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Patterns and correlates of sedentary behaviour among people with multiple sclerosis: a cross-sectional study

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High levels of sedentary behaviour are associated with poor health outcomes in people with multiple sclerosis (MS). Identifying modifiable correlates of sedentary behaviour for people with MS is essential to design effective intervention strategies to minimise sedentary time. This study aimed to quantify patterns and identify correlates of sedentary behaviour among adults with MS. Fatigue, self-efficacy, walking capability, the physical and psychological impact of MS, health-related quality of life, and participation and autonomy were assessed by questionnaire. Participants wore an activPAL monitor. Total (min/day), prolonged bouts (≥ 30 min) and breaks in sedentary time were calculated. Associations were examined using regression analysis adjusted for demographic and clinical confounders. Fifty-six adults with MS participated (mean ± SD age: 57.0 ± 9.25 years; 66% female). Self-efficacy for control over MS was associated with sedentary time (β = 0.16, 95% CI 0.01, 0.30). Self-efficacy in function maintenance (β = 0.02, 95% CI 0.00, 0.04), health-related quality of life (EuroQol-5D) (β = 31.60, 95% CI 7.25, 55.96), and the autonomy indoors subscale of the Impact on Participation and Autonomy Questionnaire (β = − 5.11, 95% CI − 9.74, − 0.485) were associated with breaks in sedentary time. Future studies should consider self-efficacy, health-related quality of life and participation and autonomy as potential components of interventions to reduce sedentary behaviour.

Sedentary behaviour (SB) is defined as any waking behaviour undertaken in a sitting, lying, or reclining posture that requires no more than 1.5 metabolic equivalents of energy expenditure[1]. SB is linked to negative health outcomes including premature mortality, cardiovascular disease, type 2 diabetes, cancer and obesity[2]. Crucially, the hazards of SB appear most pronounced in physically inactive populations[2].

People with multiple sclerosis (MS) are less physically active and demonstrate higher levels of SB than the general population[3]. In people with MS, SB is associated with higher levels of disability, slower walking speed and lower endurance[4], comorbid conditions such as hypertension [5], and secondary complications including spasms, pain and reduced skin integrity that can compound primary MS symptoms[6]. Additional to total time in SB, the pattern of accumulation may influence health outcomes[7]. Prolonged bouts of sedentary time are associated with higher mortality [8] and deleterious effects on cardiometabolic health in the general population[9,10]. Furthermore, frequent interruptions to sedentary time demonstrate beneficial effects on cardiometabolic risk[11,12]. Accordingly, there has been increasing interest in reducing SB and modifying accumulation patterns as a preventative approach to improve health and manage MS-related symptoms. Understanding the association between specific determinants and sedentary outcomes in people with MS may provide a theoretical underpinning to guide and inform intervention approaches to reduce sedentary behaviour.

Previous studies have found that demographic and clinical characteristics such as MS type, duration, and disability status are related to self-reported sedentary time[13,14]. However, self-reported measures significantly underestimate sedentary time compared to device measures [15] and typically provide estimates of volume, but not patterns of SB. Similarly, studies examining objective SB have reported age, MS type, disease duration, disability status via the Patient Determined Disease Steps (PDDS) scale [16] and fatigue [17] as correlates, with more

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recent research showing associations with Social Cognitive Theory constructs[18]. However, these studies used hip-mounted accelerometers, which characterise sedentary behaviour through periods of inactivity measured by count-based movement thresholds (e.g. < 100 counts per min)[16,18]. Since movement is determined by acceleration rather than body posture they cannot robustly differentiate between sitting and upright positions and may misclassify static postures such as standing as sedentary behaviour[19]. Differentiating between standing, sitting and lying may be particularly important for people with mobility impairment as activities in standing may require significant energy expenditure. Moreover, hip-based accelerometers typically rely on waking hour rather than 24-h measurement protocols and require removal and reattachment for sleeping, showering and aquatic activities. Premature removal or failure to reattach accelerometers may lead to an underestimation of SB. Indeed, SB estimates are more affected by non-wear time compared to physical activity[20].

Thigh worn inclinometers overcome the limitations of hip-mounted accelerometers by directly quantifying postures [21] and are often considered the gold standard for the objective measurement of volume and patterns of SB[22]. One study has explored sedentary behaviour outcomes in people with MS using this recommended measurement tool[23]. To our knowledge, correlates of inclinometer-measured sedentary time and patterns of sedentary time have not been explored in people with MS. This study aimed to quantify patterns of SB among community-dwelling people with MS using a thigh worn inclinometer and identify correlates of SB.

Methods

This study was a cross-sectional analysis of baseline data from the iStep-MS trial, a feasibility randomised controlled trial of a behaviour change intervention, which aimed to increase physical activity and reduce SB in people with MS[24].

Participants. People with MS were recruited from an MS Therapy Centre in England and the MS Society UK website. Inclusion criteria were a self-reported diagnosis of MS, ability to independently walk within the home with or without a walking aid, relapse-free for three months, and free of unstable medical conditions that would make it unsafe to participate in physical activity. Exclusion criteria were pregnancy and ongoing participation in other trials. The College of Health and Life Sciences Research Ethics Committee in Brunel University London (6181-NHS-Apr/2017-7016-2) approved this study. All research was performed in accordance with the Declaration of Helsinki. Informed consent was obtained from all participants.

Sedentary behaviour. Sedentary behaviour was assessed using the activPAL activity monitor (PAL Technologies, Glasgow, UK). The activPAL was waterproofed, attached on the midline, anterior aspect of the upper thigh using a Hypafix dressing and worn 24 h day^{-1}. Data were processed in Stata (StataCorp LP, College Station, Texas) using a validated automated algorithm[25] to separate valid waking wear data from time in bed, non-wear data and invalid data. Heatmaps were created to visually inspect the processed valid and invalid data. Where the algorithm appeared to incorrectly code data as valid/invalid, activity diaries were checked against the heat maps and data were corrected if necessary. Data were considered valid if a day consisted of ≥ 10 h of waking wear data[25]. Participants were required to have at least 2 valid days to be included in the analysis[26]. After identification of valid waking wear data, the following outcomes were calculated: (1) total sedentary time (sitting/lying time in minutes); (2) number of prolonged bouts of sedentary time (sitting/lying bouts lasting ≥ 30 min); (3) number of breaks in sedentary time (defined as a transition from sitting or lying to an upright posture); (4) time in moderate to vigorous physical activity (MVPA) (in min). Sedentary behaviour outcomes and MVPA were averaged over the number of valid wear days.

Independent variables. Fatigue was assessed using the Modified Fatigue Impact Scale (MFIS); higher scores indicated greater impact of fatigue on activities. Self-efficacy was assessed using the Multiple Sclerosis Self-Efficacy Scale (MSSE); higher scores indicated greater self-efficacy. Walking capability was assessed using the 12-item MS Walking Scale (MSWS-12); higher scores indicated poorer walking capability. The physical and psychological impact of MS was assessed using the Multiple Sclerosis Impact Scale (MSIS-29); higher scores indicated greater disease impact on daily function. Health-related Quality of life (HRQOL) was assessed using EuroQol-5D-5L (EQ-5D-5L). The United Kingdom value set was used to calculate a utility score [27]. Participation and autonomy over four domains (autonomy indoors, family role, autonomy outdoors, social life and relationships) was assessed using the Impact on Participation and Autonomy Questionnaire (IPA). The median score was obtained for each participant for each subscale. A detailed description of the measurement of these variables is provided elsewhere[28]. Variable scoring is outlined in Supplementary Table 1.

Demographic and clinical confounders. The following variables were considered as potential confounders: age (years); body mass index (BMI: kg/m^2), sex (male, female), ethnicity (White, Black, Asian), living arrangement (living alone, living with family/partner), employment (employed, not employed), marital status (married/partnered, not married/partnered), MS type (relapsing–remitting, secondary progressive, primary progressive or unknown), disease duration (years), disability status (Expanded Disability Status Scale (EDSS) 1.0–4.0 or 4.5–6.5) and falls history (non-fallers i.e. no self-reported falls in preceding 12 months, or fallers i.e. ≥ 1 falls in previous 12 months).

Data analysis. Statistical analyses were performed using Stata, version 16.0. Data distribution was examined using histograms, Q–Q plots and cross-tabulations. Data are summarized as mean, standard deviation, median, minimum, maximum, frequencies and proportions as appropriate. Regression analysis was used to examine (1)

	n (%)	Mean (SD)	Range
Age (years)	56	57.0 (9.25)	37–74
Women	37 (66)		
Ethnicity			
White	50 (89.3)		
Black	3 (5.36)		
Asian	3 (5.36)		
Living arrangement			
Lives alone	6 (10.71)		
Lives with partner/spouse/family member	50 (89.29)		
Employment status			
Employed	19 (33.93)		
Not employed	37 (66.07)		
Marital status			
Married/partnered	45 (80.36)		
Not married/partnered	11 (19.64)		
BMI (kg m^2)	56	25.9 (4.72)	16.7–39.5
MS duration (years)	55	15.54 (9.95)	1–42
Falls history			
0 falls in previous 12 m	16 (28.57)		
> 0 falls in previous 12 m	40 (71.43)		
Type of MS			
Relapsing–remitting	19 (34)		
Secondary progressive	20 (36)		
Primary progressive	13 (23)		
Unknown	4 (7)		
EDSS			
1.0–4.0	15 (27)		
4.5–6.5	41 (73)		

Table 1. Participant characteristics. *SD* standard deviation, *BMI* body mass index, *MS* multiple sclerosis, *EDSS* Expanded Disability Status Scale.

the associations between demographic and clinical characteristics and SB outcomes (2) the associations between each SB outcome (as the dependent variable) and each independent variable. Potential confounding variables were added to each regression model one at a time and included in the final adjusted model if they modified the regression coefficient for the independent variable by > 10%. Interaction terms between the independent variable and EDSS category were separately added to the final models to examine whether the associations between the independent variable and SB outcome were modified by disability status. Finally, as there is mixed evidence that correlates of sedentary behaviour are independent of MVPA in the general population [29], MVPA was added to the final model to assess if correlates of sedentary behaviour in people with MS were independent of MVPA.

Results

Sixty people with MS were recruited. Fifty-six participants were included in the analysis. Three participants did not return their monitor and data from another did not meet the analysis validity criteria. Table 1 displays participant characteristics. Participants had a mixed presentation of MS type and were predominantly female, white and classified in EDSS score subgroup 4.5–6.5.

Participants wore the activPAL for a mean ± SD 905.4 ± 71.4 min/day (range 713.3–1040.7 min/day). Sedentary time, bouts and breaks in sedentary time, and MFIS, MMSE, MSIS, EQ-5D-5L and IPA scores are described in Table 2.

Table 3 presents the associations between demographic and clinical characteristics and SB outcomes. People with secondary progressive and primary progressive MS spent more time in sedentary behavior than those with relapsing remitting MS. People with secondary progressive MS also had more prolonged bouts and fewer breaks in sedentary time than those with relapsing–remitting MS ($p = 0.007$ and $p = 0.039$). Participants of Asian ethnicity had fewer breaks in sedentary time than White participants ($p = 0.039$). No other associations were demonstrated. Sedentary outcomes based on demographic and clinical characteristics are described in Supplementary Table 2.

Sedentary time. No associations with sedentary time (min/day) were demonstrated (Table 4). After adjustment for confounders, the MMSE control subscale was associated with sedentary time ($\beta = 0.16$, 95% CI 0.01, 0.30, $p = 0.042$). A one-unit increase in MMSE control score, indicating greater confidence to manage disease

	n = 56 Mean (SD)
Average sedentary time (min/day)	604.47 (107.55)
Average sedentary time as % of waking wear time (%)	67.07 (12.94)
Average prolonged bouts (≥ 30 min) of sitting/lying (n/day)	5.90 (1.67)
Average number of breaks in sitting per day (n/day)	49.58 (17.72)
Average MVPA time (min/day)	32.46 (28.03)
MFIS cognitive subscale (score 0–40)	16.88 (9.80)
MFIS physical subscale (score 0–36)	22.01 (8.12)
MFIS psychosocial subscale (score 0–8)	3.83 (2.10)
MFIS total score (score 0–84)	42.73 (18.26)
MMSE control subscale (score 90–900)	579.64 (200.19)
MMSE function subscale (score 90–900)	661.96 (201.08)
MSWS-12 total score (%)	74.37 (20.20)
MSIS-29 physical (0–100)	42.63 (21.55)
MSIS-29 psychological (0–100)	30.55 (19.12)
EQ-5D-5L utility	0.63 (0.19)
IPA: autonomy indoors (score 0–4)	0.64 (0.86)
IPA: family role (score 0–4)	1.32 (0.95
IPA: autonomy outdoors (score 0–4)	1.51 (1.07)
IPA: social life and relationships (score 0–4)	0.46 (0.60)

Table 2. Descriptive statistics of all variables. *MVPA* moderate to vigorous physical activity, *MFIS* Modified Fatigue Impact Scale, *MSSE* Multiple Sclerosis Self-Efficacy Scale, *MSWS-12* Twelve Item MS Walking Scale, *MSIS* Multiple Sclerosis Impact Scale, *EQ-5D-5L* EuroQol-5D-5L, *IPA* Impact on Participation and Autonomy Questionnaire, *SD* standard deviation.

	Sedentary time, (min/day)		Average prolonged bouts (≥ 30 min) of sitting/lying (n/day)		Average number of breaks in sitting per day (n/day)	
	Unadjusted β (95% CI)	p value	Unadjusted β (95% CI)	p value	Unadjusted β (95% CI)	p value
Age (years)	0.16 (− 3.01 to 3.33)	0.922	0.00 (− 0.05 to 0.05)	0.989	− 0.04 (− 0.56 to 0.48)	0.882
Sex	− 6.30 (− 67.69 to 55.09)	0.838	− 0.34 (− 1.29 to 0.61)	0.478	8.82 (− 1.01 to 18.65)	0.078
Ethnicity[a]						
Black	41.64 (− 85.59 to 168.86)	0.514	0.22 (− 1.78 to 2.22)	0.826	− 5.79 (− 26.43 to 14.84)	0.576
Asian	101.23 (− 25.99 to 228.45)	0.116	1.22 (− 0.78 to 3.22)	0.227	− 21.74 (− 42.38 to − 1.10)	0.039
Living arrangement	45.45 (− 47.75 to 138.64)	0.333	0.57 (− 0.88 to 2.02)	0.436	− 0.61 (− 16.10 to 14.88)	0.938
Employment status	− 8.71 (− 70.08 to 52.66)	0.777	− 0.28 (− 1.23 to 0.68)	0.562	5.64 (− 4.36 to 15.64)	0.263
Marital status	22.20 (− 50.74 to 95.14)	0.544	0.42 (− 0.71 to 1.55)	0.462	− 1.34 (− 13.39 to 10.72)	0.825
BMI (kg m^2)	1.36 (− 4.84 to 7.55)	0.663	0.01 (− 0.09 to 0.11)	0.844	− 0.42 (− 1.44 to 0.59)	0.407
MS duration (years)	1.57 (− 1.41 to 4.54)	0.295	0.04 (− 0.01 to 0.08)	0.112	− 0.39 (− 0.88 to 0.09)	0.107
Falls history	9.49 (− 54.83 to 73.80)	0.769	0.13 (− 0.87 to 1.13)	0.799	− 6.11 (− 16.59 to 4.36)	0.247
Type of MS[b]						
SPMS	92.54 (26.97 to 158.10)	0.007	1.14 (0.08 to 2.20)	0.036	− 11.36 (− 22.60 to − 0.12)	0.048
PPMS	77.78 (4.12 to 151.45)	0.039	0.64 (− 0.55 to 1.83)	0.287	− 2.72 (− 15.35 to 9.91)	0.667
Unknown	27.33 (− 85.25 to 139.92)	0.628	0.84 (− 0.98 to 2.66)	0.357	− 2.09 (− 21.39 to 17.21)	0.829
EDSS	0.36 (− 0.66 to 1.38)	0.480	0.36 (− 0.66 to 1.38)	0.480	− 5.51 (− 16.22 to 5.21)	0.308

Table 3. Associations between demographic and clinical characteristics and sedentary behaviour outcomes. [a]Reference group = white. [b]Reference group = relapsing remitting MS.

symptoms, reactions and impact on daily life, was associated with an additional 1.6 min/day of sedentary time. This association remained after controlling for MVPA (β = 0.16, 95% CI 0.02, 0.30, p = 0.023). After adjusting for confounders, there was also weak evidence of an association between sedentary time and MFIS total score (β = − 1.53, 95% CI − 3.08 to 0.02, p = 0.053).

There was evidence, as indicated by the p-value for the interaction term, that EDSS score modified the association between the MFIS physical subscale and sedentary time (p = 0.018) and the association between the MFIS total score and sedentary time (p = 0.030). The MFIS physical subscale and MFIS total score were associated with sedentary time among people with EDSS score 4.5–6.5, but not among those with EDSS score 1.0–4.0 (Table 5).

Dependent variable: sedentary time (min/day)	Unadjusted β (95% CI)	p value	Adjusted β (95% CI)	p value
MFIS cognitive				
Adjusted for EDSS, ethnicity, marital status, MS duration	− 1.31 (− 4.29 to 1.66)	0.380	− 2.66 (− 5.89 to 0.57)	0.104
MFIS physical				
Adjusted for ethnicity, living arrangement, MS type	− 0.17 (− 3.78 to 3.44)	0.380	− 3.30 (− 6.91 to 0.30)	0.072
MFIS psychological				
Adjusted for EDSS, employment, ethnicity living arrangement, marital status, MS duration	2.68 (− 11.30 to 16.66)	0.925	− 1.80 (− 18.80 to 15.21)	0.833
MFIS total				
Adjusted for ethnicity, living arrangement, MS type	− 0.38 (− 1.98 to 1.23)	0.702	− 1.53 (− 3.08 to 0.02)	0.053
MSSE function				
Adjusted for EDSS, ethnicity, MS type	− 0.11 (− 0.26 to 0.03)	0.640	0.01 (− 0.17 to 0.19)	0.913
MSSE control				
Adjusted for ethnicity, living arrangement, MS type	0.02 (− 0.13 to 0.16)	0.112	0.16 (0.01 to 0.30)	0.042
MSWS-12				
Adjusted for employment, ethnicity, falls history, MS type	1.11 (− 0.31 to 2.53)	0.822	0.10 (− 2.00 to 2.20)	0.923
MSIS-29 psychological				
Adjusted for ethnicity, marital status, MS type, sex	0.15 (− 1.38 to 1.69)	0.124	− 0.95 (− 2.56 to 0.66)	0.242
MSIS-29 physical				
Adjusted for EDSS, ethnicity, living arrangement, MS type	0.79 (− 0.56 to 2.13)	0.842	− 0.42 (− 2.06 to 1.23)	0.614
EQ-5D-5L utility				
Adjusted for EDSS, ethnicity MS type	− 116.55 (− 265.67 to 32.57)	0.245	40.60 (− 201.50 to 120.30)	0.614
IPA: autonomy indoors				
Adjusted for EDSS, ethnicity, MS type	26.60 (− 6.67 to 59.86)	0.115	3.39 (− 34.33 to 41.11)	0.857
IPA: family role				
Adjusted for ethnicity, marital status, MS duration, MS type	11.03 (− 19.53 to 41.59)	0.472	− 12.58 (− 45.12 to 19.96)	0.441
IPA: autonomy outdoors				
Adjusted for EDSS, ethnicity, living arrangement, marital status, MS duration, MS type	8.99 (− 18.10 to 36.09)	0.509	− 11.75 (− 45.21 to 21.71)	0.483
IPA: social life and relationships				
Adjusted for ethnicity, MS type, MS duration	35.41 (− 12.37 to 83.18)	0.143	14.85 (− 35.35 to 65.04)	0.555

Table 4. Associations between independent variables and sedentary time.

	β	95% CI	p value
MFIS physical[a]			
EDSS 1.0–4.0	2.01	− 3.60 to 7.61	0.474
EDSS 4.5–6.5	− 6.74	− 11.37 to − 2.11	0.005
MFIS total[a]			
EDSS 1.0–4.0	0.87	− 1.78 to 3.53	0.511
EDSS 4.5–6.5	− 2.85	− 4.84 to− 0.86	0.006

Table 5. Sedentary time interaction analysis by EDSS subgroup. [a]Adjusted for ethnicity, living arrangement, MS type.

For people with EDSS score 4.5–6.5, a 1-unit increase in MFIS physical subscale and total score were associated with a 6.74 min/day (95% CI 2.11–11.37) and 2.85 min/day (95% CI 0.86–4.84) decrease in SB respectively.

Prolonged bouts of sedentary time. Only the IPA social relationships subscale was associated with prolonged bouts of sedentary time ($p = 0.037$; Table 6). However, this association did not remain after adjusting for confounders ($\beta = 0.67$, 95% CI − 0.07, 1.42, $p = 0.077$).There was no evidence that associations between independent variables and prolonged bouts of sedentary time were modified by EDSS score.

Breaks in sedentary time. The MMSE function subscale, the MSIS-29 physical subscale, EQ-5D-5L utility score, the IPA autonomy indoors subscale and the IPA social life and relationship subscale were associated with breaks in sedentary time (Table 7). However, after adjustment for confounders, only the MMSE function subscale ($\beta = 0.02$, 95% CI 0.00, 0.04, $p = 0.032$), EQ-5D-5L utility score ($\beta = 31.60$, 95% CI 7.25, 55.96, $p = 0.012$),

	Unadjusted β (95% CI)	p value	Adjusted β (95% CI)	p value
MFIS cognitive				
Adjusted for EDSS, employment, ethnicity, marital status, MS type	−0.01 (−0.06 to 0.04)	0.632	−0.04 (−0.09 to 0.01)	0.155
MFIS physical				
Adjusted for EDSS, ethnicity, marital status, MS type	−0.01 (−0.06 to 0.05)	0.807	−0.05 (−0.11 to 0.02)	0.153
MFIS psychological				
Adjusted for ethnicity, employment, marital status, sex	0.06 (−0.15 to 0.28)	0.556	0.04 (−0.21 to 0.29)	0.740
MFIS total				
Adjusted for EDSS, employment ethnicity, marital status, MS duration, MS type, living arrangement	0.00 (−0.03 to 0.02)	0.766	−0.02 (−0.05 to 0.01)	0.179
MSSE function				
Adjusted for Ethnicity, MS type	0.00 (0.00 to 0.00)	0.204	0.00 (0.00 to 0.00)	0.926
MSSE control				
Adjusted for EDSS, ethnicity, MS type, marital status	0.00 (0.00 to 0.00)	0.871	0.00 (0.00 to 0.00)	0.174
MSWS-12				
Adjusted for falls history, MS type	0.01 (−0.01 to 0.04)	0.219	0.01 (−0.02 to 0.04)	0.529
MSIS-29 psychological				
Adjusted for ethnicity, MS duration, sex	0.01 (−0.01 to 0.04)	0.207	0.01 (−0.02 to 0.03)	0.533
MSIS-29 physical				
Adjusted for Ethnicity, MS type	0.01 (−0.01 to 0.03)	0.214	0.00 (−0.20 to 0.25)	0.828
EQ-5D-5L utility				
Adjusted for Ethnicity, MS duration, MS type	−1.53 (−3.86 to 0.80)	0.194	−1.01 (−3.64 to 1.63)	0.446
IPA: autonomy indoors				
Adjusted for ethnicity, MS type	0.39 (−0.13 to 0.91)	0.138	0.16 (−0.45 to 0.76)	0.601
IPA: family role				
Adjusted for EDSS, living arrangement, MS duration, MS type	0.11 (−0.37 to 0.58)	0.653	−0.06 (−0.59 to 0.47)	0.828
IPA: autonomy outdoors				
Adjusted for marital status MS type	0.25 (−0.17 to 0.67)	0.231	0.16 (−0.29 to 0.60)	0.486
IPA: social life and relationships				
Adjusted for: MS Type	0.78 (0.05 to 1.50)	0.037	0.67 (−0.07 to 1.42)	0.077

Table 6. Associations between independent variables and prolonged bouts of sedentary time.

and IPA autonomy indoors subscale (β = −5.11 95% CI −9.74, −0.48, p = 0.031) remained associated with breaks in sedentary time. Each 1-unit increase in MMSE function, indicating greater confidence in engaging in daily living activities, was associated with an additional 0.2 breaks in sedentary time/day. A 0.1 increase (i.e. improvement) in EQ-5D-5L utility score was associated with an additional 3.16 breaks/day. Each 1-unit increase in the IPA autonomy indoors subscale (i.e. worse autonomy indoors) was associated with 5.11 fewer breaks in sedentary time/day. After adjustment for MVPA, MMSE function score (β = 0.02, 95% CI −0.01, 0.05, p = 0.122) and IPA autonomy indoors (β = −4.44, 95% CI −9.83, 0.96, p = 0.105) were no longer associated with breaks in sedentary time. EQ-5D-5L utility score remained associated with breaks in sedentary time after adjusting for MVPA (β = 30.17, 95% CI 4.67, 55.66, p = 0.021). There was no evidence that associations between independent variables and breaks in sedentary time were modified by EDSS score.

Discussion

This study quantified inclinometer measured sedentary behaviour and identified correlates in people with MS. Participants spent on average 605 min in sedentary time, had 5.9 prolonged bouts and 49.6 breaks in sedentary time per day. The control subscale of the MMSE was associated with sedentary time. The autonomy indoors subscale of the IPA, the function subscale of the MMSE and the EQ-5D-5L utility score were associated with breaks in sedentary time. No associations were demonstrated for prolonged bouts of sedentary time.

One previous study has explored sedentary behaviour outcomes in people with MS using the activPAL[23]. Participants in Manns (2020) spent on average 626.4 min in sedentary time, had 5.8 prolonged bouts and 54.6 breaks in sedentary time per day which is comparable to the present study. The average number of prolonged bouts of sedentary time are comparable to studies utilising an ActiGraph, which have shown between 4.3, and 6.1 bouts per day [16,30,31]. Inclinometer determined sedentary time was higher than previously described self-report (range 450.9–505.6 min sitting)[13,14,18] and count-based estimates of sedentary behaviour (range 504.5–594 min sedentary time)[16,18,30,32]. The mean number of breaks in sedentary time is also higher than previously reported accelerometer derived breaks which range from 6.9 to 14.7 [16,30,31] but comparable to inclinometer derived breaks in sedentary time in older adults[33,34]. Given the beneficial associations between more frequent interruptions to sedentary time and health markers[11] quantification of sedentary breaks with a measurement tool that can robustly differentiate between sitting and standing postures is important.

	Unadjusted β (95% CI)	p value	Adjusted β (95% CI)	p value
MFIS cognitive				
Adjusted for BMI, EDSS, employment, ethnicity, falls history, MS type	− 0.05 (− 0.54 to 0.44)	0.841	0.33 (− 0.21 to 0.87)	0.223
MFIS physical				
Adjusted for : EDSS, employment, ethnicity, falls history, MS duration, MS type, sex	− 0.15 (− 0.74 to 0.44)	0.615	0.16 (− 0.50 to 0.82)	0.627
MFIS psychological				
Adjusted for EDSS, employment, falls history, MS type, sex	− 0.16 (− 2.47 to 2.15)	0.889	0.96 (− 1.75 to 3.68)	0.481
MFIS total				
Adjusted for BMI, employment, ethnicity, MS type	− 0.05 (− 0.31 to 0.22)	0.729	0.14 (− 0.14 to 0.43)	0.313
MSSE function[a]				
Adjusted for ethnicity	0.03 (0.01 to 0.05)	0.011	0.02 (0.00 to 0.04)	0.032
MSSE control				
Adjusted for employment, ethnicity	0.01 (− 0.01 to 0.04)	0.260	0.00 (− 0.02 to 0.03)	0.878
MSWS-12				
Adjusted for EDSS, employment, ethnicity, falls history, MS duration, MS type, sex	− 0.10 (− 0.34 to 0.14)	0.411	0.02 (− 0.35 to 0.39)	0.915
MSIS-29 psychological				
Adjusted for : Employment, ethnicity, MS duration, MS type, sex	− 0.12 (− 0.37 to 0.13)	0.340	0.01 (− 0.27 to 0.29)	0.961
MSIS-29 physical				
Adjusted for Ethnicity, falls history, MS type	− 0.23 (− 0.45 to − 0.02)	0.035	− 0.16 (− 0.39 to 0.08)	0.192
EQ-5D-5L utility				
Adjusted for Ethnicity	36.65 (13.59 to 59.70)	0.002	31.60 (7.25 to 55.96)	0.012
IPA: autonomy indoors[a]				
Adjusted for Ethnicity, falls history	− 5.95 (− 11.32 to − 0.58)	0.030	− 5.11 (− 9.74 to − 0.48)	0.031
IPA: family role				
Adjusted for Employment, ethnicity, MS duration, MS type, sex	− 2.44 (− 7.46 to 2.58)	0.334	0.87 (− 4.44 to 6.18)	0.743
IPA: autonomy outdoors				
Adjusted for ethnicity, MS type, living arrangement	− 3.98 (− 8.33 to 0.37)	0.072	− 2.03 (− 7.01 to 2.94)	0.415
IPA: social life and relationships				
Adjusted for MS type, sex	− 9.62 (− 17.21 to − 2.03)	0.014	− 7.28 (− 15.35 to 0.80)	0.076

Table 7. Associations between independent variables breaks in sedentary time. [a]Robust standard error.

In line with previous research MS type was associated with the volume and pattern of sedentary behaviour[16]. No other demographic or clinical associations were identified. This contrasts existing research which identifies age, BMI, marital status, employment status, disease duration, and disability status as correlates of self-reported sitting time and Actigraph measured SB in people with MS[13,14,16].

Previous studies have sampled participants with mild-to-moderate mobility disability, who could walk with or without assistive devices. Differences between findings may be attributable at least in part to the different participant characteristics. Moreover, divergent measurement techniques preclude comparison. A limitation of current evidence is the use of self-report and waist worn accelerometry, which estimates SB through a lack of movement rather than postural assessment. Self-report and device-based measures of SB associate differently with health outcomes and risk[15]. Moreover, activPAL and ActiGraph measured sedentary behaviours associate differently with some health markers[35]. Accurate measurement is therefore important to determine the prevalence of SB and associated factors to target in interventions. Future studies should utilize direct assessment of sitting postures to ensure accurate measurement of sedentary behaviour.

In the present study, HRQOL and self-efficacy for function were positively associated with breaks in sedentary time. HRQOL is a multidimensional concept that examines the impact of health status on quality of life. Recent longitudinal research in the general population demonstrates a cumulative and bidirectional relationship between SB and HRQOL, implying that an action in one can result in an effect on the other in a possible virtuous cycle[36]. Indeed interventions that reduce sitting time are associated with improved HRQOL in people with MS[37]. However, targeting increases in HRQOL through interventions such as social cognitive wellness programmes [38] may also represent a mechanism to reduce SB among people with MS.

The positive association between self-efficacy for function (i.e. confidence in performing behaviours associated with engaging in daily living activities) and breaks in sedentary time mirrors analogous associations for self-reported and accelerometer derived sedentary time in people with MS[18]. Recent research in COPD populations demonstrates that baseline self-efficacy contributes to changes in SB[39]. Strategies to increase self-efficacy such as vicarious experience, social persuasion and performance experience of success may therefore represent important intervention strategies for sitting less and moving more. After adjusting for MVPA this association was no longer significant. Self-efficacy is positively associated with physical activity in people with MS and may have attenuated the relationship in this cohort[40].

Enhanced feelings of control and confidence were associated with higher sedentary time in the present study. The MMSE control subscale describes an individual's confidence to manage disease symptoms, reactions and impact on daily activities and contains items on fatigue management and activity regulation. Moreover, interaction analysis indicated higher levels of fatigue were associated with reduced time in a sitting or lying posture in participants with EDSS scores 4.5–6. Sitting represents a commonly used energy conservation strategy in this population where fatigue is a persistent and highly debilitating issue[41,42]. Collectively these results highlight the potential value of utilising sedentary time as a resting or pacing mechanism to control symptoms and reduce fatigue. However, excessive sedentariness may aggravate disease and SB comorbidities in the long term. Future interventions should promote sedentary modification while acknowledging the value of rest and pacing for fatigue and symptom management.

The IPA autonomy indoors subscale which explores the ability to look after oneself and get around the house as wanted was associated with less breaks in sedentary time. Autonomy indoors correlates with physical function [43,44] and activities of daily living (ADLs) performance[45]. Accordingly, low autonomy over self-care and the home environment may limit opportunities to move more and sit less resulting in sedentary time accumulation. Limited research has identified environmental factors [46] and appraisal (i.e. a positive view of situations and the ability to deal with them) [47] as predictors of participation and autonomy among people with MS. Consideration of environmental barriers and their impact on perceived participation and incorporation of interventions that foster positive appraisal, coping styles and empowerment may represent potential strategies to enhance autonomy for performance of ADLs with corresponding benefits to SB.

The cross-sectional study design precludes any inferences of causality between SB and independent variables. Participants were community dwelling, mostly female, and white. Results therefore are not necessarily generalizable to the wider population of people with MS. Furthermore, data is drawn from a self-selecting sample from a behaviour change intervention. It is possible that the sample was biased towards those already engaged in activity or conversely to those who were inactive, which may have impacted the baseline sedentary data.

Understanding of the determinants of sedentary time and pattern may inform future interventions for reducing SB. This study represents an initial step towards classifying modifiable correlates of sedentary time and patterns. Based on our findings, interventions targeting reductions in SB should consider strategies that enhance self-efficacy, foster participation and autonomy and improve perceived health related quality of life domains.

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Author contributions

J.F. and J.M.R. conceived the idea and analysed the data. M.N., A.S., C.K., G.L., W.H., C.V. contributed to the writing and assisted with the interpretation. All authors have read and approved the final manuscript. J.F. completed this work while working at Brunel University London.

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Competing interests

The authors declare no competing interests.

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