* (Mexican American, other Hispanic, non-Hispanic white, non-Hispanic black, other); *poverty-to-income ratio* (range: 0-5); *measured body mass index* (BMI; kg/m^2); *C-reactive protein* (CRP; mg/dL; biomarker of systemic inflammation known to associate with MVPA and smoking); and *comorbid illness* (ordinal variable: range, 0-8 chronic diseases) based on self-report of arthritis, coronary artery disease, stroke, congestive heart failure, heart attack, emphysema, chronic bronchitis, and hypertension [18]. With regard to these illnesses, participants were asked if they had ever been told by a physician or other health professional that they had this disease. High sensitivity CRP concentration was quantified using latex-enhanced nephelometry.

Analysis

Using Stata, multivariable linear regression was employed to examine the association between smoking status and cognitive function (outcome variable). Multiplicative interaction was assessed by creating a cross-product term of physical activity and smoking status, and included it in a regression model along with their main effects and the covariates. Analyses accounted for the complex survey design employed in NHANES by utilizing sample weights, primary sampling units and strata via the Taylor series (linearization) method.

RESULTS

Characteristics of the analyzed sample (N=2,441) are shown in Table 1. With regard to the main findings, and after adjusting for age, gender, race-ethnicity, body mass index, C-reactive protein and comorbid illness, and when compared to never smokers, current smokers had a lower cognitive function DSST score ($\beta_{adjusted}$ = -3.61; 95% CI: -6.59 to -0.64; *P*=0.01); there was no difference between current smokers and former smokers with regard to cognitive function ($\beta_{adjusted}$ = 0.73; 95% CI: -1.20 to 2.66; *P*=0.44). When adding physical activity status (meets guidelines vs. not) to the model, physical activity associated with improved cognitive function ($\beta_{adjusted}$ = 6.71; 95% CI: 5.20 to 8.22; *P*<0.001), and current vs. never smoker was no longer associated with cognitive function ($\beta_{adjusted}$ = -2.51; 95% CI: -5.30 to 0.27; *P*=0.08). These findings suggest that physical inactivity may be accounting for 30% of the total association between smoking and cognitive function ([3.61 – 2.51 / 3.61]*100).

Table 1. Weighted characteristics of the study variables, 1999-2002 NHANES (N=2,441)

Variable	Point Estimate	Standard Error
DSST, mean	47.61	0.65
Age, mean yrs	69.98	0.26
Female, %	55.2	
Non-Hispanic white, %	83.5	
BMI, mean kg/m^2	28.14	0.13
CRP, mean mg/dL	0.51	0.01
Comorbid illness, mean	1.38	0.03
MVPA, mean MET-min-month	3569.8	289.9
Smoking Status, %		
Current	12.5	
Former	41.3	
Never	46.2	

BMI, Body mass index
CRP, C-reactive protein
DSST, Digit Symbol Substitution Test
MET, Metabolic equivalent of task
MVPA, Moderate-to-vigorous physical activity

In a multiplicative interaction model, the interaction term of physical activity and smoking on cognitive function was not significant ($\beta_{adjusted}$ = -0.41; 95% CI: -3.11 to 2.28; *P*=0.75). These findings suggest that physical activity does not moderate the relationship between smoking and cognitive function, but physical inactivity may play a potential mediational role on the smoking-cognitive function relationship, which is not entirely surprising as physical activity is an established behavior affecting cognitive function and smokers tend to be less active than non-smokers. The latter is also supported in this study as current smokers (2216.5 MVPA MET-min-month) engaged in less physical activity than never smokers (2925.4 MVPA MET-min-month); however, this did not reach statistical significance (P=0.22). Notably, there was also no interaction effect of MVPA and gender on cognition (β = -0.44; 95% CI: -2.5-1.6, P=0.66).

In addition to the potential partial mediational role of physical activity on the smoking-cognitive function relationship, Figure 1 illustrates the influence of physical activity on cognitive function among both smokers and never smokers. Smokers had worse cognitive function than never smokers, irrespective of their physical activity status. However, and encouragingly, smokers who were physically active had better cognitive function than smokers who were not physically active.

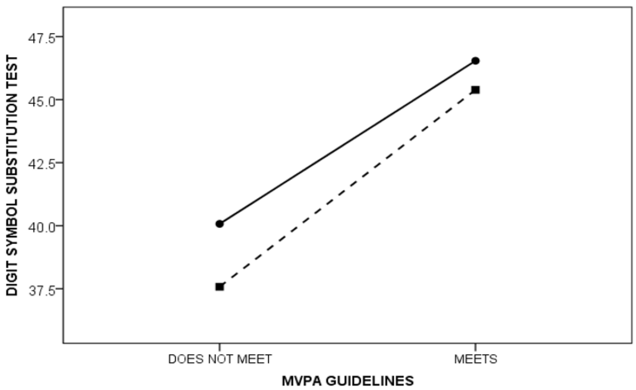

Figure 1. Displays the association of meeting or not meeting MVPA guidelines with number of correct 2-minute timed DSST responses (solid line never smokers; dashed line smokers). Estimated marginal means adjusted for model covariates: age (70.89 yrs.), gender, race-ethnicity, body mass index (27.98 kg/m^2), C-reactive protein (0.55 mg/dL), and comorbid illness.

MVPA (moderate-to-vigorous physical activity).

Meeting MVPA guidelines defined as engaging in at least 2000 MET (metabolic equivalent of task) minutes per month.

DISCUSSION

The main findings of this study are twofold: 1) physical inactivity may partially mediate the relationship between smoking and cognitive function; that is, one potential mechanism through which smoking influences cognitive function is that smokers are less physically active and physical activity may help to preserve cognitive function among older adults; and 2) although we observed no interaction effect of physical activity and smoking on cognitive function (interaction term not significant and lines in Figure 1 are parallel), smokers who were physically active had better cognitive function than smokers who were not physically active. This latter point is particularly important as, although smoking abstinence is a key priority for smokers, relatively few smokers are able to successfully quit smoking, so identification of other health behaviors to preserve cognitive function is important.

In the NHANES, cognitive function among participants aged 60 and older was evaluated using the Digit Symbol Substitution Test. Considered a sensitive cognitive measure, the DSST probes sustained attention, psychomotor coding speed, visual spatial skills, verbal working memory, and associative learning [22]. Adult DSST scores demonstrate robust age-related effects that correlate in the -0.46 to -0.77 range and are routinely employed as a general marker in age-comparative studies [23]. Within this framework, large scale epidemiologic work in adults has associating physical inactivity with reduced cognitive performance [24]. Further, the cumulative effects of smoking duration and intensity are particularly detrimental to cognitive function, with evidence of age-related decrements in problem solving and abstract reasoning performance [2], as well as an association between cigarette use and physical inactivity among older smokers [25]. Commonly these effects are explained by the tendency of negative (and positive) behaviors to cluster, with smokers more likely to engage in risky behaviors than nonsmokers. To the extent behavioral clusters may explain the nexus of smoking and physical inactivity, improving physical activity may serve as a gateway for improving unhealthful behaviors [26, 27]. Taken further, regular participation in physical activity may help to attenuate the effects of smoking on neurocognitive decline as physical activity has been shown to improve cognition [12], increase memory [13], increase information processing speed [14], increase prefrontal cortex activity during memory tasks [15], increase cerebral blood flow [16], reduce atherosclerosis [28], and improve endothelial function [29]. This study's findings suggest that negative neurocognitive effects associated with smoking may be attenuated in association with physical activity.

In conclusion, the present study suggests that physical inactivity may be accounting for approximately 30% of the total association between smoking and cognitive function and smokers who are physically active have better cognitive function than smokers who are not physically active. This study is limited by its cross-sectional design and use of self-reported smoking status and physical activity measures. These parameters, however, have demonstrated some evidence of validity. Prospective and better quantified longitudinal work is needed to corroborate these findings.

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