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I Sit but I Don't Know Why: Investigating the Multiple Precursors of Leisure-Time Sedentary Behaviors

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ABSTRACT

Background: Precursors driving leisure-time sedentary behaviors remain poorly investigated, despite their detrimental consequences. This study aimed to investigate the predictive validity of controlled and automatic motivational precursors toward reducing sedentary behaviors and being physically active on leisure-time sedentary behaviors. The influence of demographic, physical, socio-professional, interpersonal, and environmental variables was also examined and compared with the associations of motivational precursors. **Methods**: 125 adults completed questionnaires measuring controlled motivational precursors (i.e., intentions, perceived competence), demographical (i.e., sex and age), physical (i.e., body mass index), and interpersonal (i.e., number of children) variables. Regarding automatic motivational precursors, habit strength and approach-avoidance tendencies were captured using the Self-Report Behavioral Automaticity Index and a manikin task. Time at work was computed as a socio-professional variable, days of the week and weather conditions were recorded as environmental precursors. Participants wore an accelerometer for 7 days and leisure time was identified using notebooks. Associations between the different precursors and the leisure-time sedentary behaviors were examined in linear mixed effect models. **Results**: Intention to be physically active and habit strength toward physical activity were negatively associated with leisure-time sedentary behaviors. Sex, body mass index, time at work, number of children, day of the week, and weather conditions were more strongly associated with leisure-time sedentary behaviors. **Conclusion**: Our findings show that, in comparison with other variables, the influence of motivational precursors on leisure-time sedentary behaviors is limited. This study supports the adoption of a broad-spectrum of precursors when predicting sedentary behaviors.

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Sedentary behaviors, defined as any waking behavior in a reclining, sitting, or lying position that requires an energy expenditure lower than 1.5 Metabolic Equivalent Task (Sedentary Behavior Research Network, 2012), are associated with a wide range of detrimental health consequences, including adverse metabolic conditions (Hamilton et al., 2007), depression (Teychenne et al., 2010), and cognitive decline (Olanrewaju et al., 2020). Adults spend about 77% of their waking time being sedentary (Diaz et al., 2016) and workplace settings account for a large amount of this daily time (Saidj et al., 2015). To mitigate the detrimental consequences associated with such patterns of activity at work, reducing sedentary behaviors during leisure time seems particularly important (Patel et al., 2010). However, the main precursors underlying leisure-time sedentary behaviors remain poorly investigated.

Explaining sedentary behaviors through sociocognitive models

In the past decade, a growing number of studies investigated the motivational precursors of sedentary behaviors (Biddle, 2011). Most of these studies were anchored in sociocognitive models. These models are based on the premise that imagined end states (e.g., expectancies, goals) are the most proximal precursors of behavior (Brand & Cheval, 2019) and suggest that intentions and self-perceptions (e.g., perceived competence) directly orient actions toward or away from specific behaviors.

Previous work showed higher intention to reduce sedentary behaviors was negatively associated with time spent in sedentary behaviors (Maher & Conroy, 2015; Maher & Dunton, 2020). Besides motivation

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toward sedentary behaviors, higher intention to be physically active (He et al., 2010; but see Maher & Conroy, 2015 for null findings), and higher perceived competence to adopt a more active lifestyle (Bai et al., 2015; Quartiroli & Maeda, 2014) were associated with lower time spent in sedentary behaviors. However, the associations between these motivational precursors and sedentary behaviors were only of small to medium magnitude, suggesting that others motivational variables may drive sedentary behaviors (Rollo et al., 2016). In this line, additional theoretical perspectives, such as the dual-process models (Rhodes et al., 2019), have been mobilized to explain sedentary behaviors.

Explaining sedentary behaviors through dual-process models

Dual-process models contend that behaviors are governed by both controlled and automatic motivational processes (Strack & Deutsch, 2004). Controlled processes are slow, initiated intentionally, require cognitive resources and effort, and operate within conscious awareness. The key aforementioned sociocognitive constructs are assumed to be "plugged" in this controlled dimension (Conroy & Berry, 2017). Conversely, automatic processes are fast, initiated unintentionally, require relatively less cognitive resources and effort, occur outside conscious awareness (e.g., habits, automatic affective reactions, approach-avoidance tendencies).

Despite the incidental enactment of sedentary behaviors (Spence et al., 2017), explained by the profusion of attention-grabbing cues in our modern environment (Levine, 2015), the influence of automatic motivational processes remains overlooked. Indeed, only a few studies have mobilized dual-process models to explain sedentary behaviors (Chevance et al., 2017; Conroy et al., 2013; Maher & Conroy, 2015, 2016; Maher & Dunton, 2019). Results showed that higher habit strength for sedentary behaviors (i.e., association between a contextual cue in the environment and a behavioral response, Gardner, 2015) was associated with higher time spent in sedentary behaviors (Conroy et al., 2013; Maher & Conroy, 2015, 2016; Maher & Dunton, 2019). Unlike results observed for the controlled motivational precursors, habit strength for physical activity was not associated with time spent in sedentary behaviors (Maher & Conroy, 2015). One study assessed automatic affective attitudes toward sedentary behaviors (Chevance et al., 2017), using the Single Category Implicit Association Test, a reaction time-based task (Karpinski & Steinman, 2006; Rebar et al., 2015), but did not observe association with time spent in sedentary behaviors.

Besides habits and automatic affective reactions, other automatic processes could be investigated, such as approach-avoidance tendencies (Cheval et al., 2014, 2015; Zenko & Ekkekakis, 2019). Indeed, avoiding stimuli depicting sedentary behaviors triggered larger evoked-related potentials in the medial frontal cortex and frontocentral cortex, which are related to conflict monitoring and inhibition, respectively (Cheval, Tipura, et al., 2018). Consistent with the idea that sedentary behaviors are difficult to avoid (Cheval et al., 2020; Cheval, Sarrazin, et al., 2017), these results suggest that approach-avoidance tendencies could play an important role in the regulation of sedentary behaviors. However, no study has yet assessed the association between automatic approach-avoidance tendencies and sedentary behaviors.

Importantly, previous studies rarely distinguished between leisure-time and working-time sedentary behaviors (Conroy et al., 2013; Maher & Conroy, 2015, 2016; Maher & Dunton, 2019). This lack of distinction is understandable in older populations who are retired (Maher & Conroy, 2016; Maher & Dunton, 2019), but is questionable among active adults (Conroy et al., 2013; Maher & Conroy, 2015). Students and workers may hardly control the time spent in sedentary behaviors in the workplace or at the university because such contexts often constrain to engage in prolonged sitting activities (Saidj et al., 2015; Vandelanotte et al., 2013). In this line, while specific motivational precursors are expected to drive leisure-time sedentary behaviors (Owen et al., 2011), previous work may have blurred such associations by merging leisure time and working time. Moreover, as theorized by socioecological models (Owen et al., 2011), other variables, related to the individual and one's environment, could also contribute to better explain sedentary behaviors.

Explaining sedentary behaviors through socioecological models

Socioecological models are based on the premise that behaviors are jointly driven by multiple determinants (Glass & McAtee, 2006). These variables can be classified as intrapersonal, interpersonal, and environmental factors (O'Donoghue et al., 2016). Intrapersonal variables refer to demographic (e.g., gender, age) and physical factors (e.g., body mass index), as well as motivational and socio-professional factors (e.g., time spent at work). Interpersonal variables include familial determinants, such as, the number of children. Alongside with built environmental determinants (e.g., accessibility to facilities), natural environmental factors can refer, to the days of the week or to weather conditions. Hence, far from competing with models focusing on motivational variables, the socioecological model integrates the aforementioned motivational precursors by considering individuals as actors amidst broader networks (Rhodes et al., 2019; Sniehotta et al., 2017).

To date, the application of the socioecological models to sedentary behaviors has mainly focused on demographic and physical precursors (see Chastin et al., 2015; O'Donoghue et al., 2016; Rhodes et al., 2012 for reviews). For example, being a male, older (e.g., Saidj et al., 2015), or having a greater BMI (e.g., Vandelanotte et al., 2009) were associated with higher time spent in sedentary behaviors. However, results were mixed regarding the influence of socio-professional variables on leisure-time sedentary behaviors. In line with the idea than an increase in energy expenditure may be subsequently compensated by the engagement in sedentary behaviors (Melanson, 2017), previous work revealed that greater time spent at work were associated with higher leisure-time sedentary behaviors (e.g., Stamatakis et al., 2014). However, other studies did not reveal such relationship (Tigbe et al., 2011; Vandelanotte et al., 2013). Regarding interpersonal variables, having less children was associated with higher time spent in sedentary behaviors during leisure time (Van Uffelen et al., 2012). For environmental variables, higher leisure-time spent in time sedentary behaviors was observed on weekend days (Thorp et al., 2012), and on cloudy and rainy days (Chan & Ryan, 2009).

While the socioecological model emphasizes the importance to map these different levels of influence on sedentary behaviors, previous work has mostly examined these variables in isolation (Buck et al., 2019; De Craemer et al., 2018). Although studies have jointly investigated the effects of motivational precursors with others variables (e.g., sex, body mass index, day of the week; e.g., Conroy et al., 2013), no study has yet integrated socio-professional, interpersonal, and environmental factors alongside with controlled and automatic motivational variables to predict leisure-time sedentary behaviors. Importantly, recent findings suggested that demographic, physical, socio-professional, interpersonal, and environmental factors could exert a greater influence on sedentary behaviors than motivational variables (Buck et al., 2019). However, no study has directly compared the predictive validity of these variables within the same sample.

The current study: an integrative approach

The current study aimed to investigate the predictive validity of motivational (controlled and automatic), demographic, physical, socio-professional, interpersonal, and environmental precursors of leisure-time sedentary behaviors. Therefore, this study provides an integrative approach contributing to provide a better understanding of the relative weight of motivational precursors in the regulation of sedentary behaviors (Figure 1). To this end, 135 healthy workers' leisure-time sedentary

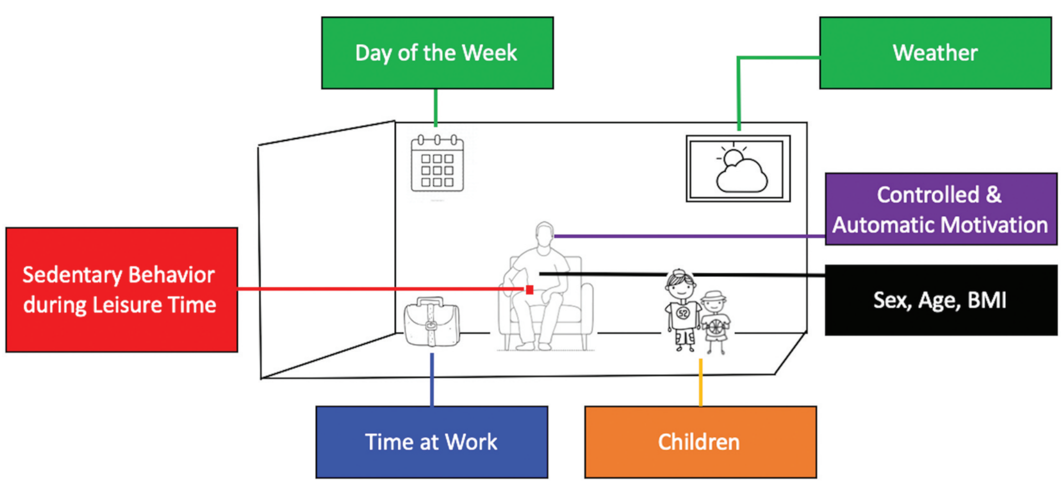

Figure 1. Predictive variables and outcome included in the mixed effects models. *Note*. Outcome (red), motivational (purple), demographic (black), physical (black), socio-professional (blue), interpersonal (orange), and environmental (green) variables used in this study. Controlled motivational variables included intentions and competence. Automatic motivational variables included habit strength and approach-avoidance tendencies. BMI: body mass index.

behaviors were monitored for one week using an accelerometer and associations with[1] aforementioned precursors were examined.

We hypothesized that both controlled and automatic motivational determinants predict leisure-time sedentary behaviors (H1). Specifically, higher controlled (H1a) (i.e., intention, perceived competence) and automatic (H1b) (i.e., habit strength and approach-avoidance tendencies) motivation to reduce sedentary behaviors and to be physically active should negatively predict leisure-time sedentary behaviors. We also expected that demographic, physical, socio-professional, interpersonal, and environmental variables should predict leisure-time sedentary behaviors (H2). Finally, we compared the strength of the associations between these variables and leisure-time sedentary behaviors. We did not formulate an priori hypothesis on the relative weight of these precursors, although recent work suggests that the association between motivational precursors and leisure-time sedentary behaviors may be weaker than associations with the other variables (Buck et al., 2019).

Methods

Participants and procedure

Sample size was initially estimated to ensure sufficient power to detect effect in another study (Cheval et al., 2015). Details about the sample size estimation can be found in this study (Cheval et al., 2015). In the present work, we used G*Power 3.1.9.4 (Faul et al., 2007) to determine post-hoc achieved power, for a multiple linear regression including 13 independent variables. We assumed a small effect size (Cohen'd ~ .25) and input the number of participants recruited for Cheval et al.'s (2015) study (N = 135). Results indicated that, in our study, achieved power was > 95% with an $\alpha < .05$.

Participants were recruited from local tertiary sector companies. The study was conducted in May and June 2013. Inclusion criteria were an age > 18 years and to be willing to participate in a laboratory session and to wear an accelerometer for one week. Participants were excluded if they had a physical impairment that constrained them to engage in excessive sedentary behaviors or if they were receiving treatment for a psychiatric disorder.

First, 135 working adults completed a computerized reaction-time task. Participants were seated in quite room in front of a computer to complete a computerized reaction-time task. After the task, they filled out a short questionnaire assessing their intention to reduce sedentary behaviors, their intention to be physically active, their perceived competence to adopt a more active lifestyle, and their habit strength toward sedentary behaviors and physical activity. Participants' height and weight were also measured. Finally, each participant received an accelerometer and was instructed on how and when to wear it. They also received a notebook and were asked to fill it in for the next seven days. At the end of each day, participants were invited to indicate the time at which they woke up, put the accelerometer on their hip, arrived at their workplace, quit their workplace, removed the accelerometer (e.g., to take a shower), and went to bed. Participants were also asked to indicate whether they felt ill or injured during the monitoring period. Daily weather conditions, day of the week, and day in the monitoring sequence were also collected over the course of the week. Eight days later, participants gave back their accelerometer and their notebook, and were debriefed. Participants gave written informed consent prior to participation and the Research Ethics Committee of the university supporting this study approved this research and informed consent process.

Measures

Device-based measure of sedentary behaviors during leisure time

A three-axis accelerometer (Actigraph GT3X+; Pensacola, USA) was used to quantify sedentary behaviors for seven days in free-living conditions. When data met the inclusion, criteria listed below, the eighth day of wear (i.e., when participants came back to the laboratory), was included in the analyses. One-minute epochs were used for data analyses and non-wear time was defined as ≥ 59 consecutive minutes of zero counts. Daily data were included if they met two conditions: a wear time ≥ ten waking hours per day (Evenson & Terry, 2009) and a wear time during leisure time four hours or ≥ 75% of the average reported leisure-time (Gupta et al., 2016; Lund Rasmussen et al., 2019). Leisure-time included two periods: i) between the time the accelerometer was placed on the hip and the time participants arrived at their workplace; ii) between the time participants left their

[1]A previous version of this manuscript included affective and instrumental attitudes toward sedentary behaviors and physical activity as predictors. These variables were removed from the analysis as affective and instrumental attitudes showed low internal consistency ($\alpha s < .58$) and are not considered as the most proximal motivational precursors of behaviors. Moderate-to-vigorous physical activity at work (at both the within- and between levels) was also initially included in the analysis. These variables were also removed from the analysis as our sample was composed adults working in the tertiary sector, in which physical activity levels have been shown to be particularly low—here the mean percentage of moderate-to vigorous physical activity at work was M = 2.46 ± 3.61%.

workplace and the time they went to bed. Working time was the duration between the time participants arrived at and left their workplace. Data were included if four days met the aforementioned conditions and included one weekend day (Matthews et al., 2012). Of 1080 possible days, 786 were included in the study (Figure 2), leading to a final sample of 125 participants. Time spent in sedentary behaviors was determined through previously validated cut-points (i.e., 0 to 100 counts/min) (Freedson et al., 1998). To standardize for differences in leisure time between and within participants, the dependent variable was the daily percentage of leisure time spent in sedentary behaviors (Healy et al., 2011). This variable was obtained by dividing the leisure-time spent in sedentary behaviors by total daily leisure-time.

Controlled and automatic motivational precursors

Intentions to reduce sedentary behaviors and to be physically active. Intention to reduce sedentary behaviors was assessed using the following two items: *During the next two weeks, I intend to spend no more than four hours in sedentary behaviors a day during my leisure-time* and *During the next two weeks, I am determined to spend no more than four hours in sedentary behaviors a day during my leisure-time* (Conroy et al., 2013; Rhodes & Rebar, 2017). Respondents answered each item on a scale ranging from one (*very unlikely*) to seven (*very likely*). The items were averaged to create an overall measure of intention to reduce sedentary behaviors (Cronbach' α = .91). Although no scientific guidelines were currently established in terms of recommended sedentary levels (Stamatakis et al., 2019), the four-hour threshold was selected because this duration was thought to represent a challenging but realistic goal for adults. Subsequent studies suggested that this threshold was appropriate for this population (Conroy et al., 2013; Saidj et al., 2015).

Intention to be physically active were assessed using the following two items: *I intend to carry out at least 30 minutes moderate-to-vigorous physical activity per day on five or more days of the week* and *I am determined to carry out at least 30 minutes moderate-to-vigorous physical activity per day on five or more days of the week*. Respondents answered each item on a scale ranging from 1 (*very unlikely*) to 7 (*very likely*). The items were averaged to create an overall measure of intention to be physically active (Cronbach' α = .95).

Perceived competence to adopt an active lifestyle. Perceived competence was captured using the five items of the competence subscale of the Needs Satisfaction-Thwarting Scale (Cheval, Chalabaev, et al., 2017). Specifically, each item began with "In terms of physical activity … " and was completed by five statements (e.g.,

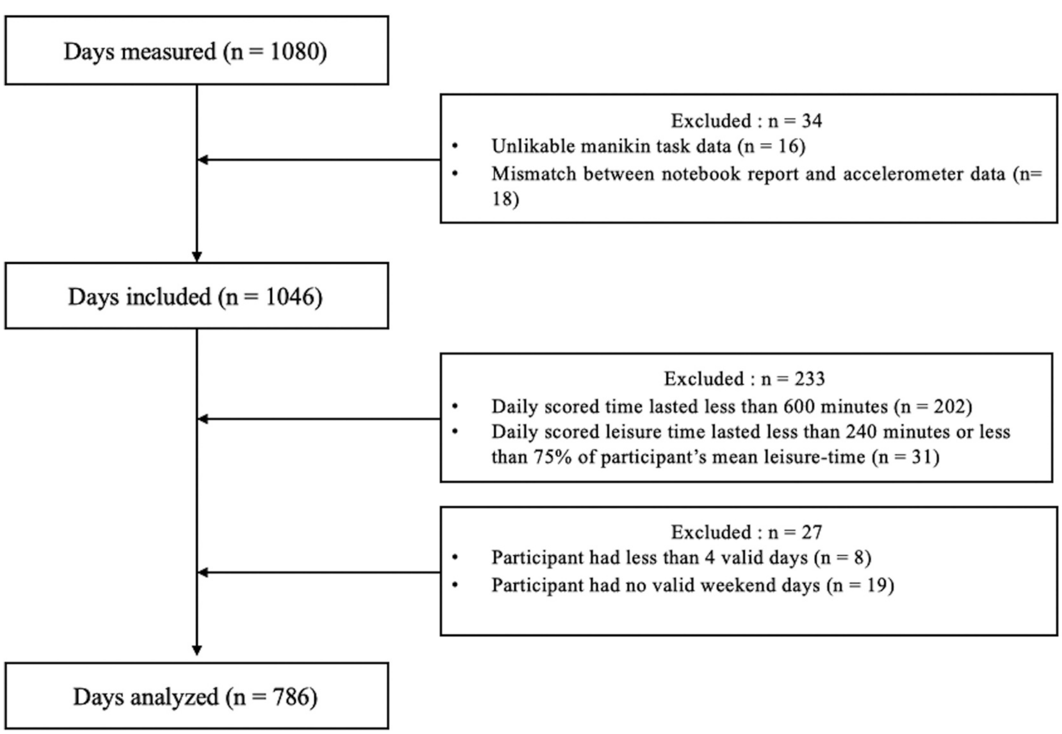

Figure 2. Flow diagram.

I feel capable (vs. incapable) of meeting up recommendations in terms of physical activity). Respondents answered each item on a seven-point scale (Cronbach' α = .85).

Habit strength toward sedentary behaviors and physical activity. Habit strength toward sedentary behaviors and toward physical activity were both assessed using the four-item automaticity subscale of the Self-Reported Habit Index (Gardner et al., 2012; Verplanken & Orbell, 2003). Items began with the proposition: *In general, the decision to engage in sedentary behavior/physical activity is something that* . . . and was completed by four statements (e.g., *I do automatically*). Participants answered on a Likert scale ranging from one (*Strongly disagree*) to seven (*Strongly agree*). Items were, respectively, averaged for sedentary behaviors (Cronbach' α = .91) and physical activity (Cronbach' α = .95).

Approach-avoidance tendencies toward physical activity and sedentary behaviors. The automatic approach-avoidance tendencies toward sedentary behaviors and toward physical activity were assessed using a manikin task (Krieglmeyer & Deutsch, 2010) (see Cheval et al., 2015 for a detailed description). As recommended by Krieglmeyer and Deutsch (2010), incorrect responses as well as responses below 150 ms and above 1,500 ms were excluded. The automatic tendency to approach sedentary behaviors was calculated by subtracting the median reaction time when approaching sedentary stimuli from the median reaction time when avoiding sedentary stimuli—a higher score indicating a higher tendency to approach (vs. avoid) sedentary stimuli. The same logic was applied to calculate the automatic approach tendency toward physical activity. The manikin task is a reliable and well-validated measure of automatic approach-avoidance tendencies toward various behaviors (Krieglmeyer & Deutsch, 2010), including physical activity (Cheval et al., 2014, 2015; Zenko & Ekkekakis, 2019). For example, studies showed that automatic approach-avoidance tendencies toward physical activity and sedentary behavior prospectively predicted involvement in a non-volitional physical activity (i.e., spontaneous strength invested in a handheld dynamometer; Cheval et al., 2014) and engagement in device-based measures (i.e., accelerometer) of moderate-to-vigorous leisure time physical activity over 1 week (Cheval et al., 2015). In our study, reliability was good, with α = .84 and α = .82 for sedentary behaviors and physical activity, respectively. Two participants were excluded from the study because they demonstrated extreme scores (i.e., more than four standard deviations away from the sample mean, which consists into a commonly used threshold to detect outliers, Cousineau & Chartier, 2010).

Demographic, physical, socio-professional, interpersonal and environmental precursors

Sex and age were included as demographic variables. Participants were invited to indicate their sex (i.e., woman vs. man) and their age (years). Body mass index was added as a physical variable and was obtained by measuring the height (cm) and weight (kg) of participants during the laboratory session. Finally, number of children was assessed by questionnaire and included as an interpersonal precursor.

Time spent at work. Time spent at work, expressed in minutes, was computed on the basis of notebook reports. This variable had two levels: an average between-person level, centered on the average value of the sample, and a daily within-person level, centered on the average value of each participant. This bidimensional approach accounted for both inter-individual differences in time at work and intra-individual changes across monitoring days for a given participant.

Days of the week. Days of the week were dummy coded. Saturdays served as the reference category as the lowest levels of leisure time sedentary were observed on this day (Table S2).

Daily weather conditions. Daily weather conditions were obtained over the study period from the website MeteoFrance.com and coded by a research assistant. Three levels were created: sunny, cloudy, or rainy. Sunny days served as the reference category because the lowest levels of leisure-time sedentary behaviors were observed on these days (Table S2).

Confounding variables

Illness or injury were added as a confounding variable because they were a potential source of higher time spent in sedentary behaviors (Maher & Conroy, 2016). Based upon participants' notebook, a dichotomous variable was coded (1 for people who reported an illness or an injury; 2 for people who did not report any illness or injury). Finally, *day in the monitoring sequence* was included as a confounding variable as self-monitoring procedures have been shown to influence sedentary behaviors across days of wear (Motl et al., 2012).

Statistical analyses

Associations of predictors with the percentage of leisure-time spent in sedentary behaviors were analyzed using mixed-effects models. This approach allows to account for the nested structure of the data (here, multiple observations within a single participant). Moreover, mixed-effects models do not require an equal number of observations from all participants and increases power compared with traditional approaches, such as linear regressions (Boisgontier & Cheval, 2016; Judd et al., 2017). All models had random intercepts for participants and random slopes were added for all the time-varying variables (Frossard & Renaud, 2019).

First, we estimated a base model (M0), which tested the associations between the confounding variables (i.e., day in the monitoring sequence, and illness or injury) and leisure-time sedentary behaviors. All the subsequent models were adjusted for these confounders. In a first set of models (Ms1), we separately added each controlled and automatic motivational variable to M0. This “one-by-one” strategy was used to account for the substantial shared variance between some of these constructs (Table S2). In a second set of models (Ms2), we separately added each demographic and physical variable to M0. In a third set of models (Ms3), we added socio-professional variables to M0. This set of models Ms3 was adjusted for the day of the week as socio-professional variables and days of the week were closely related (Table S2). In a fourth model (M4), we added interpersonal variables (i.e., number of children). In a fifth set of models (Ms5), we separately added environmental variables. Variables which were significantly associated with leisure-time sedentary behaviors in Ms1, Ms2, Ms3, M4 and Ms5 were identified on the basis of the p-value ($p < .05$) and were gathered in a last parsimonious final model (M6).[2] To examine whether the different variables included contributed to improve the fit of the final model M6, this final model was tested against models in which the variables of interest were removed. Variables which increased the fit of the models were identified on the basis of the Bayesian Information Criterion (BIC), −2-log-likehood (−2LL) and p-values (Bollen et al., 2014). All models were estimated using the lme4 and lmerTest packages in the R software (Bates et al., 2015; Kuznetsova et al., 2015). An estimate of the effect size for fixed effects was reported using the marginal pseudo-R^2, computed using the MuMin package (Barton, 2009). Statistical assumptions associated with mixed models were checked (including normality of the residuals, homogeneity of variance, multicollinearity, and undue influence) and met for all the models.

Results

Descriptive results are presented in Table 1. The final sample included 125 adults (age = 40 ± 9 years; body mass index = 24 ± 4; 75 women; 74% with at least one child). The average percentage of sedentary behaviors during leisure time was 58 ± 12%, corresponding to 5 h 38 min ± 2 h 21 min per day.

Confounding variables and sedentary behaviors (M0)

Absence of injury/illness during the monitoring sequence was associated with lower leisure-time sedentary behaviors (b = 8.152, 95% confidence interval (95 CI) = [2.457; 13.856], $p = .006$). However, position of the day in the monitoring period was not related with sedentary behaviors during leisure time ($p = .474$). This model explained 3.0% of the variance in leisure-time sedentary behaviors.

Motivational precursors and sedentary behaviors (Ms1)

For controlled motivational variables, intention to be physically active was negatively associated with leisure-time spent sedentary behaviors (b = −1.089, 95 CI = [−2.048; 0.127], $p = .028$). Moreover, a marginal negative association of perceived competence (b = −1.251, 95 CI = [−2.543; 0.041], $p = .061$) with leisure-time spent sedentary behaviors was observed.

For automatic motivational variables, habit strength toward physical activity was negatively associated with leisure-time sedentary behaviors (b = −0.943, 95 CI = [−1.712; −0.168], $p = .019$). In addition, a marginal association between habit strength toward sedentary behaviors and leisure-time sedentary behaviors (b = 0.793, 95 CI = [−0.134; 1.720], $p = .098$) was observed. In contrast, automatic approach-avoidance tendencies toward sedentary behaviors or physical were not associated with leisure-time sedentary behaviors ($ps > .345$).

[2]The influence of the precursors that were marginally associated ($p < .100$) with leisure-time sedentary behaviors was tested in a parsimonious model (M7). Results of M7 are presented in supplemental material (Table S4).

Table 1. Descriptive statistics and results of the mixed models testing the association between each variable and leisure-time sedentary behaviors.

	Descriptive statistics		Mixed models			
Variables	Mean ± SD	Range	b [95% CI]	SE	*p*	R^2
Model 0: Confounding variables						
Day in the monitoring sequence	–	–	0.127 [−0.220; 0.476]	0.177	.474	.030
Illness and injury (%)	8	–	8.152 [2.457; 13.856]	2.909	.006**	
Models 1: Controlled motivational variables						
Intention toward SB	4.32 ± 1.57	1.00–6.00	−0.617 [−1.621; 0.390]	0.513	.231	.035
Intention toward PA	4.09 ± 1.62	1.00–6.00	−1.089 [−2.048; −0.127]	0.489	.028*	.047
Perceived competence	5.06 ± 1.18	1.40–7.00	−1.251 [−2.543; 0.0413]	0.662	.061^	.042
Models 1: Automatic motivational variables						
Habit strength toward SB	4.18 ± 1.64	1.00–7.00	0.793 [−0.135; 1.720]	0.475	.098^	.041
Habit strength toward PA	3.97 ± 1.96	1.00–7.00	−0.940 [−1.712; −0.168]	0.476	.019*	.051
Approach-avoidance tendencies toward SB	−109.61 ± 227.78	−964.5–335.5	0.003 [−0.003; 0.010]	0.003	.345	.033
Approach-avoidance tendencies toward PA	28.72 ± 216.41	−961.5–469.0	0.003 [−0.004; 0.010]	0.004	.471	.031
Models 2: Demographic and physical variables						
Sex (% of men)	40	–	5.043 [1.935; 8.147]	1.591	.002**	.066
Age	39.74 ± 8.78	22–57	−0.128 [−0.301; 0.050]	0.090	.159	.037
Body mass index	24.00 ± 4.05	17.22–41.14	0.493 [0.117; 0.866]	0.191	.011*	.054
Models 3: Socio-professional variables						
Time at work (in min)						
Between-person level	228.80 ± 76.91	32.67–469.62	0.164 [−0.852; 1.179]	0.656	.752	.049
Within-person level	0.00 ± 248.61	−469.62–529.83	1.861 [0.578; 3.141]	0.519	.005**	
Model 4: Interpersonal variables						
Number of children	1.540 ± 1.230	0–6	−2.0371 [−3.264; −0.811]	0.625	.002**	.068
Models 5: Environmental variables						
Day of the week	–	–	14.146		.028	.040
Monday (% of all days)	15.013	–	2.937 [0.466; 5.405]	1.263	.020*	
Tuesday (% of all days)	12.214	–	1.980 [−0.593; 4.570]	1.321	.133	
Wednesday (% of all days)	14.885	–	0.934 [−1.513; 3.375]	1.249	.455	
Thursday (% of all days)	13.359	–	1.401 [−1.119; 3.922]	1.291	.278	
Friday (% of total days)	14.758	–	2.719 [0.291; 5.12]	1.244	.029*	
Saturday (% of all days)	14.758	–	reference			
Sunday (% of all days)	15.013	–	4.087 [1.658; 6.514]	1.242	.001**	
Weather conditions			21.96		< .001***	.047
Sunny (% of all days)	67.812	–	reference			
Cloudy (% of all days)	19.466	–	2.586 [0.612; 4.560]	1.007	.012	
Rainy (% of all days)	10.178	–	4.949 [2.613; 7.285]	1.192	< .001***	

Mean, standard-deviation (SD) and range are reported for continuous variables. Percentage of occurrences over the monitoring sequence are reported for categorical variables. Each predictive variable was entered one-by-one, with the exception of socio-professional variables. All models were adjusted for confounding variables. Saturday and sunny days served as the reference for day of the week and daily weather conditions, respectively. Coefficients b, 95% confidence interval [95% CI], standard-error (SE), *p*-value (p), pseudo-R^2 for fixed effects (R^2). Women = 1, men = 2; Absence of illness and injury = 1, Illness or injury = 2; ^: $p < .10$; *: $p < .05$; **: $p < .01$; ***: $p < .001$

Demographic, physical, socio-professional, interpersonal, and environmental precursors and sedentary behaviors (Ms2, Ms3, M4, Ms5)

For demographic and physical variables (Ms2), men (vs. women) (b = 5.043, 95 CI = [1.935; 8.147], $p = .002$) and higher body mass index (b = 0.493, 95 CI = [0.117; 0.866], $p = .011$) were associated with higher time spent in sedentary behaviors during leisure time (Table 1). Age was not associated with the dependent variable ($p = .159$).

Regarding socio-professional variables (Ms3), time at work at the within-person level (b = 1.861, 95 CI [0.578; 3.141], $p = .005$) was associated with leisure-time sedentary behaviors.

For interpersonal variables (M4), number of children (b = −2.037, 95 CI = [−3.264; −0.811], $p = .002$) was negatively associated with leisure-time sedentary behaviors.

Regarding environmental variables (Ms5), the day of the week was associated with leisure-time sedentary behaviors (p for global effect = .028). Compared to Saturdays, leisure-time sedentary behaviors were higher on Mondays (b = 2.937, 95 CI = [0.466; 5.405], $p = .020$), Fridays (b = 2.719, 95 CI = [0.291; 5.152], $p = .029$) and Sundays (b = 4.087, 95 CI = [1.658; 6.514], $p = .001$). Daily weather conditions were also associated with leisure-time sedentary behaviors (p for global effect < .001). Compared to sunny days, leisure-time sedentary behaviors were higher on cloudy days (b = 2.586, 95 CI = [0.612; 4.560], $p = .012$) and rainy days (b = 4.949, 95 CI = [2.613; 7.285], $p < .001$).

Table 2. Final model M6 gathering significant predictive variables of leisure-time sedentary behaviors during leisure time.

Fixed effects	b [95 CI]	SE	p
Motivational variables			
Intention toward PA	−0.370 [−1.560; 0.833]	0.629	.557
Habit strength toward PA	−0.558 [−1.525; 0.400]	0.506	.272
Demographic and physical variables			
Sex[a]	3.833 [0.875; 6.793]	1.554	.015*
Body mass index	0.304 [−0.064; 0.672]	0.193	.118
Socio-professional variables			
Time at work (within-person level)	1.743 [0.548; 2.943]	0.616	.005*
Interpersonal variables			
Number of children	−1.894 [−3.017; −0.777]	0.589	.002**
Environmental variables			
Day of the week			
Saturdays		reference	
Mondays	−0.831 [−3.873; 2.209]	1.561	.595
Tuesdays	−1.541 [−4.602; 1.493]	1.566	.325
Wednesdays	−1.671 [−4.473; 1.101]	1.431	.243
Thursdays	−3.622 [−6.923; −0.353]	1.688	.032*
Fridays	−0.267 [−3.014; 2.469]	1.410	.850
Sundays	2.508 [0.005; 5.009]	1.284	.050
Daily weather conditions			
Sunny days		reference	
Cloudy days	3.031 [0.867; 5.239]	1.125	.007**
Rainy days	3.984 [1.369; 6.563]	1.334	.003**
Confounding variables			
Day in the monitoring sequence	−0.065 [−0.422; 0.294]	0.184	.724
Illness or injury[b]	4.692 [−10.018; 0.673]	2.808	.097^
Random Effects			
Subjects			
Sunny days	46.221		
Rainy days	63.786		
Cloudy days	30.972		
Leisure time	7.790		
Day in the monitoring sequence	0.170		
Residuals	75.242		
Pseudo-R^2	0.158		

The final parsimonious model included only the significant predictors of the first models (Table 1) and confounding variables. Saturday and sunny days served as the reference for day of the week and daily weather conditions, respectively. Day of the week was not entered as a random effect as the number of random effects to estimate was higher than the number of observations. Coefficients b, 95% confidence interval (95 CI), standard-error (SE), *p*-value (*p*), and pseudo-R^2 for fixed effects are reported. [a]Women = 1, men = 2; [b]Absence of illness and injury = 1, Illness or injury = 2; PA = Physical Activity; ^: $p < .10$; *: $p < .05$; **: $p < .01$; ***: $p < .001$.

Motivational, demographic, physical, socio-professional, interpersonal, and environmental precursors and sedentary behaviors

The full final model (M6) included the following variables: injury/illness, day in the monitoring sequence, intention to be physically active, habit strength toward physical activity, sex, body mass index, time at work, number of children, day of the week, and daily weather conditions (Table 2) (Figure 3). Sex (b = 3.833, 95 CI = [0.875; 6.793], $p = .015$), time spent at work (b = 1.743, 95 CI = [0.548; 2.943), $p = .005$), number of children (b = −1.894, 95 CI = [−3.017; −0.777], $p = .002$), daily weather conditions (b = 3.031, 95 CI = [0.867; 5.239], $p = .007$ for cloudy days, b = 3.984, 95 CI = [1.369; 6.563], $p = .003$ for rainy days), and day of the week ($p = .027$ for global effect, b = −3.622, 95 CI = [−6.923; −0.353], $p = .032$ for Thursdays, b = 2.508, 95 CI = [0.005; 5.009] $p = .050$ for Sundays) remained associated with leisure-time sedentary behaviors. Injury or illness was marginally associated with leisure-time sedentary behaviors (b = 4.692, 95 CI [0.673; 10.018], $p = .097$). Finally, intention to be physically active, habit strength toward physical activity, and body mass index were no longer associated with leisure-time sedentary behaviors (*ps* > .118).

Comparisons of models showed that motivational variables entered in the final model (BIC = 6069.000, −2LL = −2944.500, $\chi^2 = 558.810$, $p < .001$) did not contribute to improve the fit of the model (ΔBIC = 8.800, Δ-2LL = 2.300, $\chi^2 = 4.556$, $p = .102$). By contrast, demographic and physical variables (ΔBIC = 1.500, Δ-2LL = 5.900, $\Delta\chi^2 = 11.814$, $p = .003$) as well as socio-professional (ΔBIC = −8.900, Δ-2LL = 11.100, $\Delta\chi^2 = 22.163$, $p < .001$), interpersonal (ΔBIC = −3.800, Δ-2LL = 5.200, $\Delta\chi^2 = 10.410$, $p = .001$), and environmental

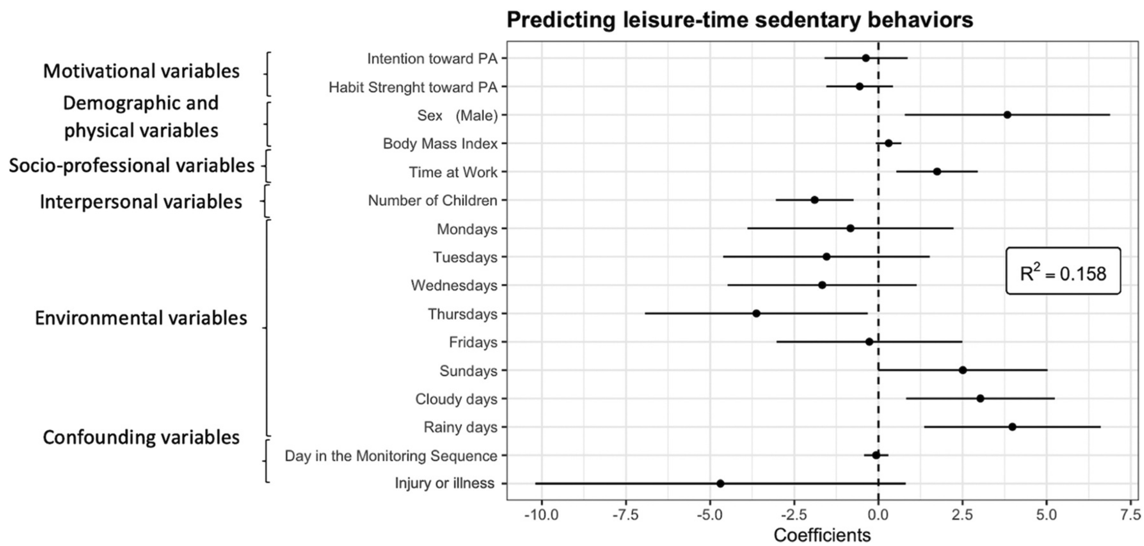

Figure 3. Associations of variables entered in the full final model (M6) with leisure-time sedentary behaviors. *Note*. Coefficients b and 95% confidence interval are reported. Women, Saturdays, and presence of injury or illness served as references for sex, day of the week, and illness or injury, respectively.

variables (ΔBIC = 58.000, Δ-2LL = 21.000, $\Delta\chi^2$ = 41.999, $p < .001$) improved the fit of the final model.

Fixed effects entered in the full final model M5 explained 15.8% of the variance in leisure-time sedentary behaviors. Demographic and physical, interpersonal, and environmental variables explained the higher part of variance with, 3.5%, 3.5% and 2.7%, respectively. Motivational and socio-professional precursors accounted for 1.2% and 0.6% of explained variance.

Discussion

This study investigated the predictive validity of motivational (controlled and automatic), demographic, physical, socio-professional, interpersonal, and environmental precursors of daily leisure time spent in sedentary behaviors. Findings suggested weak predictive validity of motivational variables relative to demographic, physical, interpersonal, and environmental determinants. Hence, our study supports previous work suggesting a limited influence of motivational variables on sedentary behaviors (Buck et al., 2019).

Comparison with previous studies

Contrary to hypothesis H1a, controlled motivational variables toward sedentary behaviors were not related to leisure-time sedentary behaviors. This result contrasts with previous literature showing an association of intention to reduce sedentary behaviors with leisure-time sedentary behaviors (Rollo et al., 2016). This discrepancy could be explained by differences in the measurement method. Our measure of the intention to reduce sedentary behaviors was derived from a time threshold (i.e., spending no more than four sedentary behaviors a day during leisure time). Yet, such global estimation may not represent an organizing target for the regulation of individuals' behaviors because sitting activities are hardly mentally represented (Gardner et al., 2019). Nonetheless, this non-significant association between the overall intention to reduce sedentary behaviors and leisure-time sedentary behaviors was already observed in previous work (Maher & Conroy, 2016; Maher & Dunton, 2019), thereby pointing out that intention may not be sufficient to reduce sedentary behaviors. In this line, volitional strategies, such as action planning and coping planning (Gollwitzer & Sheeran, 2006; Schwarzer, 2008) could play an important role in bridging the gap between intention and behaviors (Rollo & Prapavessis, 2020; Sui & Prapavessis, 2018).

Consistent with hypothesis H1a and previous research (Rollo et al., 2016), controlled motivational variables toward physical activity were negatively associated with leisure-time sedentary behaviors. Although only the association with intention was significant, these findings emphasize that controlled motivational precursors toward physical activity exert a protective, though limited, effect against the accumulation of leisure-time sedentary behaviors. This result can be accounted by a displacement effect (Rhodes & Blanchard, 2011), suggesting that a desire for one activity, such as physical activity, will take away time spent in a competing activity, such as sedentary behaviors. Indeed, previous work evidenced a weak-to-moderate inverse association between time spent physical activity and in sedentary behaviors (Mansoubi et al., 2014). This rational is in accordance with the dual-hinge approach (Spence et al., 2017), explaining that the reduction in leisure-time sedentary behaviors implies their substitution by more physically active behaviors, even the lightest ones, such as standing or walking slowly (Prince et al., 2014). Therefore, motivation toward more physically active behaviors can be conceived as important adjuvants in the reduction of sedentary behaviors.

In line with hypothesis H1b and previous literature (Conroy et al., 2013; Maher & Conroy, 2015, 2016; Maher & Dunton, 2019), higher habit strength toward sedentary behaviors was marginally associated with higher leisure-time sedentary behaviors. Moreover, consistent with the displacement effect (Rhodes & Blanchard, 2011), higher habit strength toward physical activity was associated with lower leisure-time sedentary behaviors. Finally, automatic approach-avoidance tendencies and leisure-time sedentary behaviors were not associated. This finding may suggest that, when assessed using reaction-time tasks specifically designed to capture automatic reactions (Hagger, 2020; Rebar et al., 2018), automatic motivational variables can harldy explain sedentary behaviors.

Anchored within the socioecological framework (Owen et al., 2011), the present work revealed that demographic, physical, socio-professional, interpersonal and environmental variables were associated with leisure time spent in sedentary behaviors (H2). As evidenced by previous research (O'Donoghue et al., 2016), men and individuals with higher body mass index exhibited higher leisure-time sedentary behaviors. Regarding socio-professional variables, the results showing that sedentary behaviors during leisure time were higher on days in which individuals spent more time at work than usual is in line with previous work (Stamatakis et al., 2014). These results suggest that engaging in sedentary behaviors can serve as a way to rest after a demanding working day (Rawlings et al., 2019). The observation that leisure-time sedentary behaviors was higher on Sundays, a day usually devoted to the recovering of energy (Thorp et al., 2012), provide additional support for this idea. Regarding interpersonal precursors, as already evidenced (see O'Donoghue et al., 2016 for a review), individuals with a higher number of children engaged in less leisure-time sedentary behaviors, suggesting that family commitment could protect from engaging in excessive sedentary behaviors. Moreover, for environmental factors, in comparison with sunny days, leisure-time sedentary behaviors were higher on cloudy and rainy days, underlining that natural environmental settings can represent an important barrier in reducing sedentary behaviors (Chan & Ryan, 2009).

This study revealed that, in comparison with demographic and physical, socio-professional, interpersonal and environmental factors, motivational precursors explained only a weak proportion of leisure-time sedentary behaviors. Importantly, motivational precursors were no longer associated with sedentary behaviors once the other variables were included in the models.[3] These results suggest a weak, marginal, effect of motivational precursors on sedentary behaviors. At the theoretical level, these findings echo a recent theory contending that humans are automatically attracted to effort minimization (Cheval, Radel, et al., 2018; Cheval, Sarrazin, et al., 2017). This attraction may explain why sedentary behaviors are difficult to avoid (Cheval et al., 2020; Cheval, Tipura, et al., 2018) and why motivational precursors alone can hardly prevent engagement in sedentary behaviors. In this view, environmental interventions (e.g., nudges) have proven to be more effective in reducing sedentary behaviors than interventions targeting motivational variables (Blackburn et al., 2020; Gardner et al., 2016).

Of note, as suggested by the socioecological framework (Owen et al., 2011), sedentary behaviors are thought to be influenced by complex interactions between the multiple strata of precursors. In this line, studies suggested that demographic and socioeconomic factors (e.g., age, gender, education, or income) can be associated with physical activity through their influence on socioeconomic variables such as intentions (Hagger & Hamilton, 2020). Likewise, environmental factors, such as neighborhood conditions, can hinder or facilitate the implementation of physical activity, but these effects are influenced by cognition ressources or motivation (Cheval et al., 2019; Rhodes et al., 2006). The same reasoning could be applied to sedentary behaviors. Future large-scale studies should examine how different predictors are linked together (i.e., moderation and mediation) to explain the regulation of leisure-time sedentary behaviors. Such studies would contribute to identify for whom and under what

[3]When controlling for demographic, physical, socio-professional, interpersonal, and environmental variables, motivational precursors that were marginally associated with the leisure-time sedentary behaviors (i.e., competence and habit strength toward sedentary behaviors) were no longer associated with leisure-time sedentary behavior in the parsimonious model M7 (*ps*. > .382) (Table S4).

circumstances an intervention aiming to promote an active lifestyle can be the most effective.

Strengths and limitations

The present study includes the following strengths. First, we assessed and compared a broad range of potential precursors of leisure-time sedentary behaviors. Then, we used a refined statistical analysis suited to examine daily-basis associations. However, several limitations should be considered. First, our findings should be interpreted with caution as, unlike previous studies (e.g., Maher & Dunton, 2019), our study did not assess the daily (or hourly) fluctuations in motivational variables. This feature may explain the weak associations observed in the current study (Rebar et al., 2020). Second, leisure-time sedentary behaviors were evaluated using the Actigraph GT3X+. Yet, in comparison with the ActivPal, this device has been shown to overestimate sedentary behaviors (Migueles et al., 2017). Third, leisure time and working time were identified thanks to notebooks reports, which may have led to approximative segmentation of these periods. Combining accelerometric measurement with global-positioning systems (GPS) could enable future research to refine the identification of the context in which sedentary behaviors occur (Jankowska et al., 2015). Then, we have focused our analyses on the percentage of leisure time spent in sedentary behaviors. However, although this approach ensures that the scores are comparable both within and between participants, it does not allow to prevent the undue influence of the overall amount of leisure time on the results observed. For example, spending 20% of the leisure time in sedentary behaviors is not equivalent if individuals have 8 hours vs. 2 hours of leisure time on that day (i.e., 96 minutes vs. 24 minutes). Hence, we ran supplementary analyses in which we predicted leisure-time spent in sedentary behaviors in their raw metric (i.e., in minutes), while adjusting for daily leisure time. Results were overall consistent with those observed in the main analyses (Table S3). Finally, in our study, the associations between various precursors and leisure time spent in sedentary behaviors were examined, with the latter being treated as a continuous variable. Yet, it may be interesting to consider that individuals may differ depending on whether they achieve or not their goal of not exceeding a maximum threshold of time spent in sedentary behaviors on a given day. Accordingly, although no scientific consensus is established on the definition of too much sedentary time (Stamatakis et al., 2019), future studies could investigate what factors may increase the likelihood of spending more time than recommended in sedentary behaviors.

Conclusion

This study shows that demographic, physical, interpersonal and environmental variables are associated with leisure-time sedentary behaviors, while the associations with controlled and automatic motivational precursors are weaker. As suggested by the socio-ecological framework, adopting a theoretical integrative perspective encompassing a large range of precursors can help to better characterizing the key variables involved in sedentary behaviors. These findings also suggest that interventions aiming to reduce leisure-time sedentary behaviors should pay attention to the specificities of the targeted people (i.e., men, individuals with higher body mass index, childless). Interventions could also benefit from strategies enabling individuals to cope with environmental conditions to reduce sedentary behaviors over the course of the week and on days with adverse weather conditions. By contrast, focusing on motivational variables could be rather ineffective.

Availability of data

The datasets generated and analysed during the current study are available in the Zenodo repository, [doi: 10.5281/zenodo.4010153].

Ethics approval and consent to participate

Ethical approval for the study was granted by the University of Grenoble Research Ethics Committee.

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