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Accumulation patterns of sedentary time and breaks and their association with cardiometabolic health markers in adults

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Abstract

Breaking up sedentary time with physical activity (PA) could modify the detrimental cardiometabolic health effects of sedentary time. Our aim was to identify profiles according to distinct accumulation patterns of sedentary time and breaks in adults, and to investigate how these profiles are associated with cardiometabolic outcomes. Participants ($n = 4439$) of the Northern Finland Birth Cohort 1966 at age 46 years wore a hip-worn accelerometer for 7 consecutive days during waking hours. Uninterrupted ≥1-min sedentary bouts were identified, and non-sedentary bouts in between two consecutive sedentary bouts were considered as sedentary breaks. K-means clustering was performed with 65 variables characterizing how sedentary time was accumulated and interrupted. Linear regression was used to determine the association of accumulation patterns with cardiometabolic health markers. Four distinct groups were formed as follows: "Couch potatoes" ($n = 1222$), "Prolonged sitters" ($n = 1179$), "Shortened sitters" ($n = 1529$), and "Breakers" ($n = 509$). Couch potatoes had the highest level of sedentariness and the shortest sedentary breaks. Prolonged sitters, accumulating sedentary time in bouts of ≥15–30 min, had no differences in cardiometabolic outcomes compared with Couch potatoes. Shortened sitters accumulated sedentary time in bouts lasting <15 min and performed more light-intensity PA in their sedentary breaks, and Breakers performed more light-intensity and moderate-to-vigorous PA. These latter two profiles had lower levels of adiposity, blood lipids, and insulin sensitivity, compared with Couch potatoes (1.1–25.0% lower values depending on the cardiometabolic health outcome, group, and adjustments for potential confounders).

Avoiding uninterrupted sedentary time with any active behavior from light-intensity upwards could be beneficial for cardiometabolic health in adults.

KEYWORDS
adiposity, dyslipidemias, insulin resistance, metabolic diseases, physical activity

1 | INTRODUCTION

Individuals' waking activities include sedentary behaviors, light-intensity (LPA) physical activity (PA), and moderate-to-vigorous PA (MVPA).[1,2] According to recent studies, breaking up sedentary time with short and sustained LPA and MVPA bouts could modify the detrimental effects on cardiometabolic markers caused by sedentary behavior in adults.[3,4] However, it is still unclear when sedentary time should be interrupted before it becomes detrimental to health, and even less is known about the length and intensity of interruptions to minimize the detrimental health effects of uninterrupted sedentary bouts.[3-5]

Previous studies have generally examined how sedentary time and breaks are associated with markers of cardiometabolic health in isolation.[3-5] Recently, it has been suggested that sedentary time and PA intensities are compositional data and codependently related to health markers.[2,6,7] This has accordingly led to the emergence of time-use approaches to examine the associations of accumulation patterns of sedentary behavior and PA intensities with cardiometabolic health outcomes.[6,8] However, a main limitation of time-use approaches is that the interpretation of the results is not straightforward and becomes more complicated when accommodating a higher number of variables.[6,7]

An increasing number of studies have recently used data-driven, person-centered statistical approaches, such as latent profile analysis and machine learning-based clustering methods (eg, K-means), to identify groups of individuals who share similar patterns of activity behaviors and to investigate how distinct activity patterns are related to cardiometabolic health indicators[9-12] and mortality risk.[13,14] A notable advantage of these approaches compared with other commonly used variable-centered approaches is that a higher number of variables can be accommodated in the analyses for forming the groups,[11,12,15] offering a better understanding of combined accumulation patterns of sedentary and activity behaviors in a population.[9,11,12]

Previous data-driven studies have typically focused on the combined accumulation patterns of sedentary time and PA in different populations, and how they are related to markers of cardiometabolic health.[9-11] Few studies have been performed on adults,[10-12] and none of them have included variables characterizing how sedentary time was accumulated and interrupted. The present cross-sectional study applied a clustering approach on accelerometer-estimated variables characterizing how sedentary time was accumulated and interrupted in a large population-based sample of adults (1) to identify, characterize, and compare participants according to distinct patterns of accumulation of sedentary time and breaks, and (2) to investigate how these derived patterns are associated with cardiometabolic outcomes including adiposity level, blood glucose and insulin, and cholesterol level.

2 | MATERIALS AND METHODS

2.1 | Study population

Data for the present study were from the population-based Northern Finland Birth Cohort 1966 study (NFBC1966) including participants whose date of birth was expected to be in the year 1966 in northern Finland (n = 12 058). Since birth, NFBC1966 participants have been followed up prospectively on a regular basis, and data on their health, lifestyle, and socioeconomic status have been collected. Detailed information about the NFBC1966 study, recruitment, and follow-ups is presented elsewhere.[16]

The present cross-sectional study included those members of NFBC1966 who participated in the latest follow-up performed at the age of 46 years (during 2012–2014), and who agreed to wear an accelerometer for measurement of daily activity (n = 5861). The data collection in the 46-year follow-up further included completion of postal questionnaires, a clinical examination for collection of fasting blood samples and anthropometric measurements, and on a separate day an oral glucose tolerance test.

2.2 | Measurements

2.2.1 | Sedentary time and physical activity intensities

Activity intensities were assessed with a hip-worn accelerometer (Hookie AM20; Traxmeet Ltd). Participants were instructed to wear the accelerometer during all waking activities (excluding water-based activities) for 14 consecutive days. The accelerometers were set to record and store raw acceleration data at 100 Hz. The acceleration data were segmented into 6-s epochs and mean amplitude deviation (MAD) values were computed.[17] Non-wear time intervals were removed from the 6-s MAD values. Non-wear intervals were identified with a widely used approach for count-based data[18] with the modification of a shorter window size for handling the artifactual acceleration (30 s instead of 2 min). The remaining time-epochs were then marked as sedentary behavior (<1.5 metabolic equivalents [MET]), LPA (1.5–3.0 MET), or MVPA (≥3 MET) using a validated set of thresholds for MAD values, and time spent in each activity (min/day) was obtained by dividing the total time by the number of valid days.[17] The patterns and levels of sedentary time and physical activities may vary substantially between weekdays and weekends.[19] To minimize the effects of these variations on the analyses, participants with at least seven consecutive valid days (one full week) of accelerometry data, with each valid day defined as ≥10 h of monitor wear time, were included in the analyses.

2.2.2 | Accumulation patterns of sedentary time and sedentary breaks

According to standardized definitions,[20] we identified all the sedentary bouts lasting for ≥1 min with no tolerance time and considered the whole time period between two consecutive sedentary bouts as sedentary breaks, if no time-epoch was marked as non-wear, starting from the first sedentary bout to the end of the second sedentary bout (Figure 1). A sedentary break could therefore consist of a combination of one or more PA bouts (LPA and/or MVPA) of any duration with one or more sedentary bouts of <1 min in between.

Thereafter, we computed 10 variables to describe the accumulation pattern of sedentary bouts in the population, and 55 variables to describe how these sedentary bouts of different lengths were interrupted. The variables computed for characterizing the accumulation patterns of sedentary time included duration (min) and frequency (number) of 1–5 min, 5–10 min, 10–15 min, 15–30 min, and ≥30 min sedentary bouts. These variables were averaged to the seven consecutive valid days to derive per day values. The accumulation pattern variables computed for describing the characteristics of sedentary breaks were the total duration of break and accumulated MVPA time, LPA time, and sedentary time (in bouts <1 min) in the breaks. We also computed the frequency (number) of <5 min, 5–10 min, and ≥10 min LPA and MVPA bouts, and the

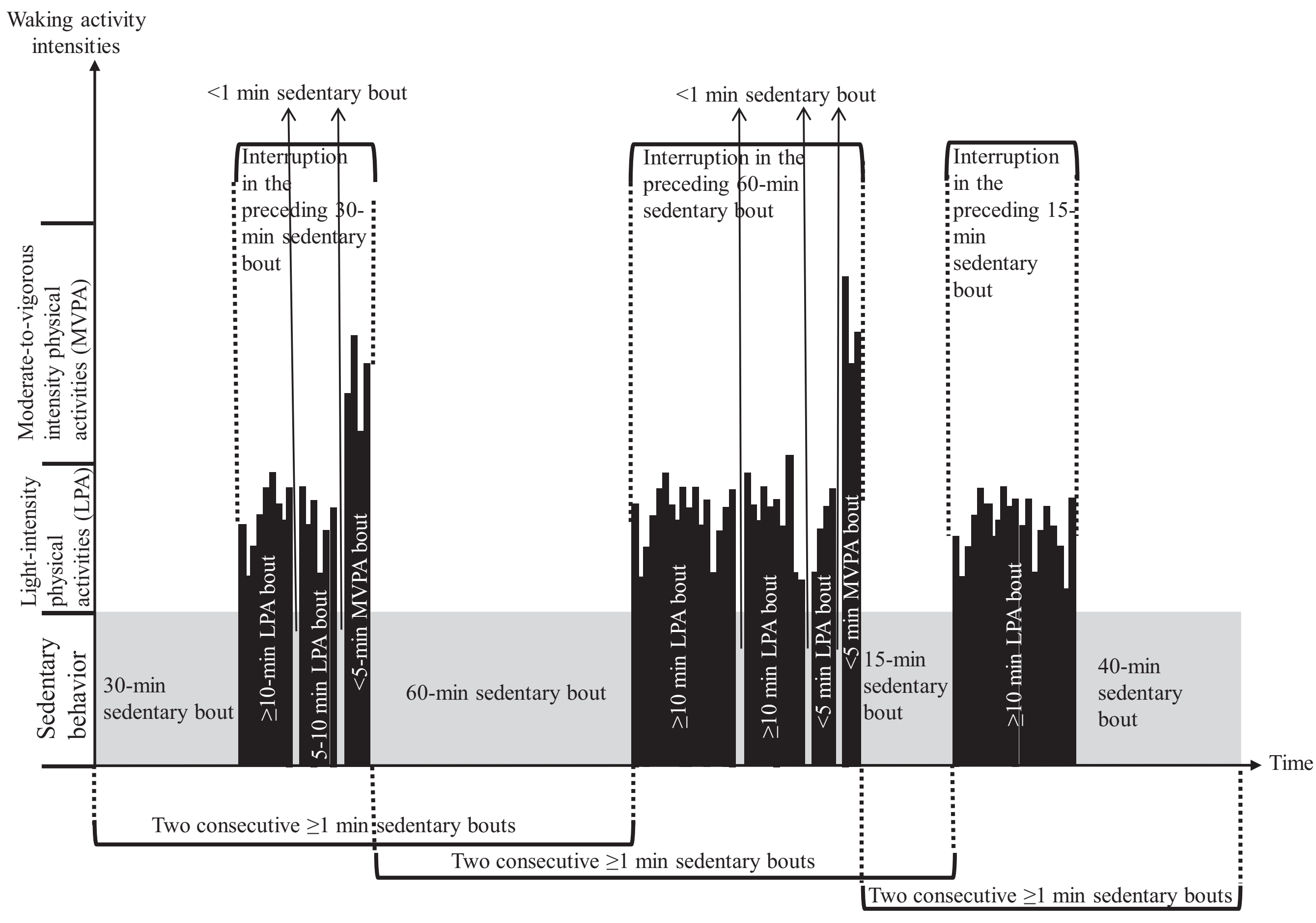

FIGURE 1 Schematic representation of how sedentary bouts and sedentary breaks were defined and identified

frequency (number) of <1 min sedentary bouts within the sedentary breaks. We stratified all the variables describing the characteristics of sedentary breaks based on the length of their precedent sedentary bout (ie, 1–5 min, 5–10 min, 10–15 min, 15–30 min, ≥30 min sedentary bouts), and averaged them over the number of corresponding sedentary bouts to derive per-sedentary-bout values. We used these per-sedentary-bout values for describing the characteristics of sedentary breaks since they would altogether be indicative of the total duration and frequency of sedentary breaks, how much (total duration) LPA and MVPA were included in the sedentary breaks on average per sedentary bout, and how often (number) these LPA and MVPA were accumulated in bouts of <5 min, 5–10 min, and ≥10 min.

2.2.3 | Cardiometabolic health markers

Participants attended a clinical examination after fasting overnight for 12 h and abstained from smoking and drinking coffee on the day of the clinical examination. Trained nurses measured anthropometrics including height, weight, and waist circumference, and the body mass index (BMI) was calculated. Body fat, fat mass, and visceral fat area were estimated by bioelectrical impedance analysis (InBody720; InBody).[21] Fasting blood samples were taken and analyzed for plasma glucose, serum insulin, total cholesterol, high-density lipoprotein (HDL) cholesterol, low-density lipoprotein (LDL) cholesterol, and triglycerides as previously described elsewhere.[22] The ratios of total to HDL (total/HDL cholesterol ratio) and LDL to HDL (LDL/HDL cholesterol ratio) cholesterol levels were computed.[23]

Participants who were not previously diagnosed with type 1 or type 2 diabetes were also asked to attend to a 75 g oral glucose tolerance test on another fasted day.[24] Participants' fasting glucose was initially assessed based on a finger-prick type of glucose meter on the test day, and the oral glucose tolerance test was administered for those participants who had fasting glucose <8.0 mmol/L. From the results of the oral glucose tolerance test, 2-h postload plasma glucose and insulin levels were obtained.

2.2.4 | Confounders

Potential confounders were chosen a priori based on previous research on the association between PA and sedentary behavior with cardiometabolic health markers. Self-reported education level, employment status, marital status and household income, as well as lifestyle (smoking status and alcohol consumption), health-related quality of life, previous diagnosis of hypertension, heart problems, and diabetes, and use of medication for hypertension, high cholesterol, and diabetes were used as confounders.

2.3 | Statistical analyses

2.3.1 | Profiles of accumulation patterns of sedentary time and breaks

All participants with valid accelerometry data, regardless of missing values in health outcomes or confounders, were included in the profile analysis to identify distinct classes of adults who share similar accumulation patterns of sedentary time and breaks. Clustering analysis was performed with the K-means clustering algorithm.[25] K-means partitions the data into a user-defined number (K) of disjoint clusters based on the input variables (features), such that, according to the cost function, the objects (participants) within the same cluster have maximized similarity compared to each other, and minimized similarity compared to the objects that are assigned to other clusters.[25] All the 65 accumulation pattern variables were included in the cluster analysis. Prior to inclusion in the cluster analysis, all the input variables were standardized using the min-max method to have a range of 0–1.[26] The similarity of subjects was assessed using Euclidian distance. We used the "elbow method" to obtain the optimal number of clusters, in which the optimal number of clusters is selected based on a trade-off between a reasonable number of clusters and minimization of within-cluster differences.[27] Clustering analysis was performed using MATLAB (version R2019b; MathWorks).

2.3.2 | Profile characteristics and associations with cardiometabolic health outcomes

Differences between profiles according to the variables used for describing the accumulation pattern of sedentary bouts and breaks were examined with one-way analysis of variance (ANOVA), and the *p*-values of the overall tests were presented. When the differences between groups were found significant ($p < .05$), pairwise comparison was performed with Tukey post-hoc tests for normally distributed variables and Kruskal-Wallis tests for skewed variables.

Linear regression models were conducted to analyze the associations (% difference) between the group/profile membership (included as categorical predictor) and each of the cardiometabolic health outcome in separate models. All the cardiometabolic outcomes were log-transformed prior to inclusion in the regression analyses. For each outcome, we tested the association with four incremental models, including an unadjusted model and three adjusted models. The unadjusted included only profile membership and

TABLE 1 Participant characteristics for whole sample, analytical sample with valid accelerometry data, and for the four distinct groups

Variable	Full sample ($n = 5840$)	Analytical sample ($n = 4439$)	Coach potatoes ($n = 1222$)	Prolonged sitters ($n = 1179$)	Shortened sitters ($n = 1529$)	Breakers ($n = 509$)
Demographics						
Age, years	46.6 (0.6)	46.6 (0.6)	46.6 (0.5)	46.5 (0.5)	46.6 (0.6)	46.5 (0.6)
Sex						
Male	2565 (44.1%)	1914 (43.2%)	545 (44.6%)	554 (47.1%)	552 (36.1%)	263 (51.9%)
Female	3257 (55.9%)	2515 (56.8%)	676 (55.4%)	620 (52.9%)	975 (63.9%)	244 (48.1%)
Education						
Comprehensive school	383 (7.1%)	275 (6.6%)	62 (5.4%)	57 (5.1%)	102 (7.1%)	54 (11.5%)
Vocational/college level education	3455 (64.3%)	2666 (64.3%)	744 (64.9%)	562 (51.1%)	1003 (70.1%)	357 (76.0%)
Polytechnic/university degree	1531 (25.5%)	1206 (29.1%)	341 (29.7%)	480 (43.8%)	326 (22.8%)	59 (12.5%)
Employment status						
Employed	4672 (88.2%)	3669 (88.8%)	1017 (89.0%)	964 (87.2%)	1269 (89.5%)	419 (90.2%)
Unemployed	295 (5.6%)	226 (5.5%)	68 (5.9%)	73 (6.6%)	62 (4.4%)	23 (4.9%)
Other (eg, student, homemaker)	333 (6.3%)	237 (5.7%)	59 (5.1%)	68 (6.2%)	87 (6.1%)	23 (4.9%)
Marital status						
Married/cohabiting	4348 (78.8%)	3378 (79.3%)	892 (76.0%)	854 (74.9%)	1221 (83.6%)	411 (84.6%)
Divorced/Widowed	555 (10.1%)	424 (10.0%)	145 (12.3%)	119 (10.5%)	121 (8.3%)	39 (8.0%)
Unmarried	615 (11.1)	459 (10.7%)	137 (11.7%)	167 (14.6%)	119 (8.1%)	36 (7.4%)
Household income (€ per year)						
≤50 000	2149 (42.8%)	1633 (41.8%)	448 (41.4%)	386 (36.7%)	589 (44.2%)	210 (48.0%)
50 001 to 100 000	23.5 (45.9%)	1813 (46.4%)	512 (47.4%)	479 (45.5%)	629 (47.1%)	193 (44.2%)
>100 000	564 (11.2%)	458 (11.8%)	121 (11.2%)	187 (17.8%)	116 (8.7%)	34 (7.8%)
Lifestyle factors, medication use, and health-related quality of life						
Alcohol consumption, grams/day	10.7 (17.3)	10.1 (16.4)	11.3 (18.6)	10.3 (15.3)	9.1 (15.7)	10.1 (15.1)
Health-related quality of life score	0.9 (0.1)	0.9 (0.1)	0.9 (0.1)	0.9 (0.1)	0.9 (0.1)	0.9 (0.1)
Smoking status						
Non-smoker	2941 (53.8%)	2305 (54.4%)	572 (49.2%)	690 (60.8%)	755 (51.8%)	288 (61.1%)
Former smoker	1485 (27.1%)	1153 (27.3%)	309 (26.6%)	298 (26.3%)	413 (28.3%)	133 (27.8%)
Current smoker	1045 (17.9%)	775 (18.3%)	281 (24.2%)	146 (12.9%)	290 (19.9%)	58 (12.1%)
Diseases						
Hypertension	1103 (18.9%)	831 (18.7%)	276 (22.6%)	217 (18.4%)	244 (15.9%)	94 (18.5%)
Heart diseases	218 (3.7%)	161 (3.6%)	49 (4.0%)	39 (3.3%)	60 (3.9%)	13 (2.5%)

(Continues)

TABLE 1 (Continued)

Variable	Full sample (n = 5840)	Analytical sample (n = 4439)	Coach potatoes (n = 1222)	Prolonged sitters (n = 1179)	Shortened sitters (n = 1529)	Breakers (n = 509)
Diabetes	179 (3.0%)	127 (2.9%)	41 (3.5%)	33 (2.8%)	36 (2.3%)	17 (3.3%)
Diabetes, cholesterol, and/or hypertension medication						
Yes	943 (17.0%)	706 (16.5%)	224 (19.0%)	189 (16.5%)	218 (14.8%)	75 (15.3%)
No	4597 (83.0%)	3573 (83.5%)	952 (81.0%)	954 (83.5%)	1253 (85.2%)	414 (84.7%)
Cardiometabolic biomarkers						
Fasting insulin, pmol/L	9.8 (8.8)	9.6 (8.1)	10.4 (9.2)	10.1 (9.2)	8.8 (6.5)	8.8 (6.6)
2-h insulin, pmol/L	61.3 (58.4)	60.2 (58.6)	68.6 (69.9)	61.6 (59.4)	56.4 (52.2)	60.2 (58.6)
Fasting glucose, mmol/L	5.5 (0.9)	5.5 (0.9)	5.6 (1.0)	5.5 (0.9)	5.4 (0.7)	5.5 (0.8)
2-h glucose, mmol/L	5.9 (1.7)	5.8 (1.6)	5.9 (1.8)	5.8 (1.7)	5.8 (1.5)	5.7 (1.5)
Triglycerides, mmol/L	1.3 (0.8)	1.2 (0.8)	1.3 (0.9)	1.3 (0.8)	1.2 (0.7)	1.2 (0.7)
Total/HDL cholesterol ratio	3.6 (1.0)	3.6 (1.0)	3.8 (1.1)	3.7 (1.0)	3.5 (1.0)	3.5 (1.0)
LDL/HDL cholesterol ratio	2.4 (0.9)	2.4 (0.9)	2.5 (0.9)	2.4 (0.9)	2.3 (0.9)	2.2 (0.9)
Adiposity measures						
Body fat, %	28.9 (9.3)	28.8 (9.1)	29.9 (9.1)	28.9 (9.3)	28.5 (8.7)	26.6 (9.3)
Fat mass, kg	23.1 (10.7)	22.9 (10.5)	24.4 (10.9)	23.6 (11.3)	21.8 (9.4)	22.9 (10.5)
Visceral fat area, cm^2	105.1 (41.6)	104.1 (40.9)	109.9 (41.6)	105.3 (43.2)	100.6 (38.4)	98.1 (39.1)
BMI, kg/m^2	26.9 (4.9)	26.7 (4.8)	27.3 (4.9)	26.9 (5.2)	26.2 (4.4)	26.5 (4.4)
Waist circumference, cm	91.8 (13.6)	91.3 (13.4)	92.3 (13.6)	92.3 (14.0)	89.4 (12.8)	90.8 (12.8)
Total daily volumes						
Wear time, hours per day	-	15.8 (2.0)	16.3 (2.3)	15.8 (2.5)	15.5 (1.6)	15.8 (2.0)
Sedentary time, min/day	-	635.4 (140.1)	717.2 (133.3)	689.6 (131.9)	578 (89.5)	485.7 (95.1)
LPA time, min/day	-	265.6 (79.2)	223.7 (46.1)	207.8 (51.5)	307.5 (53.0)	374.2 (77.3)
MVPA time, min/day	-	47.6 (26.8)	38.2 (20.9)	51.6 (27.3)	44.4 (21.3)	70.5 (35.2)

Values are mean (SD) or count (%). BMI, body mass index; LDL, low-density lipoprotein; HDL, high-density lipoprotein; LPA, light-intensity physical activity; MVPA, moderate-to-vigorous physical activity.

cardiometabolic outcomes. Model 1 was partially adjusted for selected confounders including age, sex, education, and employment and marital status, and Model 2 was further adjusted for medication use, health-related quality of life score, smoking, alcohol consumption, and income. Model 3 was additionally adjusted for sedentary time and Model 4 for MVPA time to examine whether the associations would persist independent of these two variables. To address reverse causation,[28] we repeated the regression analyses after excluding those participants who had hypertension, heart diseases, and/or diabetes. For the association analyses, the group that was considered unhealthiest based on their accumulation patterns according to existing literature was selected as the referent group.[20,29] Significance was assessed at the level of $p < .05$. Association analyses were performed using IBM SPSS Statistics (version 25.0; IBM Corporation).

3 | RESULTS

3.1 | Participants

A total of 5840 NFBC1966 cohort members participated in the 46-year follow-up. Of these, 4439 participants (37% of all cohort members and 43% of those invited to the 46-year follow-up) wore the accelerometer and provided valid data for 7 consecutive days, and accordingly were included in the cluster analysis. Full descriptive statistics of the cohort members participating in the 46-year follow-up and the subsample with valid accelerometry data are shown in Table 1. Compared with those participating in the follow-up, a similar percentage of participants with valid accelerometry data were men (44.1% vs. 43.2%), married/cohabiting (78.8% vs. 79.3%), non-smokers (53.8% vs. 54.4%), and with a polytechnic/university degree (25.5% vs. 29.1%). The total mean (SD) daily wear time was 15.2 (2.0) h.

3.2 | Cluster analysis and accumulation patterns

The within-cluster sums for K-means cluster analysis with 65 variables and the number of clusters ranging from 1 to 50 are shown in Supplementary File, Figure 1. According to the elbow method,[27] 4 was selected as the optimal number of clusters. All the 65 variables describing patterns of the accumulation of sedentary time and sedentary breaks were significantly different between clusters (Table 2), indicating the relevance of all the variables used for creating the analysis (overall p-values for all variables in ANOVA tests <.001).

Groups of participants with similar accumulation patterns were labelled according to their distinguishing accumulation patterns, as shown by high and low Z-values (Figure 2) and means (SD) for all the 65 accumulation pattern variables (Table 2). We named the four accumulation pattern profiles “Couch potatoes,” “Prolonged sitters,” “Shortened sitters,” and “Breakers.” Couch potatoes ($n = 1222$, 28% of the sample) had a high number of sedentary bouts of different lengths that, compared with the other three groups, were interrupted less frequently by non-sedentary bouts lasting for relatively shorter durations. The duration of interruptions of sedentary bouts of different lengths were comparable in Prolonged sitters ($n = 1179$, 27% of the sample) and Shortened sitters ($n = 1529$, 34% of the sample), but Prolonged sitters accumulated most of their sedentary time in longer bouts of ≥15–30 min, while Shortened sitters did so in bouts of <15–30 min. Breakers ($n = 509$, 11% of the sample) were engaged in short sedentary bouts, which were, compared with the other three groups, more frequently interrupted by non-sedentary bouts of relatively longer duration. Since Couch potatoes spent the longest time in sedentary activities and had the shortest duration of interruptions of sedentary time, this group was considered the unhealthiest and was used as a reference for comparisons.

3.3 | Differences between groups

The distribution of demographical, lifestyle, markers of cardiometabolic health, and other indicators across the four distinct profiles is shown in Table 1. The proportion of females was lowest in the Breakers (47.9%), followed by Prolonged sitters (52.6%), Couch potatoes (55.3%), and Shortened sitters (63.8%). The average consumption of alcohol was highest among the Couch potatoes (11.3 grams/day), and they were least frequently non-smokers (46.8%) and most frequently (18.3%) on medication for diabetes, cholesterol, and/or hypertension.

3.4 | Associations between groups with distinct accumulation patterns and cardiometabolic outcomes

Tables 3 and 4 show the associations between the four distinct groups and cardiometabolic biomarkers and adiposity measures, respectively. In unadjusted regression models, Prolonged sitters had favorable differences in adiposity measures and cardiometabolic biomarkers compared with Couch potatoes (range: 1.7–8.1% lower values depending on the outcome), for example lower levels of 2-h insulin (8.1%), triglycerides (5.2%), and body fat (1.7%). However, although the favorable associations for triglycerides, total/HDL cholesterol, LDL/HDL cholesterol, and visceral fat area were

TABLE 2 Included variables in the cluster analysis, characterizing how sedentary time was accumulated and interrupted

	Coach potatoes (n = 1222)	Prolonged sitters (n = 1179)	Shortened sitters (n = 1529)	Breakers (n = 509)	Overall p-value
Characteristics of sedentary bouts					
Duration of 1–5 min sedentary bouts (min/day)	111.09 (23.37)*	82.79 (17.56)*	127.52 (23.39)*	98.56 (20.42)*	<.001
Frequency of 1–5 min sedentary bouts (num/day)	47.95 (10.09)*	36.37 (7.80)*	56.89 (10.41)*	44.89 (9.60)*	<.001
Duration of 5–10 min sedentary bouts (min/day)	101.05 (18.64)*	72.04 (13.82)[a,c]	93.96 (17.04)*	70.39 (15.11)[a,c]	<.001
Frequency of 5–10 min sedentary bouts (num/day)	14.32 (2.68)*	10.22 (1.97)[a,c]	13.47 (2.45)*	10.07 (2.14)[a,c]	<.001
Duration of 10–15 min sedentary bouts (min/day)	80.78 (13.98)*	56.38 (11.90)*	61.66 (13.72)*	48.21 (12.68)*	<.001
Frequency of 10–15 min sedentary bouts (num/day)	6.63 (1.14)*	4.62 (0.97)*	5.08 (1.13)*	3.97 (1.03)*	<.001
Duration of 15–30 min sedentary bouts (min/day)	158.29 (30.61)*	132.76 (27.25)*	106.10 (25.08)*	89.06 (26.83)*	<.001
Frequency of 15–30 min sedentary bouts (num/day)	7.58 (1.42)*	6.28 (1.28)*	5.14 (1.19)*	4.28 (1.26)*	<.001
Duration of ≥30 min sedentary bouts (min/day)	209.07 (109.77)*	289.96 (120.01)*	127.75 (69.94)[a,b]	121.44 (75.95)[a,b]	<.001
Frequency of ≥30 min sedentary bouts (num/day)	4.02 (1.55)*	5.17 (1.47)*	2.53 (1.04)[a,b]	2.34 (1.17)[a,b]	<.001
Characteristics of sedentary breaks after 1–5 min sedentary bouts					
Total duration of sedentary breaks (min/1-5 min sedentary bout)	3.84 (0.81)*	4.85 (1.20)[a,d]	4.95 (0.98)[a,d]	7.75 (2.08)*	<.001
Accumulated MVPA time in the sedentary breaks (min/1-5 min sedentary bout)	0.54 (0.34)[b,d]	0.91 (0.56)*	0.57 (0.33)[b,d]	1.16 (0.76)*	<.001
Accumulated LPA time in the sedentary breaks (min/1-5 min sedentary bout)	2.93 (0.61)*	3.53 (0.90)*	3.89 (0.82)*	6.05 (1.66)*	<.001
Accumulated sedentary time (in bouts <1 min) in the sedentary breaks (min/1-5 min sedentary bout)	0.37 (0.06)*	0.41 (0.07)*	0.48 (0.07)*	0.55 (0.10)*	<.001
Frequency of <5 min MVPA bouts in the sedentary breaks (num/1-5 min sedentary bout)	0.40 (0.21)*	0.57 (0.34)*	0.52 (0.26)*	1.12 (0.67)*	<.001
Frequency of 5–10 min MVPA bouts in the sedentary breaks (num/1-5 min sedentary bout)	0.01 (0.01)[b,d]	0.02 (0.02)[a,c]	0.01 (0.01)[b,d]	0.02 (0.02)[a,c]	<.001
Frequency of ≥10 min MVPA bouts in the sedentary breaks (num/1-5 min sedentary bout)	0.01 (0.01)[b,d]	0.01 (0.02)*	0.01 (0.01)[b,d]	0.01 (0.01)*	<.001
Frequency of <5 min LPA bouts in the sedentary breaks (num/1-5 min sedentary bout)	2.43 (0.28)*	2.70 (0.40)*	2.83 (0.32)*	3.55 (0.71)*	<.001
Frequency of 5–10 min LPA bouts in the sedentary breaks (num/1-5 min sedentary bout)	0.06 (0.03)*	0.08 (0.04)*	0.10 (0.04)*	0.18 (0.07)*	<.001
Frequency of ≥10 min LPA bouts in the sedentary breaks (num/1-5 min sedentary bout)	0.01 (0.01)*	0.02 (0.02)*	0.02 (0.02)*	0.06 (0.04)*	<.001
Frequency of <1 min sedentary bout in the sedentary breaks (num/1-5 min sedentary bout)	1.08 (0.18)*	1.20 (0.22)*	1.41 (0.20)*	1.64 (0.31)*	<.001
Characteristics of sedentary breaks after 5–10 min sedentary bouts					
Total duration of sedentary breaks (min/5-10 min sedentary bout)	3.18 (0.78)*	3.92 (1.15)*	4.11 (0.96)*	6.50 (2.09)*	<.001

(Continues)

TABLE 2 (Continued)

	Coach potatoes (*n* = 1222)	Prolonged sitters (*n* = 1179)	Shortened sitters (*n* = 1529)	Breakers (*n* = 509)	Overall *p*-value
Accumulated MVPA time in the sedentary breaks (min/5-10 min sedentary bout)	0.41 (0.34)*	0.73 (0.63)*	0.47 (0.35)*	1.03 (0.79)*	<.001
Accumulated LPA time in the sedentary breaks (min/5-10 min sedentary bout)	2.47 (0.57)*	2.88 (0.76)*	3.25 (0.77)*	5.04 (1.70)*	<.001
Accumulated sedentary time (in bouts <1 min) in the sedentary breaks (min/5-10 min sedentary bout)	0.30 (0.06)*	0.31 (0.08)*	0.39 (0.07)*	0.43 (0.10)*	<.001
Frequency of <5 min MVPA bouts in the sedentary breaks (num/5-10 min sedentary bout)	0.35 (0.21)*	0.47 (0.29)[a,d]	0.44 (0.25)[a,d]	0.99 (0.62)*	<.001
Frequency of 5–10 min MVPA bouts in the sedentary breaks (num/5-10 min sedentary bout)	0.01 (0.01)[b,d]	0.02 (0.02)[a,c]	0.01 (0.01)[b,d]	0.02 (0.03)[a,c]	<.001
Frequency of ≥10 min MVPA bouts in the sedentary breaks (num/5-10 min sedentary bout)	0.01 (0.01)[b,d]	0.01 (0.02)[a,c]	0.0 (0.0)[b,d]	0.01 (0.02)[a,c]	<.001
Frequency of <5 min LPA bouts in the sedentary breaks (num/5-10 min sedentary bout)	2.17 (0.28)*	2.34 (0.36)*	2.50 (0.31)*	3.10 (0.67)*	<.001
Frequency of 5–10 min LPA bouts in the sedentary breaks (num/5-10 min sedentary bout)	0.04 (0.03)*	0.06 (0.04)*	0.07 (0.04)*	0.14 (0.07)*	<.001
Frequency of ≥10 min LPA bouts in the sedentary breaks (num/5-10 min sedentary bout)	0.01 (0.01)*	0.01 (0.02)*	0.01 (0.02)*	0.04 (0.04)*	<.001
Frequency of <1 min sedentary bouts in the sedentary breaks (num/5-10 min sedentary bout)	0.86 (0.18)*	0.92 (0.21)*	1.13 (0.21)*	1.27 (0.30)*	<.001
Characteristics of sedentary breaks after 10–15 min sedentary bouts					
Total duration of sedentary breaks (min/10-15 min sedentary bout)	3.0 (0.93)*	3.67 (1.47)*	3.98 (1.26)*	6.33 (3.20)*	<.001
Accumulated MVPA time in the sedentary breaks (min/10-15 min sedentary bout)	0.37 (0.40)*	0.63 (0.73)*	0.44 (0.47)*	0.99 (1.03)*	<.001
Accumulated LPA time in the sedentary breaks (min/10-15 min sedentary bout)	2.36 (0.67)*	2.76 (0.98)*	3.18 (0.97)*	4.95 (2.68)*	<.001
Accumulated sedentary time (in bouts <1 min) in the sedentary breaks (min/10-15 min sedentary bout)	0.27 (0.08)[c,d]	0.28 (0.10)[c,d]	0.36 (0.11)*	0.38 (0.15)*	<.001
Frequency of <5 min MVPA bouts in the sedentary breaks (num/10-15 min sedentary bout)	0.33 (0.24)*	0.44 (0.33)[a,d]	0.43 (0.30)[a,d]	0.96 (0.72)*	<.001
Frequency of 5–10 min MVPA bouts in the sedentary breaks (num/10-15 min sedentary bout)	0.01 (0.02)[b,d]	0.02 (0.03)[a,c]	0.01 (0.02)[b,d]	0.02 (0.04)[a,c]	<.001
Frequency of ≥10 min MVPA bouts in the sedentary breaks (num/10-15 min sedentary bout)	0.01 (0.01)[b]	0.01 (0.02)[a,c]	0.01 (0.01)[b,d]	0.01 (0.03)[c]	<.001
Frequency of <5 min LPA bouts in the sedentary breaks (num/10-15 min sedentary bout)	2.08 (0.34)*	2.23 (0.46)*	2.41 (0.45)*	2.94 (0.87)*	<.001

(Continues)

TABLE 2 (Continued)

	Coach potatoes ($n = 1222$)	Prolonged sitters ($n = 1179$)	Shortened sitters ($n = 1529$)	Breakers ($n = 509$)	Overall p-value
Frequency of 5–10 min LPA bouts in the sedentary breaks (num/10-15 min sedentary bout)	0.04 (0.04)*	0.05 (0.05)*	0.07 (0.06)*	0.14 (0.11)*	<.001
Frequency of ≥10 min LPA bouts in the sedentary breaks (num/10-15 min sedentary bout)	0.01 (0.01)*	0.01 (0.02)*	0.01 (0.02)*	0.04 (0.08)*	<.001
Frequency of <1 min sedentary bouts in the sedentary breaks (num/10-15 min sedentary bout)	0.79 (0.23)*	0.83 (0.27)*	1.05 (0.32)*	1.14 (0.43)*	<.001
Characteristics of sedentary breaks after 15–30 min sedentary bouts					
Total duration of sedentary breaks (min/15-30 min sedentary bout)	2.97 (0.84)*	3.61 (1.27)[a,d]	3.72 (1.20)[a,d]	6.06 (2.61)*	<.001
Accumulated MVPA time in the sedentary breaks (min/15-30 min sedentary bout)	0.36 (0.38)[b,d]	0.64 (0.66)*	0.42 (0.48)[b,d]	0.94 (1.02)*	<.001
Accumulated LPA time in the sedentary breaks (min/15-30 min sedentary bout)	2.35 (0.62)*	2.70 (0.82)*	2.97 (0.93)*	4.74 (2.03)*	<.001
Accumulated sedentary time (in bouts <1 min) in the sedentary breaks (min/15-30 min sedentary bout)	0.26 (0.08)[c,d]	0.27 (0.09)[c,d]	0.33 (0.11)*	0.38 (0.14)*	<.001
Frequency of <5 min MVPA bouts in the sedentary breaks (num/15-30 min sedentary bout)	0.32 (0.22)*	0.44 (0.30)*	0.39 (0.27)*	0.90 (0.68)*	<.001
Frequency of 5–10 min MVPA bouts in the sedentary breaks (num/15-30 min sedentary bout)	0.01 (0.02)[b,d]	0.01 (0.02)*	0.01 (0.02)[b,d]	0.01 (0.03)*	<.001
Frequency of ≥10 min MVPA bouts in the sedentary breaks (num/15-30 min sedentary bout)	0.0 (0.0)[b]	0.01 (0.02)[a,c]	0.0 (0.0)[b,d]	0.01 (0.03)[c]	<.001
Frequency of <5 min LPA bouts in the sedentary breaks (num/15-30 min sedentary bout)	2.05 (0.30)*	2.19 (0.41)*	2.28 (0.41)*	2.87 (0.79)*	<.001
Frequency of 5–10 min LPA bouts in the sedentary breaks (num/15-30 min sedentary bout)	0.04 (0.03)*	0.05 (0.04)*	0.06 (0.05)*	0.12 (0.09)*	<.001
Frequency of ≥10 min LPA bouts in the sedentary breaks (num/15-30 min sedentary bout)	0.0 (0.0)*	0.01 (0.02)[a,d]	0.01 (0.02)[a,d]	0.04 (0.06)*	<.001
Frequency of <1 min sedentary bouts in the sedentary breaks (num/15-30 min sedentary bout)	0.75 (0.21)*	0.79 (0.24)*	0.95 (0.30)*	1.11 (0.41)*	<.001
Characteristics of sedentary breaks after ≥30 min sedentary bouts					
Total duration of sedentary breaks (min/≥30 min sedentary bout)	3.02 (1.18)*	3.66 (1.53)[a,d]	3.80 (1.89)[a,d]	5.12 (3.27)*	<.001
Accumulated MVPA time in the sedentary breaks (min/≥30 min sedentary bout)	0.37 (0.50)[b,d]	0.67 (0.77)[a,c]	0.46 (0.85)[b,d]	0.80 (1.19)[a,c]	<.001
Accumulated LPA time in the sedentary breaks (min/≥30 min sedentary bout)	2.39 (0.84)*	2.72 (0.98)*	3.02 (1.33)*	3.98 (2.45)*	<.001

(Continues)

TABLE 2 (Continued)

	Coach potatoes ($n = 1222$)	Prolonged sitters ($n = 1179$)	Shortened sitters ($n = 1529$)	Breakers ($n = 509$)	Overall p-value
Accumulated sedentary time (in bouts <1 min) in the sedentary breaks (min/≥30 min sedentary bout)	0.27 (0.11)[c,d]	0.28 (0.11)[c,d]	0.33 (0.16)[a,b]	0.34 (0.21)[a,b]	<.001
Frequency of <5 min MVPA bouts in the sedentary breaks (num/≥30 min sedentary bout)	0.33 (0.30)*	0.45 (0.33)*	0.40 (0.40)*	0.73 (0.75)*	<.001
Frequency of 5–10 min MVPA bouts in the sedentary breaks (num/≥30 min sedentary bout)	0.01 (0.02)[b]	0.01 (0.03)[a,c]	0.01 (0.03)[b]	0.01 (0.04)[b]	<.001
Frequency of ≥10 min MVPA bouts in the sedentary breaks (num/≥30 min sedentary bout)	0.0 (0.0)[b]	0.01 (0.03)*	0.01 (0.03)[b]	0.01 (0.04)[b]	<.001
Frequency of <5 min LPA bouts in the sedentary breaks (num/≥30 min sedentary bout)	2.05 (0.45)*	2.21 (0.47)[a,d]	2.27 (0.64)[a,d]	2.59 (1.07)*	<.001
Frequency of 5–10 min LPA bouts in the sedentary breaks (num/≥30 min sedentary bout)	0.03 (0.04)*	0.04 (0.05)[c,d]	0.06 (0.08)[b,d]	0.09 (0.13)*	<.001
Frequency of ≥10 min LPA bouts in the sedentary breaks (num/≥30 min sedentary bout)	0.0 (0.0)*	0.01 (0.02)*	0.01 (0.03)*	0.02 (0.05)*	<.001
Frequency of <1 min sedentary bouts in the sedentary breaks (num/≥30 min sedentary bout)	0.75 (0.29)[c,d]	0.79 (0.28)[c,d]	0.93 (0.44)[a,b]	0.96 (0.63)[a,b]	<.001

Values are mean (standard deviation). Differences were tested with one-way analysis of variance (ANOVA), and only significant ($p < .05$) pairwise comparison p-values are reported.

LPA, light-intensity physical activity; MVPA, moderate-to-vigorous physical activity; num, number; min, minute.

[a]Indicates significant difference from Couch potatoes.

[b]Indicates significant difference from Prolonged sitters.

[c]Indicates significant difference from Shortened sitters.

[d]Indicates significant difference from Breakers.*Indicates significant difference from all other profiles.

still significant in partially adjusted models (Model 1), none remained significant when the models were further adjusted for all potential confounders (Model 2) and total sedentary time (Model 3) or MVPA time (Model 4).

When included in unadjusted models, compared to Couch potatoes, Shortened sitters and Breakers both had favorable differences in cardiometabolic biomarkers and in all adiposity measures (range: 2.1–23.5% lower values depending on the outcome and group), for example, lower levels of 2-h insulin (12.6% and 23.5%), fasting serum insulin (13.6% and 13.2%), triglycerides (11.1% and 12.9%), and body fat (2.2% and 5.6%). When unadjusted, Shortened sitters also had significantly lower fasting plasma glucose (2.2%) compared to Couch potatoes. These associations were all retained significantly in partially adjusted models (Model 1) and when the models were adjusted for all potential confounders (Model 2); the only exception was that Shortened sitters were not associated with a percentage difference in 2-h glucose (in Model 1 and Model 2).

When included in adjusted models for all potential confounders and sedentary time (Model 3), compared to Couch potatoes, Shortened sitters, and Breakers both had typically favorable differences in cardiometabolic biomarkers and adiposity measures, for example, lower levels of fasting serum insulin (8.0% and 7.6%), body fat (1.8% and 2.8%), and fat mass (5.4% and 6.2%). Shortened sitters had also favorable differences in cardiometabolic biomarkers and adiposity measures compared to Couch potatoes when the models were adjusted for both potential confounders and MVPA time (Model 4), such as lower levels of 2-h insulin (6.5%), fasting serum insulin (8.8%), triglycerides (5.2%), and body fat (2.2%). However, when the models were adjusted for both potential confounders and MVPA time (Model 4), compared to Couch potatoes, the differences in Breakers for 2-h insulin, fasting

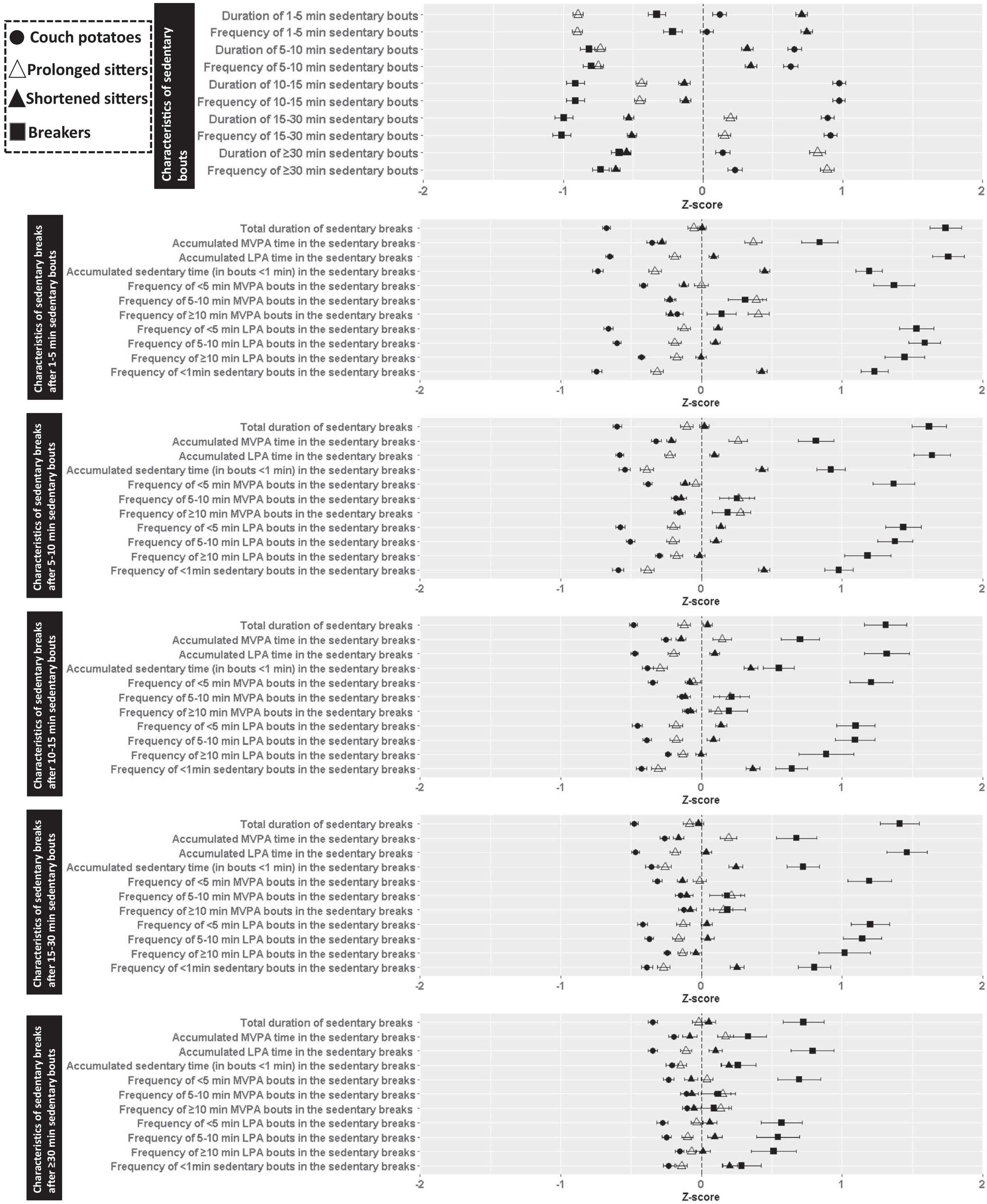

FIGURE 2 *Z*-scores with 95% confidence intervals of the 65 variables characterizing how sedentary time was accumulated and interrupted among the four distinct groups of participants

serum insulin, triglycerides, 2-h glucose, and all adiposity measures did not reach the level of significance. Similar patterns of associations were observed when the analyses were repeated after excluding those participants who had hypertension, heart diseases, and/or diabetes (see Supplementary File, Table S1, and Table S2).

TABLE 3 Linear regression analysis of the association (percentage difference with 95% confidence intervals (CI)) between the four distinct groups and cardiometabolic biomarkers

			Prolonged sitters vs. Couch potatoes		Shortened sitters vs. Couch potatoes		Breakers vs. Couch potatoes	
Cardiometabolic outcome	**Model**	***n***	**%difference (95% CI)**	***p*-value**	**%difference (95% CI)**	***p*-value**	**%difference (95% CI)**	***p*-value**
2-h insulin	Unadjusted model	3822	**−8.1 (−13.8, −2.0)**	**.011**	**−12.6 (−17.8, −7.1)**	**<.001**	**−23.5 (−29.7, −16.8)**	**<.001**
	Model 1	3373	−5.2 (−11.5, 1.5)	.129	**−11.8 (−17.4, −6.0)**	**<.001**	**−25.0 (−31.5, −18.0)**	**<.001**
	Model 2	2917	−4.1 (−10.7, 3.0)	.258	**−10.0 (−15.9, −3.7)**	**.002**	**−24.3 (−31.3, −16.6)**	**<.001**
	Model 3	2917	−3.2 (−10.0, 4.0)	.372	−6.2 (−12.9, 1.0)	.088	**−18.5 (−26.9, −9.0)**	**<.001**
	Model 4	2917	3.6 (−3.6, 11.2)	.342	**−6.5 (−12.5, −0.1)**	**.048**	−6.9 (−15.8, 2.8)	.157
Fasting serum insulin	Unadjusted model	4348	−4.2 (−8.6, 0.5)	.077	**−13.6 (−17.4, −9.7)**	**<.001**	**−13.2 (−18.4, −7.8)**	**<.001**
	Model 1	3804	−3.3 (−8.0, 1.5)	.168	**−13.8 (−17.7, −9.8)**	**<.001**	**−15.5 (−20.7, −9.9)**	**<.001**
	Model 2	3258	−0.7 (−5.6, 4.5)	.788	**−11.3 (−15.5, −6.9)**	**<.001**	**−13.2 (−18.9, −7.1)**	**<.001**
	Model 3	3258	0.1 (−4.9, 5.3)	.963	**−8.0 (−12.7, −3.0)**	**.002**	**−7.6 (−14.4, −0.1)**	**.047**
	Model 4	3258	4.6 (−0.5, 10.1)	.080	**−8.8 (−13.1, −4.4)**	**<.001**	−0.3 (−7.1, 7.0)	.928
Triglycerides	Unadjusted model	4409	**−5.2 (−8.7, −1.4)**	**.008**	**−11.1 (−14.3, −7.8)**	**<.001**	**−12.9 (−17.1, −8.3)**	**<.001**
	Model 1	3857	**−5.1 (−8.8, −1.3)**	**.009**	**−9.5 (−12.8, −6.1)**	**<.001**	**−14.4 (−18.7, −10.0)**	**<.001**
	Model 2	3306	−1.5 (−5.4, 2.7)	.481	**−6.7 (−10.2, −3.0)**	**.001**	**−11.3 (−16.1, −6.3)**	**<.001**
	Model 3	3305	−0.8 (−4.9, 3.5)	.706	−3.8 (−7.9, 0.4)	.074	**−6.6 (−12.3, −0.5)**	**.036**
	Model 4	3305	1.7 (−2.5, 6.0)	.435	**−5.2 (−8.8, −1.4)**	**.008**	−3.4 (−8.9, 2.3)	.237
Total/HDL cholesterol	Unadjusted model	4408	**−2.8 (−4.9, −0.6)**	**.013**	**−6.9 (−8.8, −5.0)**	**<.001**	**−7.5 (−10.1, −4.9)**	**<.001**
	Model 1	3856	**−3.2 (−5.3, −1.1)**	**.003**	**−5.4 (−7.3, −3.5)**	**<.001**	**−9.2 (−11.7, −6.7)**	**<.001**
	Model 2	3304	−1.8 (−4.0, 0.5)	.119	**−4.1 (−6.1, −2.1)**	**<.001**	**−8.2 (−11.0, −5.4)**	**<.001**
	Model 3	3304	−1.5 (−3.7, 0.8)	.200	**−2.8 (−5.1, −0.5)**	**.019**	**−6.0 (−9.2, −2.7)**	**<.001**
	Model 4	3304	0.2 (−2.1, 2.5)	.862	**−3.1 (−5.2, −1.0)**	**.004**	**−3.1 (−6.2, −0.1)**	**.049**

(Continues)

TABLE 3 (Continued)

Cardiometabolic outcome	Model	*n*	Prolonged sitters vs. Couch potatoes		Shortened sitters vs. Couch potatoes		Breakers vs. Couch potatoes	
			%difference (95% CI)	*p*-value	%difference (95% CI)	*p*-value	%difference (95% CI)	*p*-value
LDL/HDL cholesterol	Unadjusted model	4409	**−3.8 (−6.9, −6.8)**	**.018**	**−9.4 (−12.2, −6.7)**	**<.001**	**−10.6 (−14.3, −6.9)**	**<.001**
	Model 1	3857	**−4.1 (−7.1, −1.0)**	**.010**	**−7.6 (−10.3, −4.8)**	**<.001**	**−13.3 (−16.9, −9.6)**	**<.001**
	Model 2	3305	−2.5 (−5.7, 0.9)	.151	**−6.0 (−9.0, −3.0)**	**<.001**	**−12.4 (−16.3, −8.3)**	**<.001**
	Model 3	3305	−2.1 (−5.4, 1.3)	.229	**−4.4 (−7.7, −1.0)**	**.012**	**−9.6 (−14.2, −4.9)**	**<.001**
	Model 4	3305	0.4 (−3.0, 3.9)	.819	**−4.6 (−7.6, −1.5)**	**.004**	**−5.3 (−9.7, −0.6)**	**.026**
2-h glucose	Unadjusted model	3816	−1.6 (−3.7, −0.6)	.160	**−2.1 (−4.1, −0.1)**	**.046**	**−2.8 (−5.5, −0.1)**	**.05**
	Model 1	3365	−1.8 (−4.1, 0.5)	.130	−2.0 (−4.1, 0.2)	.072	**−3.5 (−6.5, −0.5)**	**.023**
	Model 2	2910	−2.0 (−4.3, 0.5)	.122	−1.7 (−3.9, 0.6)	.149	**−3.9 (−7.1, −0.7)**	**.017**
	Model 3	2910	−1.5 (−3.9, 1.0)	.230	0.3 (−2.2, 2.8)	.812	−0.4 (−4.1, 3.5)	.842
	Model 4	2910	−0.6 (−3.1, 1.9)	.662	−1.1 (−3.3, 1.3)	.374	−0.3 (−3.7, 3.4)	.887
Fasting plasma glucose	Unadjusted model	4323	−0.5 (−1.5, 0.5)	.299	**−2.2 (−3.1, −1.3)**	**<.001**	0.0 (−1.3, 1.3)	.986
	Model 1	3748	−0.4 (−1.5, 0.6)	.342	**−1.7 (−2.6, −0.7)**	**.001**	−0.6 (−2.0, −0.7)	.401
	Model 2	3241	0.2 (−0.9, 1.3)	.711	**−1.1 (−2.1, −0.1)**	**.032**	0.4 (−1.1, 1.8)	.617
	Model 3	3241	0.3 (−0.8, 1.4)	.584	−0.7 (−1.8, 0.4)	.235	1.1 (−0.5, 2.8)	.177
	Model 4	3241	0.6 (−0.5, 1.7)	.262	−0.9 (−1.9, 0.1)	.084	1.5 (0.0, 0.03)	.055

Couch potatoes were considered as the unhealthiest profile and selected as the referent group. Unadjusted models included only group membership. Model 1 was partially adjusted for age, sex, education, employment, and marital status, and Model 2 was further adjusted for medication use, health-related quality of life score, smoking, alcohol consumption, and income. Model 3 was additionally adjusted for total sedentary time, and Model 4 for total MVPA time. Significant associations are shown in bold.

4 | DISCUSSION

The present study is the first one to investigate the association of patterns of accumulation of sedentary time and sedentary breaks with cardiometabolic health markers among a large population-based sample of middle-aged adults using a cluster analysis approach. We found four unique accumulation patterns, including "Couch potatoes," "Prolonged sitters," "Shortened sitters," and "Breakers." We considered Couch potatoes the unhealthiest accumulation patterns, since they had the highest amount of sedentary time with less frequent interruptions and with relatively shorter physical activity bouts compared to the other three groups. Compared with Couch potatoes, Breakers characterized by avoiding uninterrupted sedentary bouts had the lowest level of cardiometabolic health indicators, followed by Shortened sitters characterized by avoiding prolonged sedentary time of ≥15–30 min. After adjustments for all potential confounders, Prolonged sitters, characterized by accumulating their sedentary time in ≥15–30 min bouts, had no significant differences across all the cardiometabolic outcomes examined compared with Couch potatoes. From distinguished differences across accumulation pattern profiles, it appeared that restricting sedentary time to <15–30 min in duration by physical activity of any intensity and duration could be beneficial for cardiometabolic health in adults.

TABLE 4 Linear regression analysis of the association (percentage difference with 95% confidence intervals (CI)) between the four distinct groups and adiposity measures

			Prolonged sitters vs. Couch potatoes		Shortened sitters vs. Couch potatoes		Breakers vs. Couch potatoes	
Adiposity measure	**Model**	***n***	**%difference (95% CI)**	***p*-value**	**%difference (95% CI)**	***p*-value**	**%difference (95% CI)**	***p*-value**
Body fat	Unadjusted model	4344	**−1.7 (−2.9, −0.5)**	**.005**	**−2.2 (−3.2, −1.1)**	**<.001**	**−5.6 (−7.0, −4.2)**	**<.001**
	Model 1	3872	−1.1 (−2.1, 0.0)	.053	**−3.5 (−4.5, −2.6)**	**<.001**	**−5.3 (−6.6, −3.9)**	**<.001**
	Model 2	3318	−0.6 (−1.7, 0.5)	.301	**−3.0 (−3.9, −1.9)**	**<.001**	**−4.7 (−6.0, −3.2)**	**<.001**
	Model 3	3318	−0.3 (−1.4, −0.8)	.554	**−1.8 (−3.0, −0.7)**	**.002**	**−2.8 (−4.4, −1.1)**	**.001**
	Model 4	3318	0.8 (−0.3, 1.9)	.176	**−2.2 (−3.2, −1.2)**	**<.001**	−1.1 (−2.7, 0.4)	.156
Fat mass	Unadjusted model	4344	**−3.9 (−7.3, −0.5)**	**<.001**	**−10.1 (−13.2, −7.1)**	**<.001**	**−14.4 (−18.2, −10.3)**	**.025**
	Model 1	3872	−2.5 (−6.0, 1.1)	.176	**−11.5 (−14.4, −8.3)**	**<.001**	**−15.0 (−19.0, −10.9)**	**<.001**
	Model 2	3318	−0.9 (−4.5, 2.9)	.656	**−9.4 (−12.6, −6.1)**	**<.001**	**−13.1 (−17.3, −8.5)**	**<.001**
	Model 3	3318	0.1 (−3.6, 4.0)	.950	**−5.4 (−9.1, −1.6)**	**.005**	**−6.2 (−11.5, −0.7)**	**.029**
	Model 4	3318	3.6 (−0.2, 7.6)	.064	**−7.2 (−10.5, −3.9)**	**<.001**	−2.1 (−7.0, 3.3)	.440
Visceral fat area	Unadjusted model	4344	**−5.2 (−8.2, −1.9)**	**.002**	**−8.9 (−11.7, −5.9)**	**<.001**	**−11.4 (−15.1, −7.5)**	**<.001**
	Model 1	3872	**−3.8 (−7.1, −0.4)**	**.029**	**−10.0 (−12.9, −6.9)**	**<.001**	**−13.2 (−17.1, −9.1)**	**<.001**
	Model 2	3319	−2.0 (−5.5, 1.6)	.274	**−8.1 (−11.1, −4.8)**	**<.001**	**−11.4 (−15.5, −6.9)**	**<.001**
	Model 3	3318	−1.2 (−4.8, 2.4)	.515	**−4.6 (−8.1, −0.9)**	**.015**	**−5.6 (−10.7, −0.2)**	**.042**
	Model 4	3318	2.5 (−1.2, 6.3)	.182	**−5.7 (−8.9, −2.6)**	**.001**	0.0 (−4.9, 5.2)	.985
BMI	Unadjusted model	4425	−1.3 (−2.6, 0.1)	.07	**−3.7 (−5.0, −2.5)**	**<.001**	**−2.4 (−4.0, −0.6)**	**.007**
	Model 1	3872	−0.9 (−2.4, −0.5)	.197	**−3.6 (−4.9, −2.4)**	**<.001**	**−3.5 (−5.4, −1.8)**	**<.001**
	Model 2	3318	−0.3 (−1.7, 1.2)	.699	**−2.8 (−4.1, −1.5)**	**<.001**	**−2.8 (−4.6, −0.9)**	**.005**
	Model 3	3318	0.1 (−1.4, 1.5)	.914	−1.2 (−2.7, 0.3)	.119	0.0 (−2.2, 2.2)	.987
	Model 4	3318	0.9 (−0.5, 2.4)	.202	**−2.2 (−3.4, −0.8)**	**.002**	0.5 (−1.5, 2.6)	.604

(Continues)

TABLE 4 (Continued)

Adiposity measure	Model	*n*	Prolonged sitters vs. Couch potatoes %difference (95% CI)	*p*-value	Shortened sitters vs. Couch potatoes %difference (95% CI)	*p*-value	Breakers vs. Couch potatoes %difference (95% CI)	*p*-value
Waist circumference	Unadjusted model	4402	−0.8 (−2.0, 0.3)	.170	**−3.8 (−4.9, −2.9)**	**<.001**	**−2.4 (−3.7, −0.9)**	**.002**
	Model 1	3854	−0.7 (−1.9, −0.4)	.190	**−3.0 (−4.0, −2.0)**	**<.001**	**−3.9 (−5.3, −2.6)**	**<.001**
	Model 2	3303	−0.1 (−1.3, 1.0)	.809	**−2.3 (−3.3, −1.2)**	**<.001**	**−3.1 (−4.6, −2.7)**	**<.001**
	Model 3	3303	0.1 (−1.0, 1.3)	.818	−1.1 (−2.2, 0.1)	.077	−1.0 (−2.8, 0.6)	.215
	Model 4	3303	1.0 (−0.1, 2.1)	.086	**−1.7 (−2.7, −0.6)**	**.002**	−0.1 (−1.7, 1.5)	.877

Couch potatoes were considered as the unhealthiest profile and selected as the referent group. Unadjusted models included only group membership. Model 1 was partially adjusted for age, sex, education, employment, and marital status, and Model 2 was further adjusted for medication use, health-related quality of life score, smoking, alcohol consumption, and income. Model 3 was additionally adjusted for total sedentary time, and Model 4 for total MVPA time. Significant associations are shown in bold.

Our results for the associations between the accumulation patterns of sedentary time and breaks with cardiometabolic markers appeared to be more consistent compared to previous studies. Several observational studies have investigated the associations of sedentary time and breaks with a similar subset of cardiometabolic health outcomes to those examined here, but with separate inclusion of daily sedentary time and breaks in the statistical analyses.[4,5,30-32] They have consistently reported that less sedentary time and a higher number of sedentary breaks are associated with lower adiposity levels,[4,5,30,32] but they have tended, often contrary to the findings of experimental studies,[3,33,34] to suggest no associations between sedentary breaks with other cardiometabolic biomarkers such as blood glucose, insulin level, triglycerides, and/or cholesterol levels.[4] Relatively weaker or no associations between sedentary breaks and some cardiometabolic markers in previous observational studies could be partially because the true associations were obscured due to separate inclusion of daily sedentary time and breaks in the analyses, given the evolving evidence suggesting that daily movement behaviors are interrelated.[2,6,35] Our results being more consistent with experimental studies might also be attributable in part to the methodological decision to include only those participants who had one full week of accelerometry data.[36] This likely conferred a more accurate estimation of habitual sedentary time and breaks in sedentary time during both weekdays and weekends, and in turn a better distinction between individuals with different profiles.

Prolonged sitters had no significant differences in the cardiometabolic health markers compared to Couch potatoes, when the models were adjusted for all potential confounders, even though their sedentary breaks included more LPA and MVPA time and were longer in duration. This finding, overall, accords with findings of existing studies, likewise reporting that accumulating sedentary time in uninterrupted bouts is detrimentally associated with cardiometabolic health outcomes[37] and mortality risk[38] in adults. However, our results further indicate that longer sedentary breaks after prolonged sedentary bouts, at least to the extent that was performed in this sample of adults, may not alone be adequate to have favorable differences in cardiometabolic health markers compared with Couch potatoes.

Both Breakers and Shortened sitters were associated with favorable differences in cardiometabolic health outcomes compared to Couch potatoes, and Breakers had larger favorable differences in cardiometabolic health markers than Shortened sitters. Additionally, Breakers and Shortened sitters were associated with favorable differences in cardiometabolic health outcomes compared to Couch potatoes even after accounting for potential confounders and sedentary time. These results are collectively in agreement with the existing studies, indicating that, in addition to the total volume of sedentary time, patterns of accumulation of sedentary time may also be related to cardiometabolic health markers and mortality risk in adults.[5,39] Nevertheless, after accounting for potential confounders and MVPA time, compared with Couch potatoes, Shortened sitters were associated with favorable differences in cardiometabolic health outcomes, but the associations between Breakers and the same cardiometabolic health outcomes did not generally reach the significance level. This was not surprising considering that MVPA was a major part of Breakers' PA profile, while Shortened sitters were more active through LPA. These results further support the recent studies, suggesting that, in addition to MVPA, LPA may also confer meaningful cardiometabolic health benefits in adults.[8,40]

There were two distinguishable differences in the underlying accumulation patterns of sedentary time and breaks of Breakers and Shortened sitters compared with other groups. First, these two groups were both engaged in relatively fewer uninterrupted sedentary bouts of ≥15–30 min and simultaneously included more LPA bouts of different lengths in their sedentary breaks. Second, Breakers also had a relatively lower number of shorter sedentary bouts lasting <15 min and, in addition to LPA bouts of different lengths, included more spontaneous MVPA bouts in their sedentary breaks. Currently, little is known about the underlying mechanisms by which prolonged sedentary time may cause detrimental changes to cardiometabolic outcomes.[37] Hence, epidemiological evidence is continuing to accumulate that frequent sedentary breaks could be beneficial for counteracting such detrimental changes to cardiometabolic health markers in adults caused by sedentary time.[3-5,31,32] Experimental studies have generally supported this evidence and shown that avoiding prolonged sedentary bouts with light-intensity activities (eg, walking) could be beneficial for cardiometabolic health in adults.[3] For instance, consistent with our results, a recent study in a sample of adults with type-2 diabetes showed that interrupting sedentary time every 15 min with light-intensity walking could be beneficial for glucose control.[41] This evidence has also been supported by recent compositional-based[6,8] and other studies,[42,43] suggesting that increasing total physical activity volume through LPA can confer both mortality and cardiometabolic health benefits in adults, especially when LPA replaces sedentary behaviors.[8,44] Our results, while supporting this evolving evidence,[4,5,30-32] further indicate that in addition to more sedentary breaks it is also important to keep the sedentary bouts shorter than 15–30 min for better cardiometabolic health.

Breakers had the highest MVPA time in their sedentary breaks, but mostly performed their MVPA in bouts of <5 min. Although the number of longer MVPA bouts (5–10 and ≥10 min) was overall low, Prolonged sitters had a comparable number of MVPA bouts lasting for 5 min or more in their sedentary breaks as compared to Breakers, and the total amount of MVPA time in their sedentary breaks was relatively lower. These results collectively suggest that accumulating more MVPA time in between sedentary bouts may confer favorable differences on cardiometabolic health markers, even if accumulated sporadically in bouts lasting <5 min. In agreement with our results, several studies have consistently shown that overall, more active behaviors (LPA and/or MVPA) could be beneficial for cardiometabolic health in adults, either accumulated sporadically or in sustained bouts.[42,43] More similarly to our study, an experimental study among healthy adults reported that breaking up prolonged sitting regularly with short bouts of PA was more effective (9 h sitting interrupted by 18 PA breaks, each lasting for 1 min and 40 seconds) for lowering postprandial glucose and insulin concentrations in comparison with a single continuous bout of PA (30-min physical activity before 9-h sitting).[33] In many situations, such as at work and during leisure time, sedentary breaks with higher intensity physical activities and of longer duration may not be feasible for adults.[3,40] Therefore, a possible implication of our results could be that to achieve a better cardiometabolic profile, health promotion efforts would consider encouraging adults to more frequently break up their sedentary time with any active behavior of any duration, while simultaneously stressing the importance of avoiding prolonged sedentary bouts.

Strengths of this study include the relatively large population-based sample of adults and the wide range of cardiometabolic health markers, including both cardiometabolic biomarkers and adiposity measures. Additionally, movement behaviors were assessed with raw accelerometry and quantified using a robust analytical approach.[17] Creating profiles using both weekdays and the weekend (one full week of valid accelerometry data) for all participants, potentially resulting in better estimation of habitual activities in the population,[36] is also a strength. One limitation of the study is the cross-sectional design, which limits the inference about the causality of associations with cardiometabolic health markers. The findings of this study therefore need to be verified using prospective study designs. Additionally, given that this is observational data, we cannot completely rule out concerns around reverse causality because undiagnosed diseases may have still played a role in altering patterns of accumulation of sedentary time and breaks for some participants. To address this possibility, we repeated the regression analyses after excluding those participants who had hypertension, heart problems, and/or diabetes in sensitivity analyses, and similar patterns of associations were observed. Also, our adjustment for potential confounders only had a modest impact on the associations, but unmeasured confounding remains a possibility.

Due to the birth cohort setting, the study sample was homogenous in terms of age and ethnicity. This may limit the generalizability of our study results to more diverse populations. Allowing for <1-min sedentary bout in between sedentary breaks may also be a limitation because, although still unknown,[3] even such a short sedentary bout in between physical activities may potentially have implications on cardiometabolic health. The concept of Breakers, Prolonged sitters, and Couch potatoes has been theorized and investigated previously in the existing literature,[20] but Shortened sitters is rather a novel activity profile that was found here. Similar studies should be performed with other populations to determine whether similar profiles to those identified here, particularly Shortened sitters, exist in other populations, and whether similar associations between the profiles and cardiometabolic health outcomes could be found. Although accelerometer wear-time was high in this study, only accelerometer data during awake time were explored. Since sleep patterns and duration might affect waking activities,[45] further studies with 24-h accelerometry and characterization of sleep patterns are needed to warrant our findings.

5 | PERSPECTIVES

Avoiding uninterrupted sedentary bouts of longer than 15–30 min by breaking them frequently with short LPA bouts may be beneficial for cardiometabolic health in middle-aged adults. In addition to LPA bouts, further inclusion of spontaneous MVPA bouts in the sedentary breaks may confer additional cardiometabolic health benefits for adults. Health promotion efforts may therefore consider encouraging adults to more frequently break up their sedentary time with any active behavior from light-intensity upwards.

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CONFLICT OF INTEREST

The authors declare that they have no competing interests.

DATA AVAILABILITY STATEMENT

The datasets analyzed in the present study are available from the NFBC Project Centre repository upon request, https://www.oulu.fi/nfbc/materialrequest.

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REFERENCES

1. Grgic J, Dumuid D, Bengoechea EG, et al. Health outcomes associated with reallocations of time between sleep, sedentary behaviour, and physical activity: a systematic scoping review of isotemporal substitution studies. *Int J Behav Nutr Phys Act*. 2018;15(1):69.
2. Rosenberger ME, Fulton JE, Buman MP, et al. The 24-hour activity cycle: a new paradigm for physical activity. *Med Sci Sports Exerc*. 2019;51(3):454-464.
3. Chastin SFM, Egerton T, Leask C, Stamatakis E. Meta-analysis of the relationship between breaks in sedentary behavior and cardiometabolic health. *Obesity*. 2015;23(9):1800-1810.
4. Healy GN, Matthews CE, Dunstan DW, Winkler EAH, Owen N. Sedentary time and cardio-metabolic biomarkers in US adults: NHANES 2003–06. *Eur Heart J*. 2011;32(5):590-597.
5. Carson V, Wong SL, Winkler E, Healy GN, Colley RC, Tremblay MS. Patterns of sedentary time and cardiometabolic risk among Canadian adults. *Prev Med (Baltim)*. 2014;65:23-27.
6. Chastin SFM, Palarea-Albaladejo J, Dontje ML, Skelton DA. Combined effects of time spent in physical activity, sedentary behaviors and sleep on obesity and cardio-metabolic health markers: a novel compositional data analysis approach. *PLoS One*. 2015;10(10):e0139984.
7. Dumuid D, Pedišić Ž, Stanford TE, et al. The compositional isotemporal substitution model: a method for estimating changes in a health outcome for reallocation of time between sleep, physical activity and sedentary behaviour. *Stat Methods Med Res*. 2019;28(3):846-857.
8. Farrahi V, Kangas M, Walmsley R, et al. Compositional associations of sleep and activities within the 24-h cycle with cardiometabolic health markers in adults. *Med Sci Sports Exerc*. 2021;53(2):324-332.
9. Verswijveren SJJM, Lamb KE, Leech RM, et al. Activity accumulation and cardiometabolic risk in youth: a latent profile approach. *Med Sci Sport Exerc*. 2020;52(7):1502-1510.
10. Gupta N, Hallman DM, Dumuid D, et al. Movement behavior profiles and obesity: a latent profile analysis of 24-h time-use composition among Danish workers. *Int J Obes*. 2020;44(2):409-417.
11. Niemelä M, Kangas M, Farrahi V, et al. Intensity and temporal patterns of physical activity and cardiovascular disease risk in midlife. *Prev Med (Baltim)*. 2019;124:33-41.
12. Lee PH, Yu Y-Y, McDowell I, Leung GM, Lam TH. A cluster analysis of patterns of objectively measured physical activity in Hong Kong. *Public Health Nutr*. 2013;16(8):1436-1444.
13. von Rosen P, Dohrn I-M, Hagströmer M. Latent profiles analysis of physical activity and sedentary behaviour with mortality risk: a 15-year follow-up. *Scand J Med Sci Sports*. 2020;30(10):1949-1956.
14. del Pozo CB, McGregor DE, del Pozo CJ, et al. Integrating sleep, physical activity, and diet quality to estimate all-cause mortality risk: a combined compositional clustering and survival analysis of the NHANES 2005–2006 cycle. *Am J Epidemiol*. 2020;189(10):1057-1064.
15. Xu R, Wunsch D. Survey of clustering algorithms. *IEEE Trans Neural Networks*. 2005;16(3):645-678.
16. Farrahi V, Niemelä M, Kärmeniemi M, et al. Correlates of physical activity behavior in adults: a data mining approach. *Int J Behav Nutr Phys Act*. 2020;17(1):94.
17. Vähä-Ypyä H, Vasankari T, Husu P, et al. Validation of cut-points for evaluating the intensity of physical activity with accelerometry-based mean amplitude deviation (MAD). *PLoS One*. 2015;10(8):e0134813.
18. Choi L, Liu Z, Matthews CE, Buchowski MS. Validation of accelerometer wear and nonwear time classification algorithm. *Med Sci Sports Exerc*. 2011;43(2):357-364.
19. Ekblom-Bak E, Olsson G, Ekblom Ö, Ekblom B, Bergström G, Börjesson M. The daily movement pattern and fulfilment of physical activity recommendations in Swedish middle-aged adults: the SCAPIS pilot study. *PLoS One*. 2015;10(5):e0126336.
20. Tremblay MS, Aubert S, Barnes JD, et al. Sedentary behavior research network (SBRN) - terminology consensus project process and outcome. *Int J Behav Nutr Phys Act*. 2017;14(75).
21. Jensky-Squires NE, Dieli-Conwright CM, Rossuello A, Erceg DN, McCauley S, Schroeder ET. Validity and reliability of body composition analysers in children and adults. *Br J Nutr*. 2008;100(4):859-865.

22. Kiviniemi AM, Perkiömäki N, Auvinen J, et al. Fitness, fatness, physical activity, and autonomic function in midlife. *Med Sci Sport Exerc*. 2017;49(12):2459-2468.
23. Millán J, Pintó X, Muñoz A, et al. Lipoprotein ratios: physiological significance and clinical usefulness in cardiovascular prevention. *Vasc Health Risk Manag*. 2009;5:757-765.
24. Alberti KGMM, Zimmet PZ. Definition, diagnosis and classification of diabetes mellitus and its complications. Part 1: diagnosis and classification of diabetes mellitus. Provisional report of a WHO consultation. *Diabet Med*. 1998;15(7):539-553.
25. Kanungo T, Mount DM, Netanyahu NS, Piatko CD, Silverman R, Wu AY. An efficient k-means clustering algorithm: analysis and implementation. *IEEE Trans Pattern Anal Mach Intell*. 2002;24(7):881-892.
26. Mohamad I, Usman D. Standardization and its effects on k-means clustering algorithm. *Res J Appl Sci Eng Technol*. 2013;6(17):3299-3303.
27. Kodinariya TM, Makwana PR. Review on determining number of cluster in k-means clustering. *Int J Adv Res Comput Sci Manag Stud*. 2013;1(6):90-95.
28. Kivimäki M, Singh-Manoux A, Pentti J, et al. Physical inactivity, cardiometabolic disease, and risk of dementia: an individual-participant meta-analysis. *BMJ*. 2019;365:l1495.
29. Owen N, Healy GN, Matthews CE, Dunstan DW. Too much sitting: the population-health science of sedentary behavior. *Exerc Sport Sci Rev*. 2010;38(3):105-113.
30. Healy GN, Dunstan DW, Salmon J, et al. Breaks in sedentary time: beneficial associations with metabolic risk. *Diabetes Care*. 2008;31(4):661-666.
31. Cooper AR, Sebire S, Montgomery AA, et al. Sedentary time, breaks in sedentary time and metabolic variables in people with newly diagnosed type 2 diabetes. *Diabetologia*. 2012;55(3):589-599.
32. Henson J, Yates T, Biddle SJH, et al. Associations of objectively measured sedentary behaviour and physical activity with markers of cardiometabolic health. *Diabetologia*. 2013;56(5):1012-1020.
33. Peddie MC, Bone JL, Rehrer NJ, Skeaff CM, Gray AR, Perry TL. Breaking prolonged sitting reduces postprandial glycemia in healthy, normal-weight adults: a randomized crossover trial. *Am J Clin Nutr*. 2013;98(2):358-366.
34. Dunstan DW, Kingwell BA, Larsen R, et al. Breaking up prolonged sitting reduces postprandial glucose and insulin responses. *Diabetes Care*. 2012;35(5):976-983.
35. Dumuid D, Stanford TE, Martin-Fernández J-A, et al. Compositional data analysis for physical activity, sedentary time and sleep research. *Stat Methods Med Res*. 2018;27(12):3726-3738.
36. Kocherginsky M, Huisingh-Scheetz M, Dale W, Lauderdale DS, Waite L. Measuring physical activity with hip accelerometry among US older adults: How many days are enough? *PLoS One*. 2017;12(1):e0170082.
37. Powell C, Herring MP, Dowd KP, Donnelly AE, Carson BP. The cross-sectional associations between objectively measured sedentary time and cardiometabolic health markers in adults - a systematic review with meta-analysis component. *Obes Rev*. 2018;19(3):381-395.
38. Ekelund U, Tarp J, Steene-Johannessen J, et al. Dose-response associations between accelerometry measured physical activity and sedentary time and all cause mortality: systematic review and harmonised meta-analysis. *BMJ*. 2019;366:l4570.
39. Diaz KM, Howard VJ, Hutto B, et al. Patterns of sedentary behavior and mortality in US middle-aged and older adults: a national cohort study. *Ann Intern Med*. 2017;167(7):465-475.
40. Chastin SFM, De Craemer M, De Cocker K, et al. How does light-intensity physical activity associate with adult cardiometabolic health and mortality? Systematic review with meta-analysis of experimental and observational studies. *Br J Sports Med*. 2019;53(6):370-376.
41. Paing AC, McMillan KA, Kirk AF, Collier A, Hewitt A, Chastin SFM. Dose-response between frequency of breaks in sedentary time and glucose control in type 2 diabetes: a proof of concept study. *J Sci Med Sport*. 2019;22(7):808-813.
42. Glazer NL, Lyass A, Esliger DW, et al. Sustained and shorter bouts of physical activity are related to cardiovascular health. *Med Sci Sports Exerc*. 2013;45(1):109-115.
43. Warburton DER, Bredin SSD. Health benefits of physical activity: a systematic review of current systematic reviews. *Curr Opin Cardiol*. 2017;32(5):541-556.
44. Yates T, Edwardson CL, Henson J, Zaccardi F, Khunti K, Davies MJ. Prospectively reallocating sedentary time: associations with cardiometabolic health. *Med Sci Sports Exerc*. 2020;52(4):844-850.
45. Lakerveld J, Mackenbach JD, Horvath E, et al. The relation between sleep duration and sedentary behaviours in European adults. *Obes Rev*. 2016;17(Suppl 1):62-67.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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