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Research Article

Longitudinal Link between E-Bike Commuting and Total Physical Activity Increase

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Abstract

Background: Active commuting is a practical way to increase physical activity (PA). E-cycling elicits moderate-to-vigorous intensity PA (MVPA) with experimental health benefits. Less is known about real-life commuter e-cycling impact on changes in MVPA, total sedentary time (SED-time), fitness and perceived health.

Methods: 33 subjects (min-max: 27-70 years) imminently starting commuter e-cycling were monitored for 3 to 5 months. Declarative measurements in MVPA and SED-time were analyzed by multilevel modeling. Fitness (stress test and adiposity), SF12-v2 and EMAPS scores were pre-post compared.

Results: High and stable adherence to commuter e-cycling averaged 84% (95%CI, 75-91). Mean MVPA increased and plateaued after e-cycling onset, reaching 56.7 MET-h/week (95%CI 49.9-64.3) (+21 MET-h/week over baseline). Larger increases were associated with age and e-cycling volume. High SED-time persisted over time, averaging 8.6 hours/day (95%CI, 8.1-9.) though decreasing for older and initially most sedentary subjects. Cardiorespiratory fitness improved (+0.48 METs, p=0.001) as well as effort perception, heart-rate response, waist-to-height ratio and SF12-v2 Mental Score.

Conclusions: New commuter e-cyclists experience a major increase in MVPA and a persistent high sedentary behavior, associated with benefits in fitness, adiposity and perceived mental health. Results from this pilot study need to be confirmed in larger cohorts overtime.

Keywords: Active commuting; Sedentary behavior; Cardiorespiratory fitness; Multilevel modeling

Introduction

Greater amounts of moderate-to-vigorous physical activity (MVPA) reduce the risk of numerous common and costly diseases in developed countries and improve physical function, mental health and health-related quality of life [1-3]. However, in high-income countries, about a third of adults do not reach MVPA recommended levels [4]. PA should be considered in conjunction with sedentary behavior and cardiorespiratory fitness (CRF) due to their independent, but overlapping, roles in health [5-7].

Transport-related PA (hereinafter called active commuting) may overcome a reported major constraint on participation in PA which is lack of time for leisure PA [8], while being associated with positive health status [9]. Traditional methods of active commuting such as walking or conventional cycling are now surrounded by e-cycling, which elicits higher enjoyment scores and less exertion [10], represents a moderate intensity PA around 5.6 METs [11] and may increase physiological responses [12].

Limited evidence exists for how commuter e-cycling onset is related to health changes in real-life settings. This supported the need to conduct a pilot multidimensional longitudinal study on a cohort of new commuter e-cyclists. The primary goal was to evaluate whether and how MVPA (primary outcome), sedentary time (SED-time), fitness, physical and mental perceived health, and PA motivation (secondary outcomes) evolved over time. The secondary goal was to explore inter and intra-individual covariates moderating these changes for a better understanding.

Methods

Study Design and Setting

A pilot prospective single-center cohort study of new e-cyclists was carried out. Inside the urban community of Clermont-Ferrand (France) and between March to May 2017, customers buying or renting an e-bike, or receiving a free e-bike loan, were invited to take part in the study. Baseline wave of measurement was collected immediately before e-cycling onset (T0), two intermediate waves were collected at one-month intervals (T1 and T2), and last wave was collected 2 months after T2 (endpoint T3). This time spacing was minimal, and if a wave was delayed for one participant, all subsequent waves for the same participant were postponed by the same delay to

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keep the intended minimal time spacings. Measurements for T1, T2 and T3 were eventually carried out respectively on average (SD) at 35 days (6.6), 67 days (6.1) and 141 days (30.2) after T0, with mean T3 treated as study endpoint.

Selection of Participants

Potential participants were included if they: planned to e-cycle with their own means; planned to e-cycle, totally or partially, for commuting; did not e-cycle in the previous 3 months; planned to e-cycle without defined ending; had access to the Internet; were able to fulfil questionnaires; agreed to undergo two clinical visits; and did not have any medical contraindication to perform CRF testing. Out of 58 volunteers screened for eligibility, 33 were included after baseline visit.

Participants' Follow Up

After T0, participants were free to e-cycle in actual conditions. Data were collected either at each of the 4 time points for longitudinal analyses, or at T0 and T3 for pre-post comparisons. Two participants dropped out of the study: one male participant got his e-bike stolen, and one participant gave up e-cycling and quitted, both between T2 and T3. Two other measurements of two distinct participants were missed (one at T1 and one at T2) due to a too long delay in questionnaire completion, not related with any of the measured variables. In total, we collected 128 longitudinal measurements and 31 complete pre-post cases. Description of the completeness and quality of participants follow-up is depicted in Figure 1. Questionnaires were self-administered through LimeSurvey v2.50+ survey tool. Clinical visits were performed at Clermont-Ferrand University hospital (CHU), France.

Longitudinal (4-time points) Data Collection

Total moderate and vigorous physical activity and e-cycling: Total MVPA (in MET-hours/week) was self-reported using the Recent Physical Activity Questionnaire (RPAQ) [13] and assessing retrospectively MVPA over the past 4 weeks. Minor changes were applied to the RPAQ to better suit the target population and to measure e-cycling (see Supplementary Methods). Multiplying participation (hours/week) by the metabolic cost of each activity (in MET) obtained from the PA compendium [14] generated the MVPA scores. Intensity of e-cycling was assigned at 5.6 METs [11]. Total e-cycling was defined as commuting plus recreational rides. E-cycling adherence (binary variable) was defined for T1, T2 and T3 as e-cycling at least once per week during the last 4 weeks.

Sedentary time: SED-time was defined as the total daily time (hours per day, hr/d) while sitting, lying down and expending approximately 1 to 1.5 METs. Participants self-reported their SED-time using the RPAQ supplemented with additional questions (see Supplementary Methods). Adding up spent time for each of sedentary occupations generated SED-time. Very high SED-time was defined as >10 hr/d, high between 7 and 10 hr/d, moderate between 3 and 7 hr/d and low under 3 hr/d.

Pre-post (2 time-points) Data Collection

CRF, perceived exertion, HR pattern: Each participant performed a baseline and endpoint physical submaximal stress test. EvalDM tool and protocol (ActivityLab), a progressive intermittent stepping exercise, estimated indirect CRF in METs [15]. Identical within-person test parameters were used at visit 1 and visit 2 in order to detect intra-individual changes. Classification of CRF by age and sex proposed by Mandsager et al [16] was used for sample description. Effort perception was obtained by the estimation of time limit (ETL, in seconds). Immediately at the end of each exercise level, instantaneous heart rate was measured (in bpm, using Polar H7 belt monitor).

Adiposity markers: Height, weight and waist circumference (WC) were measured by identical operator and material for both visits. Overweight was defined as a body mass index (BMI) > 25 kg/m^2. Overweight was also defined as a Waist-to-height ratio (WHtR, computed by dividing WC by height) > 0.5 for both women and men [17].

Health related quality of life (HRQoL): SF-12v2 questionnaire [18] produced a physical health score (PCS) and a mental health score (MCS) normed for a mean of 50 and a standard deviation of 10 in the general population.

Motivations and barriers to physical activity: EMAPS questionnaire assessed PA motivation in the context of health-oriented behavior [19] by means of the self-determination index (SDI = 2*intrinsic motivation + identified motivation – external motivation – 2*amotivation). In general population, mean SDI has been described at 11.42 [19], with higher score indicating higher motivations. Internal consistency was satisfied with high Cronbach's alphas (0.74-0.95), except for identified (0.57-0.68) and introjected (0.55-0.63) external motivations.

Data analysis

Descriptive statistics are presented as the mean (SD) for normally distributed variables and as the median (interquartile range) for skewed data. When applicable, both p-values and confidence intervals (95%CI) were reported.

Missing data management: E-cycling and adherence were imputed as zero at T3 for the participant who aborted e-cycling between T2 and T3. Other missing data from this participant were considered as Missing At Random (MAR). Missing data from participants who missed one questionnaire, and who stopped due to a stolen e-bike were considered as Missing Completely At Random (MCAR).

Longitudinal analysis: Our approach was based on Repeated-Measures Multilevel Models (RM-MLM) [20,21]. Two-level RM-MLM were fitted to full unbalanced data in MVPA, SED-time and E-cycling, using Maximum Likelihood method on linear mixed effects models. The main hypothesis to be tested was whether and how each outcome changed over time after e-cycling onset. Exploratory analyses were then conducted to identify moderators having a time interaction or a main effect. Repeated measures were positioned at level-1, treated as nested within the individuals (level-2). Continuous time (in days) was modeled at level-1, corresponding to chronological time since e-cycling onset. E-cycling analysis didn't include T0 (null measures), and adherence was described by the percentage of adherent participants and tested with a generalized linear mixed effect model. Detailed procedure is shown in Supplementary Methods. Intraclass

Table 1: E-cycling adherence, frequency, distance and duration over time.

E-cycling adherence, frequency, distance and duration (for commuting and total rides) over time (mean over whole period and at categorical time points T1, T2 and T3), described with the proportion [95%CI] of adherent participants and p-value of the linear temporal trend obtained from a generalized linear mixed effect model, and with means (SD) of e-cycling frequency, distance and duration and p-value of the linear temporal trend obtained from linear mixed effect models.

		Time points			
E-cycling measures	Mean (SD)	T1	T2	T3	p-value (for linear time effect over time)
Commuting rides (% of n [95%CI])	84% [75,91]	81% [63,92]	84% [66,94]	88% [73,97]	0.14
All rides (% of n [95%CI])	96% [89,99]	97% [82,99]	93% [78,99]	97% [82,99]	0.41
Single e-bike commuting rides (mean (SD) in n/week)	5.4 (5.0)	4.7 (4.0)	5.7 (6.0)	5.7 (5.0)	0.25
Single e-bike total rides (mean (SD) in n/week)	6.7 (4.9)	6.0 (3.9)	6.8 (5.7)	7.4 (5.1)	0.13
Commuting rides (mean (SD) km per week)	34.8 (30.2)	32.1 (27.9)	31.1 (28.8)	41.5 (33.6)	0.03
Total rides (mean (SD) km per week)	52.2 (35.8)	50.8 (37.9)	47.1 (31.5)	58.8 (37.9)	0.078
Commuting rides (mean (SD) minutes per week)	93.4 (79.7)	83.7 (64.6)	97.6 (96.3)	107.8 (75.7)	0.042

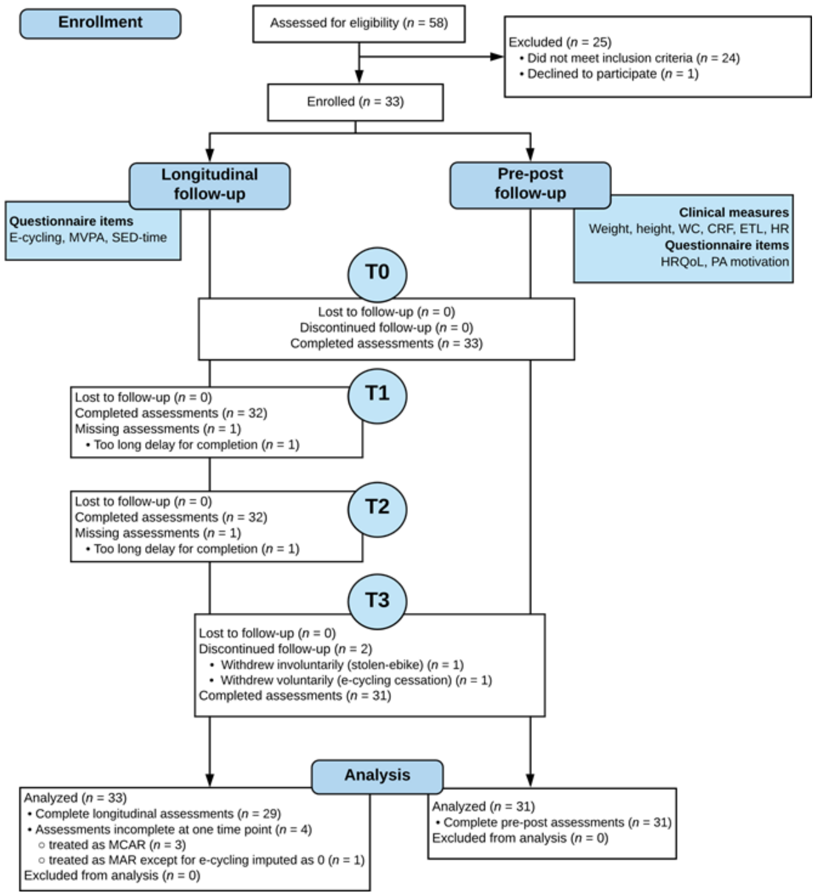

Figure 1: Flow diagram.

Flow diagram of the progress through the longitudinal phases of the study (MVPA: total moderate to vigorous physical activity, SED-time: total sedentary time, WC: waist circumference, CRF: cardiorespiratory fitness, ETL: Estimation of Time Limit, HR: Heart-Rate pattern, MCAR: missing completely at random, MAR: missing at random).

correlation (ICC) coefficient were estimated from unconditional means model and justified the use of RM-MLM (> 0.25). Time effect was tested through best fitting random intercept unconditional growth models, including quadratic term of time for MVPA and SED-time and linear term of time for E-cycling. For MVPA and SED-time, planned pairwise comparisons were conducted between all categorical time points. Finally, exploratory conditional models were constructed by adding time-invariant covariates (TIC) at level-2 (to explain between-person variability) and time-varying covariates (TVC) at both levels (to explain within and/or between-person variability) (listed in Supplemental Table 1 and with correlation matrix plot in Supplemental Figure 1) in separate univariate models. TVC were disaggregated for within-person and between-person effects. Outcomes' estimates were obtained by successively centering time at

Table 2: Total MVPA and sedentary time at each time point.
Estimates of longitudinal measures in MVPA (total moderate and vigorous physical activity) and SED-time (total sedentary time) at each time point obtained from RM-MLM (repeated-measures multilevel modelling), with p-value of time (unconditional models). Estimates of conditional models from significant covariates effects are also shown. ICC (intraclass correlation coefficients) are calculated from unconditional means models.

	Time points					
	T0	**T1**	**T2**	**T3**		
Outcomes	Estimates (95% CI)	Estimates (95% CI)	Estimates (95% CI)	Estimates (95% CI)	p	ICC (95% CI)
MVPA (MET-h/week)						0.54 (0.33, 0.67)
All (n=33)	35.9 (28.6, 43.0)	45.6 (39.1, 52.2)	52.2 (45.2, 58.8)	56.7 (49.9, 64.3)	p<0.001 quadratic growth over time	
Age ≤ 45 yo (n = 15)	33.3 (22.8, 43.7)	42.0 (32.5, 51.4)	47.3 (37.5, 57.1)	50.3 (39.8, 60.7)	p=0.02 interaction time x age	
Age > 45 yo (n = 18)	38.6 (29.7, 58.0)	46.9 (40.4, 66.1)	55.1 (49.5, 76.3)	63.1 (61.7, 90.2)		
Average commuter e-cycling < mean (n = 19)	39.2 (29.9, 48.5)	44.2 (35.7, 52.7)	47.7 (38.8, 56.5)	51.7 (42.2, 61.2)	p=0.017 interaction (time+time^2) x commuter e-cycling	
Average commuter e-cycling ≥ mean (n = 14)	31.3 (17.1, 45.6)	47.6 (34.5, 60.7)	57.9 (44.3, 71.4)	64.6 (50.3, 78.9)		
Average total e-cycling < mean (n = 15)	33.0 (23.3, 42.7)	37.1 (28.3, 45.8)	40.0 (30.9, 49.1)	43.8 (34.0, 53.5)	p=0.033 interaction (time+time^2) x total e-cycling	
Average total e-cycling ≥ mean (n = 18)	38.2 (25.1, 51.3)	52.8 (41.1, 64.7)	62.1 (49.8, 74.4)	68.4 (55.3, 81.5)		
SED-time (hours/day)						0.35 (0.15, 0.50)
All (n=33)	9.0 (8.3, 9.6)	8.5 (8.0, 9.1)	8.3 (7.8, 8.9)	8.6 (8.0, 9.3)	p=0.04 quadratic growth over time	
Age ≤ 45 yo (n = 15)	9.2 (8.2, 10.1)	9.0 (8.3, 9.7)	8.9 (8.1, 9.8)	9.2 (8.2, 10.1)	p=0.04 interaction time x commuter e-cycling	
Age > 45 yo (n = 18)	8.8 (7.6, 10.1)	8.1 (7.1, 9.0)	7.8 (6.6, 8.9)	8.3 (7.1, 9.6)		
Initial SED-time > 9 h/d (n=14)	10.2 (9.1, 11.3)	9.5 (8.6, 10.5)	9.0 (8.1, 10.0)	8.5 (7.2, 9.7)	p<0.001 interaction time x initial SED-time	
Initial SED-time ≤ 9 h/d (n=19)	8.0 (7.3, 8.8)	7.9 (7.3, 8.5)	8.0 (7.3, 8.6)	8.7 (7.9, 9.4)		
Average commuter e-cycling < mean (n = 19)	8.6 (7.8, 9.4)	8.2 (7.5, 8.8)	8.0 (7.3, 8.7)	8.3 (7.5, 9.0)	p=0.027 average commuter e-cycling main effect	
Average commuter e-cycling > mean (n = 14)	9.4 (8.5, 10.4)	9.0 (8.1, 10.0)	8.8 (7.9, 9.8)	9.1 (8.2, 10.1)		

each time point. After fitting every model, residuals were checked for normality and homoscedasticity by visual assessment of Q-Q plots and these assumptions were satisfied.

Pre-post analysis: Changes in pre-post data collection were tested using two-tailed Student's paired. Normality was checked using histograms plotting and Shapiro-Wilk test. P-values were corrected with Benjamini-Hochberg's method and 95%CI with Bonferroni's method. Two-level RM-MLM was used to compare HR patterns.

Results

Participant Characteristics

Participants (n=33) were 19 females and 14 males, with a mean age of 46.2 (10.9) years (min: 27, max: 70). Among active workers (n=27), median commuting distance was 6.0 (5.5) km, and sedentary occupation (i.e. working in sitting position most of the time) was the most common one (68%). 23 participants did not ride a conventional bicycle in the last 3 months, one did in a regular basis and others occasionally.

E-cycling

Commuter and total e-cycling are described in Table 1. Average adherence reached 84% for commuting and 96% for total rides. Positive linear time effects were found for commuting distance (ß = 0.11, SE = 0.05, p = 0.030) and duration (ß = 0.25, SE = 0.12, p = 0.042), representing an increase in commuter e-cycling of approximately 7 min per month after T1. At T3, participants were e-cycling on average 2 hr and 36 min per week, of which 67% for commuting. Correlations between average commuter e-cycling and covariates (Supplemental Figure 1), suggested that the less active and most sedentary participants at baseline, had then higher average commuter e-cycling level.

MVPA

A positive linear time effect for MVPA was found at T0 (ß$_{1(T0)}$ = 0.33, SE = 6.4e-2, p < 0.001) along with a negative quadratic time effect (ß$_2$ = -1.2e-3, SE = 3.7e-4, p = 0.002). Thus, MVPA increased concavely after e-cycling onset reaching a vertex at theoretically day 137, plateauing until endpoint. Graphical representation of the model is shown in Figure 2 and estimates in Table 2. Average MVPA increased by 21.2 MET-hr/week (95%CI 13.6-28.9) between e-cycling onset (35.9 MET-hr/week) and endpoint (57.1 MET-hr/week). Time and average e-cycling interacted for both commuting (p = 0.017) and total rides (p = 0.033). For total e-cycling, a conditional effect was found at endpoint (ß = 0.21, SE = 0.006, p = 0.001): participants with an average total e-cycling over than observed mean, had a final MVPA level 24.7 MET-hr/week (p < 0.001) higher than those under the mean. At the person-level, e-cycling (TVC) had a positive main effect on MVPA for total rides (ß = 8.8e-2, SE = 1.5e-2, p < 0.001) and commuter rides (ß = 8.2e-2, SE = 2.1e-2, p < 0.001). Thus 0.5 hr/week of commuter e-cycling more than usual led to a MVPA 2.4 MET-hr/week higher than usual.

Age had a time interaction with a conditional effect retrieved

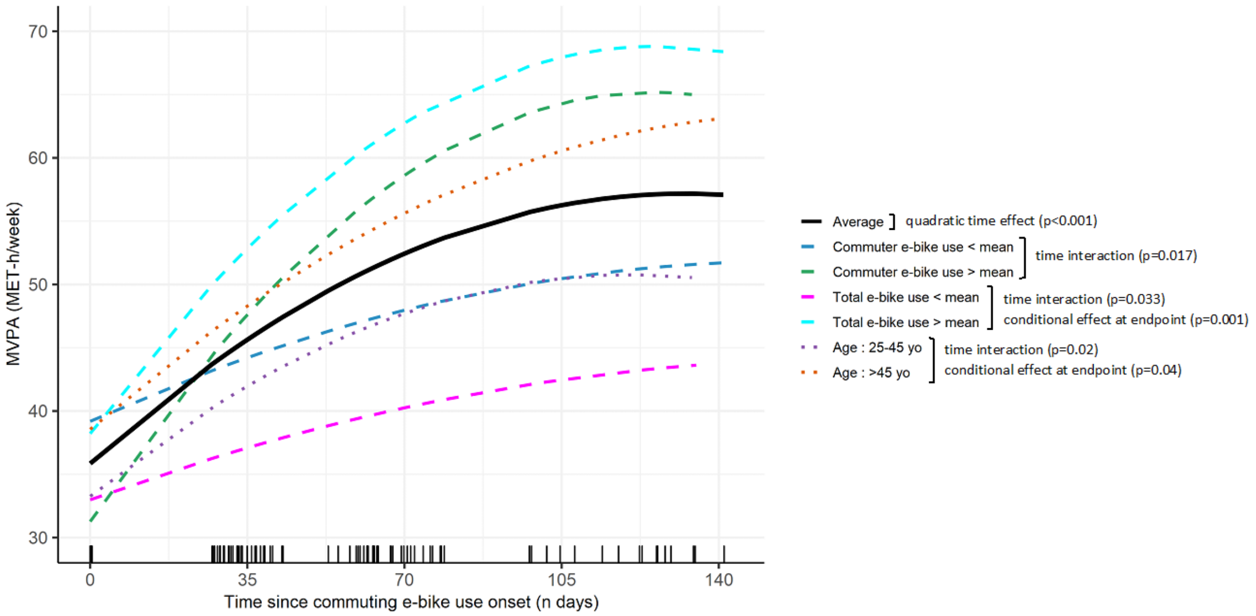

Figure 2: Total MVPA over time.
Estimates of MVPA (total moderate to vigorous physical activity, in MET-h/week) obtained from applying RM-MLM to the longitudinal data. The thick black line represents the population-average changes over time after e-bike use onset (unconditional model), the coloured dashed lines represent the effect (significant main effect or time interaction) of TIC (two-class categorized) in separate conditional models. Rug plot on x-axis shows occurrences of measurement (14 measurements occurred after endpoint and don't figure on the rug plot).

Table 3: Pre-post changes in physical and well-being parameters.
Paired t test assessing pre-post changes in adiposity markers, stress test exercise measures, perceived health and physical activity (PA) motivation (M: mean, SD: standard deviation) for all participants (n = 31) (BMI: body mass index, WC: waist circumference, WHtR: waist-to-height ratio, CRF: cardiorespiratory fitness, ETL: Estimated Time Limit, HRQoL: Health Related Quality of Life, PCS: Physical Component Score, MCS: Mental Component Score, SDI: Self Determination Index).
a) p values are adjusted for multiple comparisons with Hochberg's method,
b) 95% confidence intervals are adjusted for multiple comparisons with Bonferroni's method,
c) Changes are significant for p<0.05.

	Baseline (T0)	Endpoint (T3)	Mean Difference (MD [95%CI])	t	p
Outcomes	M (SD)	M (SD)			
Adiposity markers					
Body weight (kg)	72.3 (16.6)	72.3 (15.9)	-0.41 [-1.5,0.71]	-1.1	0.35
BMI (kg/m²)	25.2 (5.6)	25.1 (5.5)	-0.10 [-0.50,0.27]	-0.95	0.35
WC (cm)	85.5 (14.2)	84.3 (13.8)	-1.2 [-2.4,-0.030]	-3.14	0.020
WHtR	0.51 (0.08)	0.50 (0.08)	-0.010 [-0.014,-5.9e-5]	-3.1	0.020
Stress test exercise measures					
CRF (METs)	9.44 (2.5)	9.93 (2.8)	+0.48 [0.17,0.79]	4.72	<0.001
ETL (seconds)	32.8 (25.7)	61.8 (27.2)	+29 [10.6,47.4]	4.84	<0.001
Perceived health					
HRQoL SF-12v2 PCS	51.2 (7.3)	52.4 (6.3)	+1.2 [-1.6,4.0]	1.3	0.35
HRQoL SF-12v2 MCS	44.6 (9.4)	49.1 (5.9)	+3.5 [0.15,6.8]	3.2	0.020
PA motivation					
EMAPS SDI	10.8 (4.5)	11.8 (4.0)	+1.0 [-0.36,2.4]	2.3	0.12

at endpoint (ß = 0.69, SE = 0.33, p = 0.04) but not at baseline (ß = 6.6e-2, SE = 0.33, p = 0.84), meaning that higher participants' age was associated with a similar MVPA baseline level but a greater increase. Secondly, a positive main effect of initial MVPA was noted (ß = 0.86, SE = 0.10, p < 0.001), meaning that baseline MVPA level differences between individuals tended to persist over time. No further significant effects on MVPA were observed for the other examined covariates.

SED-time

Mean SED-time over whole period was 8.6 hr/d (95%CI 8.1- 9.1) from unconditional means model. A negative linear time effect ($ß_{1(T0)}$ = -1.6e-2, SE = 7.8e-3, p < 0.001) and a positive quadratic one (ß = 1e-4, SE = 5e-5, p = 0.03) were found: SED-time concavely decreased after e-cycling onset until a vertex theoretically at day 82 and then tended to increase up to endpoint (Figure 3, Table 2). Planned comparisons showed that change over time did not exceed 0.7 hr/d.

Average total e-cycling was not a between-person predictor of SED-time, but average commuter e-cycling had a positive main effect on SED-time (ß = 0.011, SE = 5e-03, p = 0.026). Participants who used their e-bike more than 2 hr/week had a SED-time level 0.84 hours higher than the others. Higher baseline SED-time was associated with a larger decline of SED-time, with respective conditional effects at baseline and endpoint of ß = 0.94 (SE = 0.16, p < 000.1) and ß = 0.24 (SE = 0.16, p = 0.15). Participants with very high baseline sedentary behavior (> 9 hr/d) experienced a SED-time decline (d_{T3-T0} = -1.6 (95%CI 1.0-2.3)), catching up a similar level than other participants at endpoint. A time interaction with age showed a negative conditional effect at endpoint (ß = -0.06, SE = 2.9e-2, p = 0.046) but not at baseline. No further differences were observed between SED-time and other covariates except a main effect of sedentary work (ß = 1.5, SE = 0.49, p = 0.005).

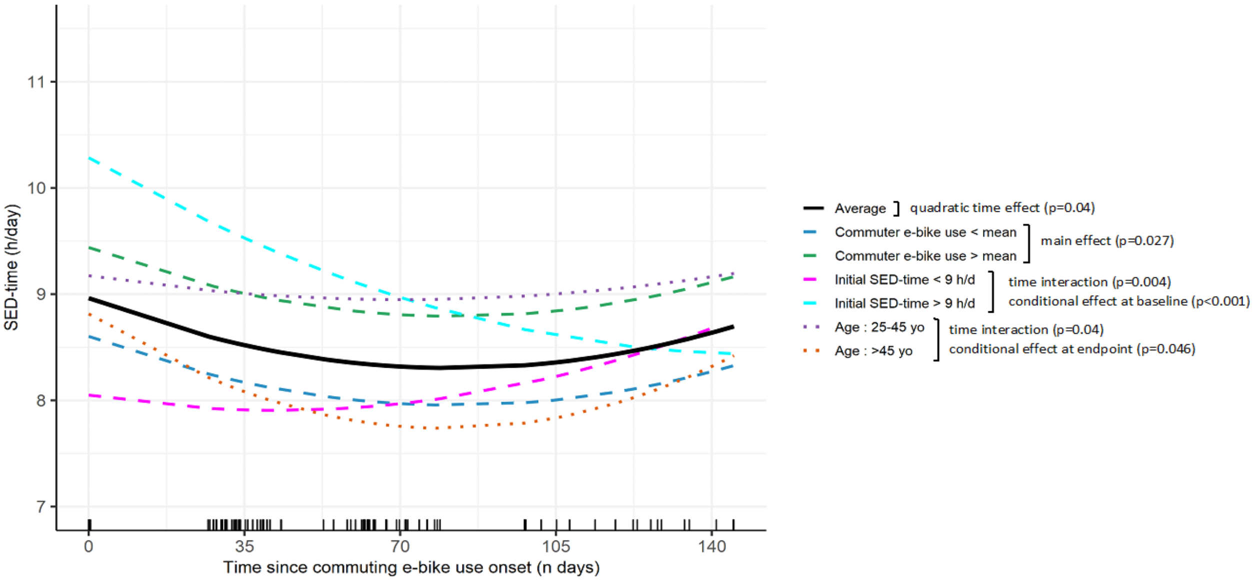

Figure 3: Total sedentary time over time.
Estimates of SED-time (total sedentary time, in h/day) obtained from applying RM-MLM to the longitudinal data. The thick black line represents the population-average changes over time after e-bike use onset (unconditional model), the colored dashed lines represent the effect (significant main effect or time interaction) of TIC (two-class categorized) in separate conditional models. Rug plot on x-axis shows occurrences of measurement (14 measurements occurred after endpoint and don't figure on the rug plot).

For subsequent pre/post comparisons, results are shown in Table 3.

Adiposity Markers

At baseline, around half of participants (13) were overweight based on BMI as well as on WHtR. In total, no clinically and statistically significant difference in BMI was observed between baseline (mean: 25.2 (5.6)) and endpoint (mean: 25.1 (5.5)). A statistically significant decrease in mean WC (-1.2 cm, p = 0.020) was observed.

Exercise Stress Test

At baseline, mean CRF was 9.44 (2.5) METs. Mean CRF improved at endpoint, reaching 9.93 (2.8) METs (+0.48 METs, p < 0.001). 4 participants (13%) experienced an increase of more than 1 METs and 2 participants a less clinically relevant decrease (-0.09 and -0.18 METs). Effort perception for stress test was reduced at endpoint, with a mean increase of + 29 seconds in ETL (p < 0.001). HR patterns indicated a linear increase (ß = 11.6, SE = 0.24, p < 0.001) in HR during the incremental exercise for both visits. A "time of visit" main effect was found between baseline and final visits (ß = -3.2, SE = 0.9, p < 0.001), indicating lower HR (-3.2 bpm in average) over the whole final stress test.

Quality of Life Measures

At baseline, mean HRQoL PCS and MCS were 51.5 (7.3) and 44.49 (9.42), respectively over and under the population-average cut-point. No significant change was found in PCS at T3 (+1.22, p = 0.35), contrary to MCS reaching a mean of 49.1 (5.9) at endpoint (+3.49, p = 0.020).

PA Motivations

A non-statistically significant increase in EMAPS SDI was found (+1.03, p = 0.12), from 10.3 (4.5) (below the general population norm) at T0 to 11.8 (4.0) at T3 (higher than the norm).

Discussion

Main Finding of this Study

Multidimensional longitudinal changes associated with real-life commuter e-cycling were examined over 4 to 5 months. After e-cycling onset, average MVPA significantly increased and plateaued (up to +21.2 MET-hr/week, 95%CI 13.6-28.9) while very high SED-time around 8.6 hr/d (95%CI 8.1- 9.1) persisted over time. Changes in participants' fitness were distinguished by an increase in CRF (+0.48 METs, p < 0.001), in effort perception and HR response to the stress test (-3.2 bpm in average, p < 0.001). During the study period, adiposity markers, PA motivations and perceived health did not change or very slightly improved.

What is Already Known on this Topic

Experimental studies examined the acute physiological impact of monitored e-cycling and tend to find increased physiological responses that may confer health benefits [11,12]. Some observational studies examined it longitudinally from 4 weeks to 8 months [11], generally following participants who were given an e-bike for the need of the study, a set-up that can reduce external validity. A few examined actual e-cycle buyers in real-life settings [22] but did not measure total MVPA nor SED-time, focusing on cycling PA. Only one study observed changes in MVPA and SED-time over 4 weeks of commuter e-cycling and did not find any improvement in these outcomes, whereas CRF slightly increased [23]. If commuter conventional cycling is known to improve CRF especially in unfit people [24], and is associated negatively with adiposity and overweight [25], little is known for commuter e-cycling. A systematic review [11] provides moderate evidence that general e-cycling elicits PA able to improve health outcomes, including CRF and cardiometabolic risk factors. Working adults population whom belongs the target population is known to have a high sedentary level [26] and it has been described that very high PA (> 35.5 MET-hr/week) appears to eliminate the increased risk of death associated with high sedentary level [6]. An interventional study [27] has also shown improvements in CRF and WC up to 6 months along with a reduction in weight, although only overweight participants were included. Results are conflicting between active commuting and well-being, suggested with physical but not mental well-being [28], or both for commuter cycling or not any for commuter walking [29].

Was this Study Adds

An objective of our study was to evaluate total MVPA and total SED-time which can be influenced by others activities that could vary while e-cycling is initiated and monitored. This study was one of the few that examined these effects in a non-experimental set-up auguring a good external validity. Although a direct causal relationship with e-cycling cannot be inferred, these findings provide a good illustration of the sequential association between e-cycling and reported changes. Our results are in favor that people starting to e-cycle with commuting objectives kept high adherence rates and experienced a substantial increase in MVPA and other health benefits while remaining sedentary. Reached endpoint mean MVPA at 56.7 MET-hr/week, could be either considered well above the common guidelines, or either still under recalibrated one recommended with extensive PA inventory [30] as employed here through the questionnaire. Found magnitude is in accordance with another study which found even higher MVPA level at 74.4 MET-hr/week using the GPAQ, another extensive PA questionnaire [31]. On the contrary, SED-time remained stable and high, which can be surprising as commuter e-cycling replaced passive commuting (from 14 participants using exclusively car to only 1 – data not shown). However, such a stability has already been described with walking to work, which was associated with higher MVPA but not in lower SED-time [32]. This illustrates if needed that PA and sedentary behavior are two independent dimensions.

Concerning the moderators of change, increase in MVPA appeared to be more pronounced in older participants and those who e-cycled the most especially for commuting purposes, starting with a lower level than other participants, but ending with a higher level. Highest baseline SED-time participants and older ones encountered a statistically significant decrease in sedentary level, although not reaching low or moderate levels. Keenest e-bike commuters were also the most sedentary ones, both before and after e-cycling onset, which favors a direction of relationship from sedentary behavior to e-cycling and not the contrary.

Subtle gain in CRF over a short period suggest that known improvements in experimental studies may be transposed to real-life commuter e-cycling which can be meaningful from a public health perspective [33]. This gain matches with a lower effort perception and a lower heart rate pattern for the same given workload as they are known results of training [34]. From the reported reduction in WC (and WHtR) but not weight (and BMI) can by hypothesized a reduction of visceral adiposity accompanied with a possible increase in mean muscle mass.

Physical health perception didn't improve contrary to objective fitness measures, maybe due to a short study period for wider and self-perceivable improvements, or because of the latency to detect positive changes. Finally, while just a small part (12%) of new commuter e-cyclists planned initially to recreationally e-cycle, more of them (79%) did it. This could enhance commuter e-cycling benefits in a population of sedentary workers who may have more sedentary leisure too [26].

Limitations of this Study

Our analyses transcend previous cross-sectional and cohort studies of e-cyclists by examining longitudinal changes and by illustrating the benefits of the RM-MLM approach for PA epidemiology.

Observed changes cannot be fully attributed to e-cycling, as other elements are also evolving at the same time. Purchasing an e-bike is often driven by health-oriented motivations [35] which can be associated with confounding factors. Another confounding factor may be a seasonal effect. In general, PA levels appear to be highest in spring and summer with a peak in July-August [36], a period included in our time window (first measurement in March, and last in November). However, no peak in summer was observed and last measurements done in fall were stable. A seasonal trend may have occurred for SED-time, whose mean was minimal at summer time.

Other limitations are having only one baseline assessment and the absence of a control group. First, we couldn't establish the stability of outcomes before e-cycling onset, as it was practically impossible to prevent new buyers or renters from e-cycling for several weeks or months. For the same reason, our study didn't include a control group because the only way to build one would have been to prevent some participants from e-cycling until the end of study, which was unrealizable as they were willing to e-cycle on their own. Besides, we did not aim to compare e-cyclists to other populations. It has already been described that commuting and total PA is similar for e-cyclists and cyclists and significantly less for non-cyclists (respectively 74.4, 60.1 and 55.1 MET-h/w), and that longer trips taken by e-cyclists may compensate the lower intensity [31].

Finally, quantitative self-reported cycling activity, and PA questionnaires in general, are imprecise and people tend to over-report PA and underestimate sedentary behaviors [37]. That's why we focused on trends rather than on absolute values, assuming that the tendency to under or over-report by a participant may be of the same magnitude at the different measurements. Objective measurements using activity trackers may be more precise, but to our knowledge, none of them could discriminate automatically cycling neither e-cycling from other ways of transport.

Conclusion

New real-life commuter e-cyclists experienced a major increase in total MVPA and a persistent high sedentary behavior, accompanied with benefits in CRF, adiposity and perceived mental health. In addition, this study supports that real-life e-cycling adherence up to 4 to 5 months is high and not restrained to trained subjects. People desiring to e-cycle should be encouraged and be helped by removing the obstacles to practice this transportation mode. This pilot study promotes further investigation through a larger sample, a longer observation time, objective measures and a multicentric design.

Supplementary Materiel

see Appendices.

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