The association between television viewing time and percent body fat in adults varies as a function of physical activity and sex

Richard R. Suminski 1*, Freda Patterson 2, Mackenzie Perkett 3, Katie M. Heinrich 4 and Walker S. Carlos Poston 5

Abstract

Background: Data suggest that sedentary behavior is an independent risk factor for obesity; however, the extent to which physical activity (PA) and sex alter this relationship remains unclear. To address this gap, the current study examined the association between television (TV) viewing time and percent body fat (%BF) as a function of PA level and sex.

Methods: Trained interviewers assessed 454 adults at their place of residence. Participants completed questionnaires to determine h of TV watched per week, PA level (inactive = not meeting PA guidelines vs. active = meeting PA guideline), and covariates including demographics (e.g., sex), depression symptoms, perceived stress, fruit and vegetable intake, and environmental support for PA. Foot-to-foot bioelectrical impedance (Tanita TBF-300, Tokyo, Japan) was used to assess %BF. Mixed models were generated to examine the association between TV h/wk. and %BF as a function of PA level and sex while accounting for the multi-level nature of the data (neighborhood- and individual-levels) and covariates.

Results: Participants were 44.4 ± 14.0 (Mean + Standard Deviation) years of age with 33.2 ± 11.1%BF, and watched 19.3 ± 15.5 h/wk. of TV. Most were female (70.9%) and inactive (63.2%). Mixed model regression demonstrated that among inactive participants, each additional h of TV viewed/wk. was associated with a 1.03% increase in %BF; TV h/wk. and %BF were not associated in active adults. When models were further stratified by sex, h of TV viewed/wk. were significantly associated with %BF only in inactive females. Each additional h of TV viewed/wk. was associated with an increase in %BF of 1.14%. Conclusion: Interventions targeting PA and/or TV viewing time may be a high-priority to curb excess BF accumulation especially among inactive females.

Keywords: Obesity, Sedentary behavior, Survey research, Cross-sectional

Background

Obesity is a leading risk factor for cardiometabolic disease and cause of death world-wide [1]. The prevalence of obesity varies by race/ethnicity and age with significantly higher rates seen among non-Hispanic Black (46.8%) and Hispanic (47.0%) versus non-Hispanic white adults (37.9%), as well as in men and women aged 40–59 (40.8 and 44.7%, respectively) versus 20–39 years (34.8 and 36.5%, respectively) [2]. Demographic transitions, such as an increasing proportion of the population being older, suggests that the population burden of obesity is only poised to grow. Behavioral approaches to reduce obesity, including increased time in moderate-vigorous physical activity (PA) and improved dietary intake, have met with limited long-term success [3, 4]. To achieve public health goals of a reduction in obesity prevalence, new approaches are needed [5].

Sedentary behavior is defined as any waking behavior characterized by an energy expenditure ≤1.5 metabolic equivalents, while in a sitting, reclining or lying posture [6]. Growing evidence consistently suggests that daily sedentary time is a strong determinant of health outcomes [7]. For example, in a 15-year prospective cohort study conducted in Sweden, data from 851 adults showed that as compared to the least sedentary adults, the most sedentary had a more than five-fold increased risk of death from cardiovascular...
diseases [8]. Importantly, several demographic and psychological factors have been associated with increased sedentary time including male gender, not having a college degree, greater stress and more depressive symptoms [9–11]. As such, decreasing sedentary time is an important behavioral target for reducing disease risk in these population subgroups as well as the general population [9].

One of the open questions in the study of sedentary behavior is the influence of PA on the sedentary behavior-obesity relationship. A large body of literature documents the positive association between sedentary behaviors – TV viewing in particular – and the odds of overweight and obesity, independent PA [12–16]. Some studies have shown an interactive association between PA and sedentary behavior whereby higher levels of PA may ameliorate the effects of sedentary behavior on obesity [17]. Whereas, other studies have not found this interaction [18, 19]. Clarifying the relationship between sedentary behavior, PA and obesity is important for prioritizing prevention strategies. For example, if sedentary behavior is an independent determinant of obesity, then reducing sedentary time may be a more attainable health behavior goal in the long-term than increasing time spent in moderate-vigorous PA [20]. Given the sex differences in both PA (i.e., men have a higher odds of meeting PA recommendations), and sedentary behavior (i.e., men tend to accrue more sedentary time per day), it is plausible that the interactive relationship between PA and sedentary behavior on obesity markers may vary by sex [21, 22].

To address these knowledge gaps regarding sedentary behavior’s role in the obesity epidemic and how PA and sex may alter this role, we investigated the association between sedentary time expressed as hours of TV viewed per week and percent body fat (%BF) and the influence of PA and sex (meeting or not meeting PA guidelines) on this association in a diverse sample of adults. Clarity in this area will inform the extent to which sedentary behavior may be a viable target for obesity prevention efforts.

Methods

Study design

Data used for this study were collected during the Kansas City Built Environment and Health Study (KC BEST) [23, 24]. Briefly, KC BEST used a three-group nested (within U.S. Census block groups), cross-sectional design and a sampling scheme to ensure maximum income variations, independence of the environmental data, and adequate ethnic representation. Face-to-face, 60-min interviews were conducted by trained personnel at a minimum of 25 households in each of the 21 U.S. Census block groups included in the study. Individuals were eligible to participate if they met the following criteria: 1) between 18 and 74 years of age; 2) lived in the area at least 12 months; 3) able to read and understand surveys in English; and 4) primarily responsible for making food decisions for the household. Pregnant women and individuals who currently had any chronic health conditions or disabilities that prevented them from participating in PA were excluded from participation. One eligible individual per household was interviewed, and the justification behind interviewing the person who was primarily responsible for making household food decisions was that the main study, KC BEST, focused on food preparation and selection. Consent was obtained from all participants. Procedures were approved by the University of Missouri-Kansas City’s Institutional Review Board for the protection of human subjects and were performed in accordance with the ethical standards as per the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

A total of 568 participants completed a face-to-face interview and, of these, 454 (80%) had complete data for all variables examined in this study and were included in the analyses. No significant differences in study variables were noted between included and excluded participants (t value ranged: t = 0.08; p = 0.94 for perceived stress to t = 1.9; p = 0.06 for TV h/wk. and Chi Square value ranged: χ² =0.01; p = 0.94 for PA category to χ² =3.17; p = 0.10 for education level).

Measures

Percent body fat

Foot-to-foot bioelectrical impedance analysis (BIA) (Tanita TBF-300, Tokyo, Japan) was used to assess %BF during the face-to-face interviews. Participants were measured wearing light clothing and were instructed to stand barefoot with heel and forefoot placed on the metal electrode plates of the analyzer. All measurements were completed by a trained investigator according to the device manufacturer’s instructions. The Tanita 300 demonstrated strong evidence of concurrent validity (r = 0.94; P < 0.001) when compared with the “criterion standard” of dual energy x-ray absorptiometry (DEXA) for %BF [25].

Physical activity

The International PA Questionnaire (IPAQ) was used to quantify the time participants spent walking, and doing moderate and vigorous PA within the past 7 days. Participants were categorized as meeting PA guidelines if they reported engaging in at least one of the following: (1) three or more days of vigorous intensity PA [Metabolic Equivalent (MET) ≥ 8] of at least 25 min/d, (2) five or more days of moderate intensity PA (4–7 METs), (3) walking (3.3 METs) of at least 30 min/d each day, (4) five or more days of any combination of walking, moderate or vigorous intensity PA attaining at least 600 MET-min/wk. Participants not meeting PA guidelines were those who failed to meet any of the preceding criteria [26]. The IPAQ has been found to have adequate test-retest reliability (p = 0.81, 95% CI 0.79–0.82) and acceptable
Sedentary behavior
The Sedentary Behavior Questionnaire (SBQ) for adults was used to assess time spent watching TV during the past week. Participants reported how much time they typically watched TV on a weekday and weekend day during the last 7 days. To arrive at TV h/wk., the weekday amount was multiplied by five and then added to the weekend amount which was multiplied by two. The SBQ has acceptable test-retest reliability [intraclass correlation coefficients between 0.828 and 0.857 for TV h/wk.] and criterion validity (TV h/wk. with BMI: partial $r = 0.16; p < 0.05$) [28].

Sociodemographic characteristics
Self-reported sociodemographic characteristics included sex (female = 0; male = 1), age in years, race/ethnicity category (non-minority = 0; minority = 1; minority included African Americans, Hispanics, Asians, native Hawaiian or other Pacific islander, or American Indian, Alaskan Native), marital status (married = 0; not married = 1), education level [high school (HS) diploma or less = 0; greater than a HS diploma = 1], employment status (unemployed = 0; employed = 1), and yearly median income [(low-income < $30,000/year = 0; middle-income $30,001 to $100,000/year = 1; high-income > $100,000/year = 2].

Depression symptoms
Symptoms of depression were measured using the 8-item Center for Epidemiologic Studies Depression (CES-D 8) scale. The response values were 4-point Likert scales, with a scoring range of 0 to 3 for each item, giving a total possible score range of 0 to 24. Higher scores indicated a higher frequency of depression symptoms. The CES-D 8 has comparable reliability estimates to those reported for the original version of the CES-D (Chronbach’s $\alpha = 0.92; r = 0.83$) [29].

Perceived stress
The 4-item Perceived Stress Scale (PSS) was used to assess feelings and thoughts related to stress during the last month. Participants were asked to respond to each question using Likert scales that ranged from 0 to 4 giving a total possible score range from 0 to 16, with higher scores associated with greater perceived stress. The PSS has been found to be highly reliable in the general U.S. population [30].

Fruit and vegetable intake
The Block Fruit/Vegetable Screener was used to estimate weekly fruit and vegetable servings. Responses were categorized as: ≤ 3 servings/wk. = 0; 4–6 servings/wk. = 1; ≥ 7 servings/wk. = 2. These self-report screeners have been highly correlated with actual intake (Spearman $r$ values range from 0.6–0.7, $p < .0001$) [31].

Environment score
The PA Neighborhood Environment Survey (PANES) was used to assess perceptions about six aspects of the built environment thought to influence PA. A 4-point Likert scale with responses ranging from strongly disagree to strongly agree, was used for questions about the presence of transit stops, sidewalks, bicycling facilities, recreation facilities, and stores within walking distance. For the question on the main type of housing, response items were graded from low-density housing (single-family homes) to high-density housing (apartments or condos > 12 stories). For data analyses, responses were divided into two groups: disagree (strongly disagree and somewhat disagree = 0) and agree (strongly agree and somewhat agree = 1). For types of housing, single-family was coded 0 and all others coded 1. Thus, summary environment scores ranged from 0 to 6, with higher scores indicating a built environment more conducive for PA. Test–retest reliability for the PANES has been shown to range from $r = 0.64$ for free or low-cost recreation facilities to $r = 0.84$ for sidewalks on most streets [32].

Analysis
Descriptive statistics were generated for all study variables and distributions checked for normality and corrected if necessary. Other assumptions (linearity, homoscedasticity, homogeneity of variance, multi-collinearity, and the presence of outliers) also were investigated and found to be within acceptable limits for the statistical tests used. The study was powered as a clustered, epidemiological survey. Thus, the number of clusters (U.S. Census block groups) was the primary driver for power. Power estimates indicated that a sample of 21 U.S. Census block-groups was needed to provide > 80% power to evaluate group differences in dichotomous outcomes and even greater power for continuous associations. Differences between groups (included vs. excluded participants and inactive vs. active) were examined using independent $t$-tests for continuous variables and Chi Square for categorical variables. Associations between the independent variables (sedentary behavior, PA, sex) and covariates (age, race/ethnicity, marital status, education, employment, yearly median income, environment score, depression symptoms, perceived stress, and fruit/vegetable intake) with %BF were examined using Pearson Product Moment correlation for continuous independent variables, Pearson point biserial correlation for dichotomous independent variables and one-way analysis of variance for multicategorical independent variables. Mixed models were generated to test the relationship between TV h/wk. and %BF and the extent to which this relationship was modified by PA level and sex while accounting for the multi-level nature of the data and covariates which were selected on the basis of being significantly ($P < 0.05$) correlated with %BF. Block group was
Results

Participant characteristics
Of the 454 study participants, 70.9% were female, 26.4% reported a yearly household income of $30,000 or less, 33.9% were minority, 45.4% were not married, 23.8% had a HS education or less, and 36.8% were unemployed. Mean %BF for the sample was 33.2 ± 11.1 and 63.2% were classified as not meeting PA guidelines. Mean TV viewing was 19.3 ± 15.5 h/wk. Descriptive statistics for the full sample and stratified by sex and activity level can be found in Table 1.

Relationships between study variables and %BF

Hours of TV viewed per week (r = .17) were positively correlated with %BF, while meeting PA guidelines (r = -.17), and male (r = -.40) were negatively related to %BF (all P values <.01). Among the study covariates, higher levels of education (r = -.12), and living in an environment more conducive to PA (r = -.15) were significantly related to lower %BF. Being a minority (r = .16), older (r = .15), and reporting higher depressive symptoms (Pearson r = .15), and greater perceived stress (r = .10), were also correlated with having a higher %BF (all P values <.05; see Table 2 for a full listing). Percent body fat did not differ across yearly median income categories [F(2,453) = 2.62;p = .07] or fruit/vegetable intake categories [F(2,452) = 1.12;p = .34].

Multivariate associations between TV viewing and %BF

In a mixed-model generated to assess the independent association between TV h/wk. and %BF using the full sample, TV h/wk. were positively and significantly associated with %BF (β = 0.86; SE = .28; p < 0.05; Table 3).

To test the modifying effects of PA, the overall mixed model was stratified by PA level (Table 4). Results showed that among participants not meeting PA guidelines, TV h/wk. were significantly associated with %BF such that for each additional h of TV watched per wk., a significant increase in %BF of 1.03% (e.g., going from a %BF of 20.0 to 21.03%) was observed after holding other variables in the model constant (β = 1.03; SE = 0.37, p < .005). Among participants meeting PA guidelines, the relationship between TV h/wk. and %BF remained non-significant (β = .16; SE = .44; p = 0.73). Several covariates were also significantly associated with %BF. Specifically, age (β = .17; SE = .05; p < .001), and sex (β = -.91; SE = 1.39; p < .001) were associated with %BF in participants not meeting PA guidelines while only sex was significantly associated with %BF in participants meeting PA guidelines (β = -7.88; SE = 1.53; p < 0.001).

In order to examine sex differences in the relationship between TV viewing, PA, and %BF, the mixed models were further stratified by sex (Table 5). These data indicated that among females not meeting PA guidelines, for every additional h of TV viewed per wk., there was a corresponding increase in %BF of 1.14% (β = 1.14; SE = .43; p < .01). No association between TV h/wk. and %BF was seen for females or males meeting PA guidelines. Of note is that the random effects for block group (level 2 variances) were negligible in all models indicating that only a small portion of the variance in %BF was accounted for by latent factors associated with block groups. Figure 1 provides a depiction of the relationship between TV, %BF, sex and PA level. As can be seen, inactive females had higher %BF than active females at any given dose of TV.

Discussion

The purpose of this study was to investigate the association between TV viewing time and %BF, and the extent to which this association varied as a function of PA level and sex. The main findings were that meeting PA guidelines ameliorated the significant, positive relationship between increased TV viewing and %BF. Moreover, among females not meeting PA guidelines, every additional h of TV viewed per wk. was independently and significantly associated with a 1.14% increase in %BF. These data substantially contribute to a complex literature reporting on the interplay between sedentary behavior, PA and sex by suggesting that reduced TV viewing time and/or increased PA may be particularly important for lowering cardiometabolic disease risk in females.

Our data showed that for each additional h of TV viewed per wk., adults not meeting PA guidelines displayed an increase in %BF of 1.06% by contrast, no such association was seen in adults meeting PA guidelines. The implication that higher levels of PA may ameliorate the positive association between TV viewing and %BF adds to a mixed body of evidence. Some studies have shown higher levels of TV viewing to be associated with overweight status independent of PA levels and other confounders such as sex and age [16, 33–35]. For example, Menai and colleagues [35] reported that in 2517 adults who completed two assessments six-years apart (2001 and 2007), a one h/d increase in TV viewing was associated with a significant, 0.28% increase in body fat mass, irrespective of PA and demographic factors. By contrast, other studies show no significant relationship between TV viewing and markers of overweight/obesity once PA levels are considered in the multivariable models [12, 36, 37]. Stratification by meeting versus not meeting PA levels allowed us to add some clarity to this mixed body of evidence by suggesting that higher levels of TV time impact %BF fat only in adults not...
meeting PA guidelines, thus affording a more nuanced understanding of these complex relationships.

Upon further stratification by sex, our results showed that the positive association between hours of TV viewed per wk. and %BF was only significant for females not meeting PA guidelines. Sex differences in the association between sedentary time and body weight markers have been previously shown [38, 39]. For instance, overall sedentary time has been positively associated with body mass index (BMI) in females but not males, whereas, longer sitting time at work has been significantly associated with higher BMI in men, but not women [40–42]. This lack of concordance in the literature regarding sex differences in the association between sedentary time and %BF markers may be partially attributed to the complex nature of sedentary behaviors. Although sedentary behavior is defined as any waking behavior characterized by an energy expenditure ≤1.5 metabolic equivalents (METs), while in a sitting, reclining or lying posture, this biological operationalization belies a range of behavioral activities (i.e., reading, computer use), and contexts (i.e., commuting, workplace, home), that can in turn alter the duration of sedentary behavior bouts (i.e., period of uninterrupted sedentary time) and sedentary time interruptions (i.e., a

| Table 1 Sample characteristics, overall, and stratified by activity level and sex |
|---------------------------------------------------------------|
|                                                                 |
| **Overall Sample** n = 454 |
| **Activity Level** Meeting PA guidelines n = 168 Not meeting PA guidelines n = 286 |
| **Sex** Female n = 322 Male n = 132 |
| % Body fat [M (SD)] 33.2 (11.1) 31.0 (9.5) 34.5 (11.8) 36.0 (10.4) 26.4 (9.7) |
| TV viewing (h/wk) [M (SD)] 19.3 (15.5) 17.7 (13.6) 20.3 (16.5) 18.6 (15.8) 21.2 (14.8) |
| Age (y) [M (SD)] 44.4 (14.0) 43.3 (14.0) 45.0 (13.9) 44.2 (13.6) 44.8 (14.9) |
| Depression symptoms [M (SD)] (Possible range 0–24) 5.9 (5.9) 5.0 (5.5) 6.5 (6.0) 6.3 (6.0) 5.1 (5.4) |
| Perceived stress [M (SD)] (Possible range 0–16) 4.0 (3.0) 3.7 (2.8) 4.1 (3.1) 3.9 (3.1) 4.0 (2.7) |
| Environment score [M (SD)] (Possible range 0–6) 3.3 (1.4) 3.4 (1.5) 3.2 (1.4) 3.2 (1.4) 3.4 (1.5) |
| Female (%) 70.9 68.5 72.4 – – |
| Race/ethnicity (%) Non-Minority 66.1 27.4 37.8 63.7 72.0 |
| Minority 33.9 72.6 62.2 36.3 28.0 |
| Income (%) ≤ $30,000/year 26.4 17.3 31.8 26.7 25.8 |
| $30,001 to $100,000/year 58.0 56.5 58.7 59.6 53.8 |
| > $100,000/year 15.6 26.2 9.4 13.7 20.5 |
| Educational attainment (%) High school or less 23.8 19.0 26.6 24.8 21.2 |
| Greater than high school 76.2 81.0 73.4 75.2 78.8 |
| Marital status (%) Married 54.6 58.3 52.4 56.2 50.8 |
| Not married 45.4 41.7 47.6 43.8 49.2 |
| Employment status (%) Employed 63.2 35.1 37.8 61.2 68.2 |
| Not employed 36.8 64.9 62.2 38.8 31.8 |
| Activity level (%) Not meeting PA guidelines 63.2 – – 64.6 59.8 |
| Meeting PA guidelines 36.8 – – 35.4 40.2 |
| Fruit and Vegetable Intake (%) ≤ 3 servings/week 7.7 4.2 9.8 8.1 6.8 |
| 4 to 6 servings/week 50.1 44.3 53.5 44.9 62.9 |
| 7 or more servings/week 42.2 51.5 36.7 47.0 30.3 |
non-sedentary bout in between two sedentary bouts) [6]. Sex differences in these behavioral and contextual seden-
tary time variables are not yet understood. Given that shorter sedentary behavior bouts and greater interruptions
have been associated with reduced cardiovascular disease risk, it could be that sex differences in TV viewing behav-
iors contribute to the significant association between TV viewing and %BF among inactive females [43]. Relevant to
this line of discussion is the moderating role of eating

Table 2 Zero-order correlations between study variables and %BF

| Study Variables               | Pearson’s r   |
|------------------------------|---------------|
| TV h/wk                       | .17***        |
| PA category (not meeting PA guidelines = 0; meeting PA guidelines = 1) | -.15**        |
| Sex (female = 0; male = 1)    | -.40***       |
| Age y                        | .15**         |
| Race/ethnicity (non-minority = 0; minority = 1) | .16**        |
| Marital status (married = 0; not married = 1) | .04          |
| Education (<HS = 0; >HS = 1) | -.12*         |
| Employment (unemployed = 0; employed = 1) | -.05         |
| Environment score            | -.15**        |
| Depression symptoms          | .15**         |
| Perceived stress             | .10*          |

*p < 0.05; **p < 0.005; ***p < 0.001

behaviors in the relationship between TV viewing and %BF. Data show that frequent consumption of calorie-
dense snack and fried foods while watching TV accentuates the association between TV viewing and increased body fatness [44, 45]. It could be that the females in our sample were more likely to eat calorie-dense foods than the males. Future studies are needed to elucidate gender differences in snacking while watching TV.

One of the key clinical and population health implications from this study is that reducing TV viewing time should be more widely regarded as a cardiometabolic risk behavior, particularly for women not meeting PA guidelines. That the average adult watches almost five h/
d of TV and that TV viewing is associated with greater food intake, poorer dietary intake, and poorer sleep
health, underscores this premise. While the efficacies of several interventions to reduce TV viewing and screen-
time to lower BMI and curb weight gain in pediatric and adolescent populations have been examined, consider-
ably fewer such studies have been carried out in adult populations [46–54]. Otten and colleagues [54] found that 20 overweight adults using an electronic lock-out system for 6 weeks displayed greater decreases in BMI than a group of observation only controls. However, in a larger study on adults (N = 153) where households were randomized to a home-based obesity intervention that involved TV-limiting devices, less TV viewing was not associated with a significant decrease in BMI 1 year later [55]. The current study adds to the literature in this area and suggests that effective clinical and population-level strategies are necessary to address TV viewing, an impor-
tant health risk behavior.

Findings from this study should be interpreted with consideration of some design, measurement, and data
limitations including the fact that the study was cross-sectional and so precludes the consideration of the tem-
poral relationship between the study variables. In terms of measurement, TV viewing was the only sedentary be-
havior assessed and it, along with other key study vari-
bles (i.e., PA) were not objectively measured. Moreover,
sleep health and tobacco use are key variables shown to
relate to PA and body composition, but they were not
considered in the current study [56–58]. The use of BIA
for assessing %BF typically requires adherence to set guide-
lines particularly concerning body water content (hydra-
tion status) [59]. However, given the large scale nature of this study with respect to directly measuring participants weight, height, %BF, conducting nearly 1 hour interviews about their health behaviors, and then also directly measuring the sur-
rounding built environment, it was not logistically possible or economically feasible to standardize the times the interviews were conducted or to ensure proper hydration status at the time of the interview. We believe that BIA was the preferred choice (based on practicality and performance) for

Table 3 Mixed model for the overall sample predicting %BF

| Fixed effects                          | Coefficient | Standard error |
|----------------------------------------|-------------|----------------|
| Grand intercept                        | 28.16***    | 2.54           |
| TV (h/wk)                              | .85**       | .28            |
| Age (y)                                | .12***      | .03            |
| Race/ethnicity                         | 2.19*       | 1.03           |
| Education                              | -.123       | 1.13           |
| Environmental score                    | -.49        | .33            |
| Depression symptoms                    | .13         | .10            |
| Perceived stress                       | .17         | .20            |
| Physical Activity Level                | -.1.90*     | .96            |
| Sex                                    | -.9.40***   | 1.02           |

| Random effects                         |             |                |
|----------------------------------------|-------------|----------------|
| Level 1 variance                       | 92.62***    | 6.43           |
| Level 2 variance                       | .98         | 2.22           |

Model fit

AIC 3345
n (individuals) 454
k (block groups) 21

*p < 0.05; **p < 0.005; ***p < 0.001. AIC – Akaike’s Information Criterion; Level 1 is the residual variance and Level 2 is the variance for intercept across block group
Table 4 Mixed models predicting %BF in inactive and active subjects

| Fixed effects       | Not meeting PA guidelines | Meeting PA guidelines |
|---------------------|---------------------------|----------------------|
|                     | Coefficient | Standard error | Coefficient | Standard error |
| Grand intercept     | 25.01****    | 3.33           | 33.56****    | 3.80           |
| TV (h/wk)           | 1.03***      | .37            | .15         | .44            |
| Age (y)             | .17****      | .05            | .06         | .05            |
| Race/ethnicity      | 2.13         | 1.35           | 2.46        | 1.55           |
| Education level     | −.56         | 1.46           | −3.40       | 1.86           |
| Environmental score | −.58         | .45            | −.55        | .48            |
| Depression symptoms | .16          | .14            | .07         | .16            |
| Perceived stress    | .22          | .27            | .17         | .32            |
| Sex                 | −9.91****    | 1.39           | −7.96****   | 1.53           |

Random effects

|                     | Level 1 variance | Level 2 variance |
|---------------------|------------------|------------------|
|                     | 105.05****       | 71.11****        |

Model fit

|                     | AIC              | n (individuals) | k (block groups) |
|---------------------|------------------|-----------------|------------------|
|                     | 2147             | 287             | 21               |

|                     | Female           | Male             |
|---------------------|------------------|------------------|
|                     | Not meeting PA guidelines | Meeting PA guidelines | Not meeting PA guidelines | Meeting PA guidelines |
|                     | Coef. | SE  | Coef. | SE  | Coef. | SE  | Coef. | SE  |
| Grand intercept     | 22.38****    | 3.91 | 29.80**** | 5.58 | 20.34**** | 6.00 | 30.67**** | 6.99 |
| TV (h/wk)           | 1.14**       | .43  | −.18  | .53  | .34   | .71  | .95   | .81  |
| Age (y)             | .20****      | .06  | .09   | .06  | .12   | .08  | −.03  | .09  |
| Race/ethnicity      | 4.06**       | 1.51 | 2.42  | 1.94 | −6.54* | 2.78 | 1.22  | 2.59 |
| Education level     | .56           | 1.73 | −3.43 | 2.15 | −2.48 | 2.61 | −3.18 | 3.47 |
| Environmental score | −.83          | .54  | .04   | .58  | −.01  | .76  | −.73  | .87  |
| Depression symptoms | .20           | .16  | −.10  | .17  | −.26  | .27  | .85*  | .35  |
| Perceived stress    | .12           | .30  | .81*  | .34  | 1.12  | .58  | −1.72** | .63  |

Random effects

|                     | Level 1 variance | Level 2 variance |
|---------------------|------------------|------------------|
|                     | 103.89****       | 99.73****        |

Model fit

|                     | AIC              | n (individuals) | k (block groups) |
|---------------------|------------------|-----------------|------------------|
|                     | 1552             | 208             | 21               |

*p < 0.05; **p < 0.01; ***p < 0.005; ****p < 0.001. AIC – Akaike’s Information Criterion; Level 1 is the residual variance and Level 2 is the variance for intercept across block group
assessing %BF in a large-scale, epidemiological study such as this one. From a data perspective, the reported relationships yielded small correlations and explained a relatively small percentage of the variance in %BF; however, this is common in studies examining TV viewing and weight indicators [60–62].

Despite these limitations, the current study has strengths worth noting. First, a multi-level, analytical approach was used to account for any effects representing unobserved (i.e., latent) block group-level characteristics that could have affected individual-level outcomes. Second, aside from the limitation mentioned above, objective assessments of body composition were obtained using state-of-the-art, high-grade equipment that provides measures of %BF comparable to those obtained with DEXA [25]. Lastly, the data were collected during in-person interviews conducted at each participant’s place of residence. No other studies on sedentary behavior and body composition have used this methodology. Besides having several advantages over phone interviews (e.g., more representative of residents in low-income areas, allow for use of visuals, verification of certain demographics, and the elimination of “dead-end” selections, e.g., non-working telephone numbers), door-to-door interviews can reach a pool of study participants that may not be captured by traditional data collection techniques requiring study participants to travel to a data collection location (e.g., lab, community center) [63–65]. These individuals may express unique characteristics relevant to examining sedentary behaviors. For example, in a previous study conducted in similar block groups in the same city as the current study, we found that respondents to door-to-door surveys reported sitting an average of 331 min/wk. while respondents to the same survey administered at centralized health fairs held in the same block groups reported sitting an average of 217 min/wk. (p < .01) [66]. Therefore, the current study may provide a missing piece of the spectrum of sedentary behavior (i.e., reduced truncation of the sedentary time distribution), thus improving analytics and providing a more accurate picture of the association between sedentary behavior and a health status indicator. This is similar to LaPorte and colleagues’ contention (1984) regarding the relationship between PA and cardiovascular disease [67].

Conclusions
Our findings indicated that time spent watching TV and engaging in PA are both important from a cardio-metabolic disease prevention perspective. Future studies to verify these associations prospectively utilizing objective assessment of multiple sedentary behaviors and PA domains across different contexts are warranted. The development and testing of accessible and effective strategies to increase PA and reduce TV viewing should be embraced as an approach to reducing excess BF accumulation especially among inactive women.

Abbreviations
%BF: percent body fat; AIC: Akaike’s Information Criterion; BMI: body mass index; CES-D 9: Center for Epidemiologic Studies Depression; Coef.: Coefficient.; DEXA: dual energy x-ray absorptiometry; h: hours; HS: high school; IPAQ: International Physical Activity Questionnaire; KC BEST: Kansas City Built Environment and Health Study; min: minutes; PA: physical activity; PANES: Physical Activity Neighborhood Environment Survey; PSS: Perceived Stress Scale; SD: standard deviation; SE: standard error; SPSS: Statistical Package for the Social Sciences; TV: television; U.S.: United States; wk: week.
Acknowledgments
Not applicable.

Authors’ contributions
RS, WP, and FP analyzed and interpreted the data. MP assisted with manuscript preparation and editing. KH assisted with data interpretation and editing. All authors read and approved the final manuscript.

Funding
Research reported in this publication was partially supported by grants from the National Institute of Diabetes and Digestive and Kidney Diseases (awarded to Dr. Poston; R01DK064284 and DK064284-S), an Institutional Development Award (IDeA) Center of Biomedical Research Excellence award from the National Institute of General Medical Sciences of the National Institutes of Health (awarded to Dr. Patterson; P20GM113125), and the University of Delaware Research Fund (awarded to Dr. Patterson; 16A01366). The funders played no role in the design of the study and data collection, analysis, interpretation of data, and in the writing of this manuscript.

Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Consent for publication
Not applicable.

Competing interests
Freda Patterson serves as an Associated Editor for BMC Public Health. The other authors declare that they have no competing interests.

Author details
1 Center for Innovative Health Research, Department of Behavioral Health and Nutrition, University of Delaware, 325 Tower at STAR, Newark, DE 19716, USA.
2 Department of Behavioral Health and Nutrition, University of Delaware, Tower at STAR, Newark, DE 19716, USA.
3 Department of Behavioral Health and Nutrition, University of Delaware, Bob Carpenter Sports Building, 26 N College Avenue, Newark, DE 19716, USA.
4 Kansas State University, Department of Kinesiology, Functional Intensity Training Lab, Nataratorium 1A, Manhattan, KS 66506, USA.
5 National Development and Research Institutes, Institutes for Biobehavioral Health Research, 1920 143rd Street, Suite 120, Leawood, KS 66224, USA.

Received: 7 November 2018 Accepted: 5 June 2019
Published online: 13 June 2019

References
1. Guidelines (2013) for managing overweight and obesity in adults. Preface to the expert Panel report (comprehensive version which includes systematic evidence review, evidence statements, and recommendations). Obesity (Silver Spring). 2014;22(Suppl 2):S40–S50.
2. Hales CM, Carroll MD, Fryar CD, Ogden CL. Prevalence of obesity among adults and youth: United States, 2015–2016. 2017;288:1–8.
3. Vincent GK, Velkoff VA. THE NEXT FOUR DECADES, THE older population in the United States, 2010 to 2050. Bureau US.C, Washington, D.C., 2010. https://www.census.gov/prod/2010pubs/p25-1138.pdf. Accessed 4 Apr 2018.
4. Lemstra M, Bird Y, Nwanwko C, Rogers M, Moraros J. Weight loss intervention adherence and factors promoting adherence: a meta-analysis. Patient Prefer Ad. 2016;10:547–59.
5. The Secretary’s Advisory Committee on National Health Promotion and Disease Prevention Objectives for 2020. In: Phase 1 Report Recommendations for the Framework and Format of Healthy People 2020. 2008. https://www.healthypeople.gov/sites/default/files/Phase1_0.pdf. Accessed 4 Apr 2018.
6. Tremblay MS, Aubert S, Barnes JD, Saunders TJ, Carson V, Latimer-Cheung AE, et al. Sedentary Behavior Research Network (SBRN) – Terminology Consensus Project process and outcome. Int J Behav Nutr Phys Act. 2017;10:14(1):75.
7. Wilmot EG, Edwardsen CL, Achara FA, Davies MJ, Gorely T, Gray LJ, et al. Sedentary time in adults and the association with diabetes, cardiovascular disease and death: systematic review and meta-analysis. Diabetologia. 2012;55(11):2895–905.
8. Dohm IM, Sjostrom M, Kivlak I, Oja P, Hagstromer M. Accelerometer-measured sedentary time and physical activity-A 15 year follow-up of mortality in a Swedish population-based cohort. J Sci Med Sport. 2017;21(4):2440–2446. https://doi.org/10.1016/j.jsms.2016.08.006
9. Patterson F, Huang L, Lozano A, Malone S, Suminski R, Hanlon A. A population analysis of socio-demographic differences in sedentary behavior among middle-age adults. In: International Society of Behavioral Nutrition and Physical Activity Victoria, Canada; 2017.
10. Harner M, Stamatakis E. Prospective study of sedentary behavior, risk of depression, and cognitive impairment. Med Sci Sports Exerc. 2014;46(4):718–23.
11. Sanchez-Villegas A, Ara I, Guifré-Giménez F, Bes-Rastrollo M, Vara-Cervera-Zubeltzabera JJ, Martínez-González MA. Physical activity, sedentary index, and mental disorders in the SUN cohort study. Med Sci Sports Exerc. 2008;40:827–34.
12. Wanner M, Richard A, Faeh D, Rohrmann S. Associations between self-reported and objectively measured physical activity, sedentary behavior and overweight/obesity in NHANES 2003-2006. Int J Obes. 2017;41(11):1866–93.
13. Golubic R, Wijndaele K, Sharp SJ, Simmons RK, Griffin SJ, Wareham NJ, et al. Physical activity, time and gain in overall and central body fat; 7-year follow-up of the ProActive trial cohort. Int J Obes. 2013;39(1):142–8.
14. Hu FB, Li TY, Colditz GA, Willett WC, Manson JE. Television watching and other sedentary behaviors in relation to obesity and type 2 diabetes mellitus in women. Jama. 2003;289(14):1785–91.
15. Heinonen I, Helajärvi H, Pahkala K, Heinonen OJ, Hirvensalo M, Palve K. Sedentary behaviours and obesity in adults: the cardiovascular risk in young finns study. J Epidemiol. 2012;22(1):50–6.
16. Inoue S, Sugiyama T, Takamya T, Oka K, Owen N, Shimomitsu T. Television viewing time is associated with overweight/obesity among older adults, independent of meeting physical activity and health guidelines. J Epidemiol. 2012;22(1):50–6.
17. Dunton GF, Berigan D, Ballard-Barbash R, Grubbard B, Atienza AA. Joint associations of physical activity and sedentary behaviour with body mass index: results from a time use survey of US adults. Int J Obes. 2000 Dec;24(12):1427–36.
18. Dunstan DW, Salmon J, Owen N, Armstrong T, Zimmet PZ, Welborn TA, et al. Associations of TV viewing and physical activity with the metabolic syndrome in Australian adults. Diabetologia. 2005;48(11):2254–61.
19. Jakes RW, Day NE, Khaw KT, Luben R, Oakes S, Welch A, et al. Television viewing and low participation in vigorous recreation are independently associated with obesity and markers of cardiovascular disease risk. EPIC-Norfolk population-based study. Eur J Clin Nutr. 2003;57:1089–96.
20. Prince SA, Saunders TJ, Greyst K, Reid RD. A comparison of the effectiveness of physical activity and sedentary behaviour interventions in reducing sedentary time in adults: a systematic review and meta-analysis of controlled trials. Obes Rev. 2014;15(11):905–19.
21. Saffer H, Dave D, Grossman M, Leung LA. Racial, ethnic, and gender differences in physical activity. Hum Cap. 2013;7(6):378–410.
22. Dzar KM, Howard VJ, Hutto B, Colabianchi N, Vena JE, Blair SN, et al. Patterns of Sedentary Behavior in US Middle-Age and Older Adults: The REGARDS Project process and outcome. Int J Behav Nutr Phys Act. 2017;10;14(1):75.
23. Heinrich KM, Hughey J, Randels A, Wall D, Peterson NA, Jtnarin R, et al. The census of social institutions (CSI): a public health direct observation measure of local land use. J Urban Health. 2010;87(3):410–5.
24. Jtnarin R, Heinrich KM, Haddock CK, Hughey J, Berek L, Poston WSC. Neighborhood environment perceptions and the likelihood of smoking and alcohol use. Int J Environ Res Public Health. 2015;12(11):7849–93.
25. Rubiano F, Nunez C, Heymsfield SB. A comparison of body composition techniques. Ann N Y Acad Sci. 2000;904:335–40.
26. Guidelines for Data Processing and Analysis of the International Physical Activity Questionnaire IPAQ Short and Long Forms.pdf. Accessed 4 Apr 2018.
27. Craig CL, Marshall AL, Sjostrom M, Bauman AE, Booth ML, Ainsworth BE, et al. International physical activity questionnaire: 12-country reliability and validity. Med Sci Sports Exerc. 2003;35(8):1381–95.
28. Rosenberg DE, Norman GJ, Wagner N, Patrick K, Calfas KJ, Sallis JF. Reliability and validity of the sedentary behavior questionnaire (SBQ) for adults. J Phys Act Health. 2010;7:697–705.

29. Van de Velde S, Leveque K, Bracke P. Measurement equivalence of the CES-D & B in the general population in Belgium: a gender perspective. Arch of Public Health. 2009;67(1):15–29.

30. Cohen SW, Williamson GM. Perceived Stress in a Probability Sample of the United States. The Soc Psych Health. 1988:31–67.

31. Block G, Gillespie C, Rosenbaum E, Jensen C. A rapid food screener to assess fat and fruit and vegetable intake. Am J Prev Med. 2000;18:284–8.

32. Sallis JF, Bowles HR, Bauman A, Ainsworth BE, Bull FC, Craig CL, et al. Neighborhood environments and physical activity among adults in 11 countries. Am J Prev Med. 2009;36(6):484–90.

33. Salmon J, Bauman A, Crawford D, Timperio A, Owen N. The association between television viewing and overweight among Australian adults participating in varying levels of leisure-time physical activity. Int J Obes Relat Metab Disord. 2002;24(5):600–6.

34. Ching PL, Willett WC, Rimm EB, Colditz GA, Stampfer MJ. Activity level and risk of overweight in male health professionals. Am J Public Health. 1996;86(12):25–30.

35. Menai M, Chareire H, Kesse-Guyot E, Andreeva VA, Hercberg S, Galan P, et al. Determining the association between types of sedentary behaviours and cardiometabolic risk factors: a 6-year longitudinal study of French adults. Diabetes Metab. 2016;42(2):112–21.

36. Tucker LA, Tucker JM. Television viewing and obesity in 300 women: evaluation of the pathways of energy intake and physical activity. Obesity (Silver Spring). 2011;19(10):1950–6.

37. Maher CA, Milre E, Harrington DM, Staiano AE, Katmarzyk PT. The independent and combined associations of physical activity and sedentary behavior with obesity in adults: NHANES 2003-06. Obesity (Silver Spring). 2013;21(12):E730–7.

38. Sugiyama T, Healy GN, Dunstan DW, Salmon J, Owen N. Is television viewing time a marker of a broader pattern of sedentary behavior? Ann Behav Med. 2008;35(2):245–50.

39. McVeigh J, Smith A, Howie E, Straker L. Trajectories of Television Watching from Childhood to Early Adulthood and Their Association with Body Composition and Mental Health Outcomes in Young Adults. PLoS One. 2016;11(4):e0152879.

40. Van Dyck D, Cerin E, De Bourdeaudhuij J, Hindonck E, Reis RS, Davey R, et al. International study of objectively measured physical activity and sedentary time with body mass index and obesity IPEN adult study. Int J Obes. 2015;39(2):199–207.

41. Mummery WK, Schofield GM, Steele R, Eakin EG, Brown WJ. Occupational sitting time and overweight and obesity in Australian workers. Am J Prev Med. 2005;29(2):91–7.

42. Lin T, Courtney TK, Lombardi DA, Venna SK. Association between sedentary work and BMI in a U.S. National Longitudinal Survey. Am J Prev Med. 2015;49(6):e17–23.

43. Kim Y, Welk GJ, Braun SJ, Kang M. Extracting Objective Estimates of Sedentary Behavior from Accelerometer Data: Measurement Considerations for Surveillance and Research Applications. PLoS ONE. 2015;10(2):e018807. https://doi.org/10.1371/journal.pone.0188078.

44. Hassan NE, Wahba SA, El-Masry SA, Abd Elhamid ER, Boseila SAW, Ahmed MI, et al. Eating habits and lifestyles among a sample of obese working Egyptian women. Open Access Maced J Med Sci. 2015;3(1):12–7.

45. Liebman M, Pelican S, Moore SA, Holmes B, Wardlaw MK, Melcher LM, et al. Dietary intake, eating behavior, and physical activity-related determinants of high body mass index in rural communities in Wisconsin, Montana, and Idaho. Int J Obes Relat Metab Disord. 2003;27(6):684–92.

46. The Nielsen Co. Americans can’t get enough of their screen time [news release]; November 24, 2008. https://www.nielsen.com/content/dam/nielsenporate/reports-downloads/2016/reports/total-audience-report-q1-2016.pdf. Accessed 14 Mar 2018.

47. León-Muñoz LM, García-Esquinas E, Soler-Vila H, Guillar-Castillon P, Banegas JR, Rodríguez-Artalejo F. Unhealthy eating behaviors and weight gain: a prospective study in young and middle-age adults. Obesity (Silver Spring). 2016;24(1):178–84.

48. Serzano S, Law M, Dehomb S, Tonstad S. The association of TV watching to sleep problems in a church-going population. Fam Community Health. 2014;37(4):279–87.

49. Robinson TN. Reducing Children’s television viewing to prevent obesity a randomized controlled trial. JAMA. 1999;282(16):1561–7.

50. Escobar-Chaves SL, Markham CM, Addy RC, Greisinger A, Murray NG, Brehm B. The fun families study: intervention to reduce children’s TV viewing. Obesity (Silver Spring). 2010;18(Suppl 1):S99–101.

51. Epstein LH, Roemmich JN, Robinson JL, Paluch RA, Winiewicz DD, Fuerch JH, et al. A randomized trial of the effects of reducing television viewing and computer use on body mass index in young children. Arch Pediatr Adolesc Med. 2008;162(3):239–45.

52. Wu L, Sun S, He Y, Jiang B. The effect of interventions targeting screen time reduction: a systematic review and meta-analysis. Medicine (Baltimore). 2016;95(27):e4029.

53. Spring B, Schneider K, McFadden HG, Vaughn J, Kozak AT, Smith M, et al. Multiple behavior changes in diet and activity: a randomized controlled trial using mobile technology. Arch Intern Med. 2012;172(10):789–96.

54. Otten JJ, Jones KE, Littenberg B, Harvey-Berino J. Effects of television viewing reduction on energy intake and expenditure in overweight and obese adults: a randomized controlled trial. Arch Intern Med. 2009;169(22):2109–15.

55. French SA, Mitchell NR, Hannan PJ. Decrease in television viewing predicts lower BMI at one year follow up in adolescents but not adults. J Nutr Educ Behav. 2014;46(5):415–22.

56. Patterson L, Lenhart CM. Characteristics of smokers from a National Sample who Engaged in any physical activity: implications for cardiovascular health intervention. Am J Health Ed. 2016;47(2):117–23.

57. Patterson F, Malone SK, Lozano A, Granada MA, Hanlon AL. Smoking, screen-based sedentary behavior, and diet associated with habitual sleep duration and chronotypes data from the UK Biobank. Ann Behav Med. 2016;50(3):715–26.

58. Audrain-McGovern J, Benowitz NL. Cigarette smoking, nicotine, and body weight. Clin Pharmacol Ther. 2011;90(1):164–8.

59. Kyle Ug, Bossaeus I, De Lorenzo AD, Deurendorn P, Elia M, Gómez JM, Heitmann BL. Et al composition of the ESPEN working group. Boeotiological impediment analysis–part I: review of principles and methods. Clin Nutr. 2004;23(5):1226–43.

60. Malone SK, Patterson F, Lu Y, Lozano A, Hanlon AL. Ethnic differences in sleep duration and morning-evening type in a population sample. Chronobiol Int. 2016;33(1):10–21.

61. Thorp AA, Owen N, Neuhaus M, Dunstan DW. Sedentary behaviors and subsequent health outcomes in adults a systematic review of longitudinal studies. 1996-2011. Am J Prev Med. 2011;41(2):207–15.

62. Drenovatz C, DeMello MM, Shook RP, Hand GA, Burgess S, Blair SN. The association between sedentary behaviors during weekdays and weekend with change in body composition in young adults. AIMS Public Health. 2016;3(2):375–88.

63. Aday L, Cornellus Lj. Choosing the Methods of Data Collection: Comparison of Personal Interviews, Telephone Interviews, and Self-Administered Questionnaires. In: Designing and Conducting Health Surveys: A Comprehensive Guide (3rd Ed.). San Francisco: Jossey-Bass; 1996. p. 105–14.

64. Aquilino WS. Interview mode effects in surveys of drug and alcohol use: a field experiment. Pub Opin Quart. 1994;58:210–40.

65. Groves R. Theories and methods of telephone surveys. Ann Rev Soc. 1990;16:221–52.

66. Suminski RR, Wasserman JA, Mayfield CA, Thelen K, Egger B. Neighborhood environments and physical activity among adults in 11 communities. BMC Public Health. 2009;67(1):15

67. LaPorte RE, Adams LL, Savage DD, Brenes G, Dearwater S, Cook T. The spectrum of physical activity, cardiovascular disease and health: an epidemiologic perspective. Am J Epid. 1984;120(4):507–17.