Sport as a medicine for health and health inequalities

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Chapter 6. Covid-19 and socioeconomic inequalities in physical activity

What is the impact of the Covid-19 crisis on socioeconomic differences in physical activity behavior?[5]

Abstract

Objective: Covid-19 and measures to contain spreading the disease have led to changed physical activity behavior. This study aims to investigate the relationship between socioeconomic status (SES) and changes in the amount of moderate to vigorous physical activity (MVPA) during the Covid-19 crisis.

Methods: Using the Dutch Lifelines Covid-19 cohort study (n = 17,749), the amount of MVPA was measured at 15 time-points between March and December 2020, and compared with the amount before the Covid19 pandemic. For SES, the population was stratified in three education and income levels. Logistic regression models were used to estimate the odds ratio (OR) and confidence interval (CI) of altered MVPA for low and high SES groups, with the middle SES category as the reference group.

Results: A clear socioeconomic gradient in changes in MVPA behavior was observed. Lower educated individuals had significantly higher odds (OR = 1.14; CI: 1.03–1.27) of decreasing MVPA, while the higher educated had significantly lower odds of decreased MVPA (OR = 0.84, CI: 0.79–0.90). Both low education (OR = 0.87; CI: 0.77–0.98) and low income (OR = 0.85; CI 0.78–0.92) had significantly lower odds to increase MVPA, while high education (OR = 1.21, CI: 1.12–1.30) and high income (OR = 1.17; CI: 1.07–1.28) had significantly higher odds to increase MVPA. Most findings were consistent over the full research period.

Conclusion: Socioeconomic inequalities in MVPA have increased during the Covid-19 pandemic, even when Covid-19 containment measures were relaxed. Our findings suggest that future public health policies need to increase efforts to improve physical activity behavior with an even larger focus on low SES groups.

[5] Joint work with J.O. Mierau, J. Schoemaker, L. Viluma, R.H. Koning and Lifelines Corona Research Initiative. A condensed version of this chapter has been published in Preventive Medicine as De Boer et al. (2021b).

6.1 Introduction

The social distancing measures and lockdowns implemented by many governments worldwide due to the coronavirus disease 2019 (Covid-19) pandemic have led to dramatic changes in physical activity (PA) levels (Tison et al., 2020; Wilke et al., 2021). These changes may vary between different societal groups. The aim of this study is to investigate the association between socioeconomic status and the chances of decreasing or increasing the amount of moderate to vigorous PA (MVPA), compared with the amount of MVPA before Covid-19 measures were implemented. Using a large population-based panel, this is the first longitudinal study which examine the socioeconomic gradient of changes in PA behavior during the Covid-19 pandemic.

Covid-19 is highly infectious and potentially deadly disease caused by SARS-CoV-2 virus that can lead to severe respiratory illness (Lai et al., 2020). Covid-19 was declared a global pandemic by the World Health Organization on 11 March 2020. To limit the spreading of the disease, most national governments implemented social distancing and other measures (Wilder-Smith & Freedman, 2020). Many of these, including the closure of schools and businesses, and bans on social gatherings and sporting events, have had a severe impact on the possibilities to engage in physical activity (PA) (Parnell et al., 2020). As a result, there have been shifts in the participation in physical activities, with the main observed effects showing a significant decrease in PA levels (Tison et al., 2020; Martínez-de-Quel et al., 2021).

Physical activity is an important determinant of health. Positive health effects of PA include lower risks of obesity, type 2 diabetes mellitus, cardiovascular diseases as well as mental health illness such as dementia and depression (Reiner et al., 2013; Pedersen & Saltin, 2015; Chekroud et al., 2018). Regular PA is also associated with longer life expectancy (Reimers et al., 2012) and lower health care costs (De Boer et al., 2020).

It is well established that there are socioeconomic differences in being physically active (Mackenbach et al., 2008; Beenackers et al., 2012). This socioeconomic gradient in PA can partly be explained by differences in available means in terms of time and money (Spinney & Millwall, 2010), availability and proximities of sport and physical activity facilities (Wicker et al., 2013), a supportive physical environment (Giles-Corti & Donovan, 2002), social capital (Lindström et al., 2001), as well as individuals' beliefs of the benefits of PA (Wardle & Steptoe, 2003). Socioeconomic differences in PA, in turn, contribute to disparities in health outcomes (Petrovic et al., 2018). The Covid-19 pandemic coincides with and intensifies an ongoing global crisis in physical activity and sedentary behavior (Hall et al., 2021). Reducing socioeconomic inequality has been a priority of international health policies to challenge physical inactivity (DiPietro et al., 2020). It is therefore important to understand the impact of the Covid-19 pandemic and the resulting measures on PA behavior in relation to socioeconomic characteristics.

A short timeline of the relevant Dutch Covid-19 measures is presented in Table 6.1. On March 12, 2020 the first social-distancing Covid-19 related measures were initiated by the Dutch

government (Rijksoverheid, 2021). From March 16, schools were closed and bans were introduced on, among others, group and indoor sport activities. As the first wave of the pandemic was contained, some of the measures were relaxed, starting in May 2020. On July 1, bans on indoor sports and PA facilities and group sports were lifted. However, in Autumn, as the pandemic saw a second wave, increasingly tight measures were being (re)instated. From October onwards, sport competitions were suspended, while from December 15, the Netherlands went in full lockdown. As a result of the pandemic and related government measures, many people have become less physically active during 2020, while others increased their amount of physical activity (RIVM, 2021).

Using panel data from the Lifelines cohort study for 15 moments from April until December 2020, our research aims to provide insights in changes in individual level MVPA behavior in relationship with socioeconomic status (SES). The outcomes provide insights in which socioeconomic groups have been most vulnerable with regard to changes in MVPA behavior during the Covid-19 pandemic and could provide guidance for curbing the negative MVPA trends and hence improve public health.

Table 6.1: Actions and measures in response to the Covid-19 pandemic, for the Netherlands, 2020

Date	Actions / measures
2020-03-11	WHO declares Covid-19 pandemic
2020-03-12	Dutch government advices to work from home, cancels sporting events
2020-03-16	Closure of schools, sport facilities; contact professions suspended
2020-05-11	Outdoor sports reopened; primary education partly reopened
2020-06-01	Primary and secondary schools reopened
2020-07-01	Indoor sports and fitness clubs reopened
2020-09-09	Sharp increase of infections leading to ban on events and gathering with over 50 persons
2020-10-13	Sport competitions suspended
2020-11-03	Closure of swimming pools; group lessons prohibited
2020-11-14	Reopening of swimming pools; group lessons allowed
2020-12-15	Full lockdown; all gatherings of more than 3 persons suspended; indoor and group sports prohibited

6.2 Methods

6.2.1 Data

The Lifelines Covid-19 cohort study is a large questionnaire-based cohort study specifically established to investigate the Covid-19 infection and its health and societal impacts in a population-based cohort in the North of the Netherlands (Mc Intyre et al., 2021). Participants were recruited from the general Lifelines prospective cohort study (Scholtens et al., 2015; Mc Intyre et al., 2021). They were asked to fill out detailed online questionnaires about

their physical and mental health and experiences on a weekly basis, starting in late March of 2020, and on a bi-weekly basis from June 2020 (Measurement moments are provided in Table A6.1 of the Appendix). Unfortunately, no data is available for August and September 2020, because the Lifelines Covid-19 questionnaire in these months did not include questions on PA.

Only people with baseline MVPA measurement (i.e. who answered the question on the amount of MVPA they performed before the Covid-19 crisis) were included in the study sample. The baseline MVPA measurement was part of the first and the second measurement moment of the Lifelines Covid-19 study. Baseline measurement from the first wave was added to the second wave to maximize the size of the cohort. Participants with missing data on socioeconomic indicators (at baseline) as well as the covariates were omitted (see figure A1 in the appendix for the flow chart). Respondents aged 25 or below, and pregnant women, were also eliminated since they could interfere with education and PA respectively. The remaining sample consisted of 17,749 individuals.

For baseline MVPA assessment, respondents were asked: 'before the corona crisis, how many minutes of (moderately) intense activity did you do each week (e.g. walking, bicycling or running)?' The answers categories were: 0-50 minutes, 50-100 minutes, 100-150 minutes, 150-180 minutes, more than 180 minutes. In the first seven measurements, respondents were asked about the amount of (moderately) intense activity they did in the previous 7 days, with the same answer possibilities as for the baseline measurement. From the 8th measurement the Covid-19 questionnaire was biweekly, with the corresponding question: 'in the last 14 days, how many minutes of (moderately) intense activity did you do?', and corresponding answers categories: 0-100 minutes, 100-200 minutes, 200-300 minutes, 300-360 minutes, and more than 360 minutes. The dependent variables were construct by comparing the amount of MVPA with the baseline measurement and categorized as being 'decreased', 'equal' or 'increased', for each individual. The incidences of decreased MVPA and increased MVPA are the subject of our investigation and form separate dependent variables in the research models.

In our study, educational attainment functions as the main indicator for socioeconomic status. For education, respondents were categorized as 'low education' if they had no, lower vocational, or low or middle secondary education as their highest finished education level. Respondents were classified as 'middle education' if they finished higher secondary education or middle vocational education and 'high education' for completing higher vocational education or university. For sensitivity analysis, we have performed additional analysis with net personal income as the SES indicator. To establish the net personal income, respondents were asked: 'what was your personal net income before the corona crisis?'; with €500-step answer categories (i.e.: less than €500; €500 to €1000; etc.). Individuals with a net income of €1500 or below were around a third of the panel and were categorized as the 'low income' group. The 'high income'

group consisted of people with a net income of €2500 or higher, comprising also roughly one third of the panel.

To adjust for confounding, sociodemographic factors sex and age were included. Since research shows that major life events (Van Houten et al., 2017; O'Donoghue et al., 2018) can impact MVPA behavior, indicators for being single and having one or more children aged 12 or below living at home (that is, children up to primary school age) were found to be strongly correlated with changes in MVPA behavior and therefor included in the analysis. Smoking and the amount of MVPA at baseline served as covariates for lifestyle (Audrain-McGovern et al., 2003). For all covariates only baseline measurement was included, since information at other moments was mostly unavailable, or else scattered and incomplete at best.

6.2.2 Analysis

In this study, we estimated the associations between socioeconomic status (education and income), and decreased and increased MVPA. First, we estimated a logistic regression model (Model 1) for whether or not MVPA had decreased, for each time point separately. For each time point T (t = 1, ..., 15), and each dependent variable Y_j of decreased MVPA (j=1) or decreased MVPA (j=2) than before the Covid-19 crisis, we have I independent observations (respondents) $y_{1,j,t}, \ldots, y_{I,j,t}$. Each observation $y_{i,j,t}$ can be treated as a realization of a $Y_{i,j,t}$. We assume that $Y_{i,j,t}$ ($Y_{i,j,t}$=0 or 1) has a specific binomial distribution function for at each moment t:

$$Y_{i,j,t} \sim B(n_{i,j,t}, \pi_{i,j,t}), \tag{6.1}$$

with binomial denominator $n_{i,j,t}$ = 1 for all observations, and probability $\pi_{i,j,t}$. We further assume that the logit of the underlying probability $\pi_{i,j,t}$ is a linear function of the socioeconomic predictor and the covariates

$$Logit(\pi_{i,1,t}) = \alpha_{1,t} + \beta_{1,low,t}\, Education_{i,low} + \beta_{1,high,t}\, Education_{i,high} + \sum_{m=1}^{M} x_{i,m}\, \boldsymbol{\gamma}_{1,m,t} + u_{i,1,t} \tag{6.2a}$$

for decreased MVPA (j=1), and

$$Logit(\pi_{i,2,t}) = \alpha_{2,t} + \beta_{2,low,t}\, Education_{i,low} + \beta_{2,high,t}\, Education_{i,high} + \sum_{m=1}^{M} x_{i,m}\, \boldsymbol{\gamma}_{2,m,t} + u_{i,2,t} \tag{6.2b}$$

for increased MVPA (j=2), with $Education_{i,k}$ a dummy for lower education (k=low) and higher education (k=high), with middle education functioning as the reference value. In each model, $\beta_{j,k,t}$ represents the regression coefficient for education; $\boldsymbol{\gamma}_{i,m,t}$ the regression coefficient for each

$x_{i,m,,t}$, the m-th covariate at the t-th time point; and $u_{i,j,t}$ the error term for each observation. We assume that $u_{i,j,t}$ follows a normal distribution with mean 0 and variance σ^2.

In a first simple model (Model 0), $x_{j,t}$ is covariate j (j is age, sex or the amount of MVPA at baseline - i.e. before the Covid-19 crisis). The amount of MVPA is by definition strongly related to the outcome variables, because, in our operationalization, it is impossible for persons in the '0-50 minutes MVPA per week' category to decrease MVPA. By using the amount of baseline MVPA as covariates, this category will be omitted for the regression estimation of decreasing MVPA. Similarly, the 'over 180 minutes MVPA per week' category is eliminated from the regression analysis on increasing MVPA. In the model that was presented in the main text (Model 1), $\mathbf{x}_{j,t}$ includes the same variables as for the first model but adds confounders for living alone, having small children living at home and smoking. Also we included the variable age squared in the analysis, since some models show that the relationship between age and doing decreased or increased MVPA was non-linear. In effect, Model 1 is an extended version of Model 0 with more covariates.

Finally, we estimate RE logistic regression model for the full panel, with time-specific effects $\delta_{j,t}$ which affect all individuals in the same way:

$$Logit(\pi_{i,j,t}) = \alpha_j + \beta_{j,low}\, Education_{i,low} + \beta_{j,high}\, Education_{i,high} + \sum_{t=1}^{T-1} \delta_{j,t} + \sum_{m=1}^{M} x_{i,m}\, \boldsymbol{\gamma}_{j,m} + u_{i,j} \quad (6.3)$$

with again SES being education or income. This model (Model 2) has time-independent estimates for all covariates for each value of j, while $\delta_{j,t}$ is the dummy variables for time point t with the final time point (t = 15) serving as the reference period. RE models consider both within-subjects variance as well as between-subjects variance. Because the socioeconomic indicators as well as the covariates are static (i.e. they do not vary over time) and likelihood-ratio tests were significant, the RE model is appropriate for our analysis.

For each of the models, the odds ratio (OR) for the SES indicators (with middle education as the reference category) and a 95% confidence interval (CI) are presented. ORs with a p-value below 0.05 were identified as statistically significant. For the analysis Stata 16 was used (Stata Corp. LLC, College Station, Texas, USA).

6.3 Results

Population characteristics at first measurement (inquiry at March 31) are presented in Table 6.2, with breakdowns by education and income levels. At baseline, 61.3% of the included individuals (n = 17,749) was female and the average age was 58.1 years. One in ten people was lower educated, while 38% had completed higher education. A third of the dataset consisted of individuals with a net income lower than €1500, while one in four had an income of €2500 or

higher. Furthermore, 12.5% were living alone, while 10.6% had children aged 12 or below living at home and 7.3% were current smokers. Low-SES categories included relatively more elderly people, smokers and people doing little MVPA (less than 100 minutes per week). High-SES categories consisted of relatively many males, adults with small children at home and people doing 150 minutes or more MVPA at baseline.

Table 6.2: Summary statistics, by SES categories and total (at first measurement)

	Education			Income (net monthly)			Total
Variable	**Low**	**Middle**	**High**	**Low**	**Middle**	**High**	
Observations	1,766	9,150	6,833	5,922	7,313	4,514	17,749
Sex (1 = female)	0.525	0.654	0.581	0.868	0.599	0.302	0.613
Age	63.5	58.6	56.2	60.2	57.1	57.2	58.1
Education							
Low	1.000			0.168	0.088	0.029	0.099
Middle		1.000		0.634	0.536	0.326	0.516
High			1.000	0.198	0.376	0.646	0.385
Income (net monthly)							
Low (<€1500)	0.562	0.411	0.172	1.000			0.334
Middle (€1500-€2500)	0.365	0.429	0.402		1.000		0.412
High (€2500 or higher)	0.073	0.161	0.426			1.000	0.254
Living alone	0.145	0.126	0.119	0.114	0.149	0.102	0.125
Child 0-12 years living at home	0.036	0.085	0.152	0.071	0.116	0.136	0.106
Smoker (current)	0.106	0.084	0.052	0.079	0.076	0.064	0.074
PA at baseline (minutes per week)							
0-50 minutes	0.115	0.092	0.070	0.090	0.090	0.073	0.086
50-100 minutes	0.229	0.190	0.161	0.191	0.181	0.174	0.183
100-150 minutes	0.163	0.171	0.179	0.178	0.172	0.171	0.174
150-180 minutes	0.315	0.359	0.406	0.357	0.371	0.397	0.373
180 minutes or more	0.178	0.188	0.184	0.184	0.187	0.184	0.185

At the first wave, 40% of the individuals decreased their amount of MVPA, while 13% increased the amount (see Figures 6.1 and 6.2). From the second measurement, decreased MVPA was more or less stable around 23%, until the middle of May when it jumped to around 28%. The percentage of people that increased MVPA grew gradually, to stabilize around 27% in the second half of 2020. The differences between SES categories here are relatively small. Over the period March to December 2020, the incidences of decreased and increased MVPA did not differ much over the three education types. It is important to realize that these are the outcomes for the whole sample, with the low-SES having a relatively large portion of people in the category with little (<50 minutes per week) MVPA and thus having a relatively larger number of people unable to decrease MVPA. Similarly, the high-SES categories include relatively many people unable to be included in the 'increase MVPA' category. To address this bias, as well as to control for other potential covariates and confounders, logistic regression models were used.

Figure 6.1: percentage decreased MVPA, by education type, March – December 2020

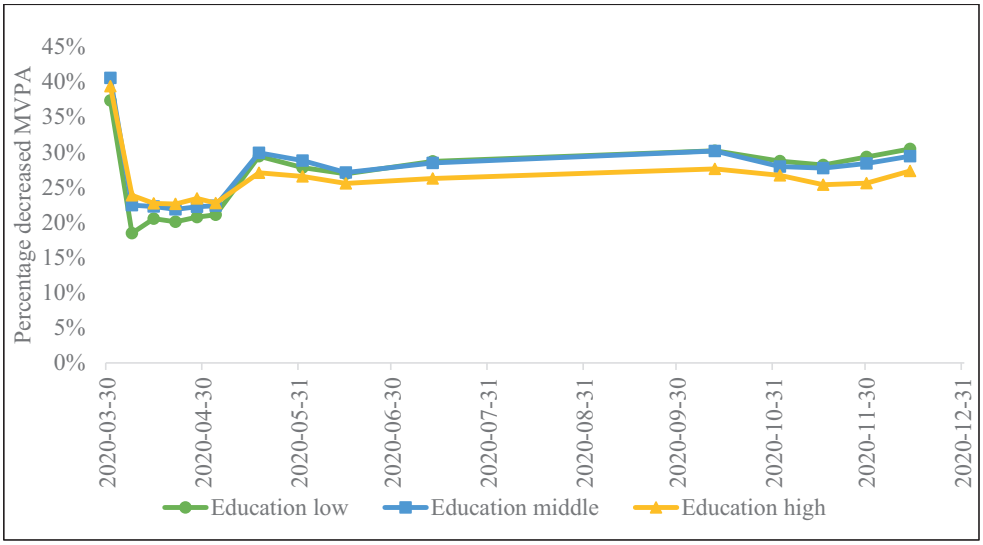
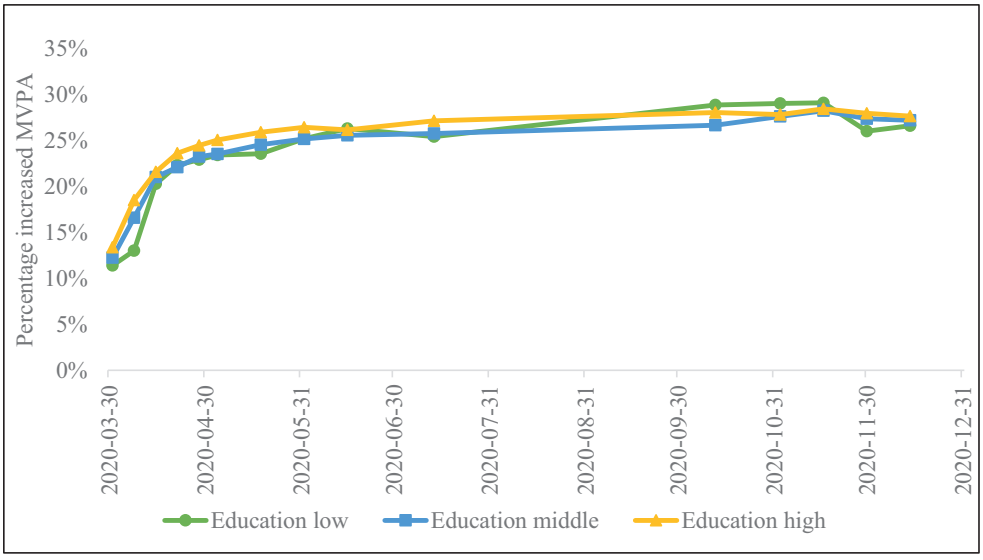


Figure 6.2: percentage increased MVPA, by education type, March - December 2020



In Model 1 we estimated the association of education with changes in MVPA behavior, for each measurement moment. Table 6.3 shows the outcomes of these models for the first (t=1) and last (t = 15) wave. At t=1, high education is associated with a significant 12% chance (OR: 0.88) of decreasing MVPA (than the middle educated), while for lower education an insignificant 9% lower chance (OR = 0.91) was found. For increased MVPA, the coefficients for all SES-

indicators are significant, with low education being associated with a 15% smaller chance (OR = 0.85) of increasing MVPA and high education with a 26% larger chance (OR = 1.26). At the final measurement (t=15), high education was significantly associated with lower chances of decreased MVPA and higher odds for increased MVPA. For low education the reverse is observed, with significant odds ratios.

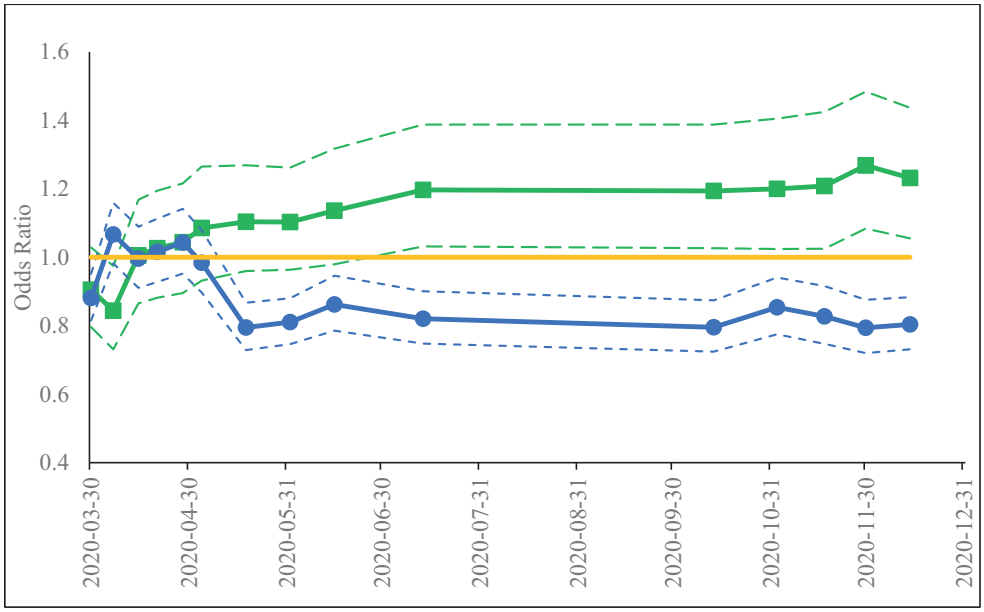
Table 6.3: Model outcomes of the logistic regressions (Model 1) for decreased MVPA and increased MVPA for education and income, at first and last measurement

Variable	First measurement (t=1)				Last measurement (t=15)			
	Decreased MVPA		Increased MVPA		Decreased MVPA		Increased MVPA	
	OR	P-value	OR	P-value	OR	P-value	OR	P-value
Sex	1.02	0.635	**1.14**	0.011	1.05	0.277	**1.12**	0.016
Age	**0.92**	0.000	**1.07**	0.002	0.97	0.114	1.01	0.726
Age2	**1.00**	0.000	**1.00**	0.001	1.00	0.491	1.00	0.913
Education								
Low	0.91	0.128	**0.86**	0.077	**1.23**	0.008	**0.83**	0.021
Middle	ref.		ref.		ref.		ref.	
High	**0.88**	0.001	**1.26**	0.000	**0.80**	0.000	**1.21**	0.000
Living alone	**1.15**	0.014	0.99	0.928	**1.14**	0.047	0.89	0.079
Child	1.06	0.367	**1.21**	0.025	**1.36**	0.000	0.95	0.517
Smoker	**1.16**	0.038	**0.69**	0.000	**1.27**	0.006	**0.77**	0.002
PA at baseline (minutes per week)								
0-50	n/a		**1.18**	0.017	n/a		0.87	0.064
50-100	**0.82**	0.000	**0.83**	0.001	**0.76**	0.000	**0.81**	0.000
100-150	ref.		ref.		ref.		ref.	
150-180	0.97	0.483	**0.05**	0.000	**1.15**	0.025	**0.08**	0.000
>180	**21.57**	0.000	n/a		**12.67**	0.000	n/a	
constant	**5.83**	0.000	**0.06**	0.000	0.93	0.884	0.76	0.624

OR = Odds ratio.

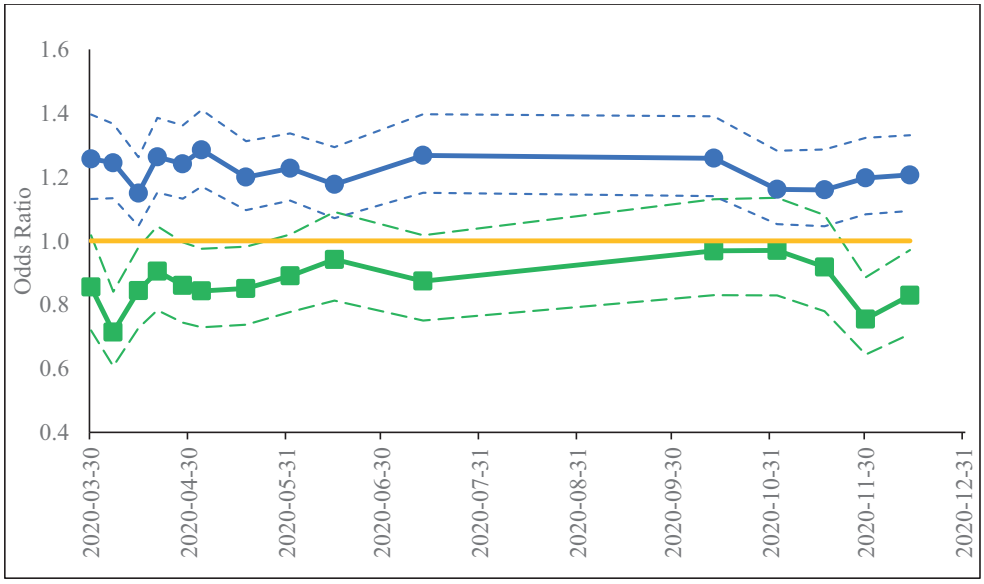
Figure 6.3 shows the Model 2 odds ratios for the association of SES with decreased MVPA on a time scale, with confidence intervals for each measurement moment. The first measurements show the SES odds ratios shifting around 1. Over time, the model outcomes shift to higher ORs of around 1.2 for low education and lower odds of around 0.8 for higher education. Both these estimates differ significantly from the middle education group (OR defined as 1). Figure 6.4 shows the odds ratios for increased MVPA. For high education, the ORs are consistently around 1.25. They also differ significantly from the middle education group for all measurement moments. Initially, the lower education group has a significantly low odds ratio (OR = 0.71 for beginning of April), but this steadily increases over the year (OR = 0.97 for early November), only to drop dramatically at the end of the year (OR = 0.83 for the final measurement). Mostly these odds ratios do not differ significantly from the middle education group.

Figure 6.3: Model 1 outcomes for decreased MVPA in odds ratios, by education level



Legend: the firm lines with markers show the odds ratios for low education (green) and high education (blue), with middle education (yellow) the reference (OR = 1). The markers are the actual estimated odds ratios for the 15 measurement moments. The dashed lines show the confidence intervals.

Figure 6.4: Model 1 outcomes for increased MVPA in odds ratios, by education level



Legend: see Figure 6.1.

Finally, Table 6.4 shows the results of the random effects logit models (Model 2) for the full panel. The outcomes show that lower education is associated with significant higher odds for decreased MVPA (OR = 1.14) and a significant lower chance of increased MVPA (OR = 0.87), compared with middle education. Similarly, individuals with higher education did significantly more often increase MVPA (OR = 1.21), while also less often decreasing MVPA (OR = 0.84). In addition, living alone (OR = 1.23), living with small children (OR = 1.20) and smoking (OR = 1.39) were associated with significantly higher chances of decreased MVPA. Smoking was associated with significantly lower odds (OR = 0.64) of increasing MVPA, while women had significantly higher odds for both decreasing (OR = 1.13) and increasing (OR = 1. 22) than men.

Table 6.4: Model outcomes of the RE logistic panel data analysis (Model 2) for decreased MVPA and increased MVPA for education

	Decreased MVPA		Increased MVPA	
Variable	**OR (CI)**	**P-value**	**OR (CI)**	**P-value**
Sex	**1.13 (**1.06 - 1.20)	0.000	**1.22** (1.13 - 1.31)	0.000
Age	**0.96** (0.93 - 0.98)	0.001	1.00 (0.97 - 1.03)	0.862
Age2	1.00 (1.00 - 1.00)	0.074	1.00 (1.00 - 1.00)	0.980
Education				
Low	**1.14** (1.03 - 1.27)	0.015	**0.87** (0.77 - 0.98)	0.020
Middle	ref.		ref.	
High	**0.84** (0.79 - 0.90)	0.000	**1.21** (1.12 - 1.30)	0.000
Living alone	**1.23** (1.12 - 1.35)	0.000	0.94 (0.84 - 1.04)	0.223
Child	**1.20** (1.07 - 1.35)	0.001	1.08 (0.95 - 1.23)	0.211
Smoker	**1.39** (1.23 - 1.57)	0.000	**0.64** (0.56 - 0.73)	0.000
PA at baseline (minutes per week)				
0-50	n.a		**0.66** (0.58 - 0.74)	0.000
50-100	**0.76** (0.69 - 0.84)	0.000	**0.53** (0.48 - 0.58)	0.000
100-150	ref.		ref.	
150-180	**1.18 (**1.08 - 1.28)	0.000	**0.02** (0.02 - 0.02)	0.000
>180	**32.96** (29.90 - 36.34)	0.000	n.a.	
Time dummies	Incl.		Incl.	
constant	0.68 (0.33 - 1.40)	0.300	1.75 (0.77 - 3.99)	0.185

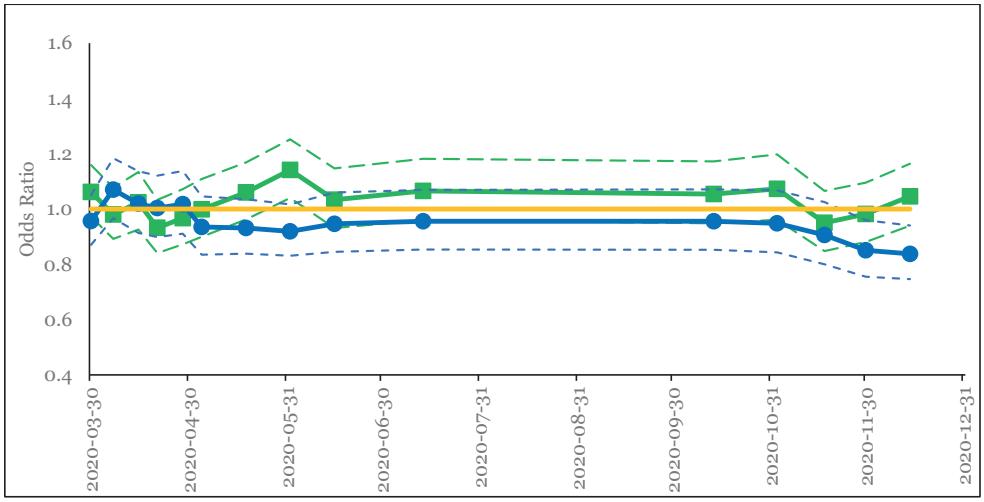
OR = Odds ratio; CI = 95% confidence interval.

6.3.1 Sensitivity analysis

For sensitivity analysis, we have estimated the same models with net personal income instead of education. Over time (Figures 6.4 and 6.5) the income gradients for changes in MVPA behavior were similar to those for education. For decreasing MVPA, the outcomes of Model 2 (Table 6.5) show larger chances for low income (OR = 1.05) and smaller chances for high income (OR = 0.94). The socioeconomic gradient for decreased MVPA is not significant and slightly less steep than for education. For increasing MVPA, the results for income were significant and similar in

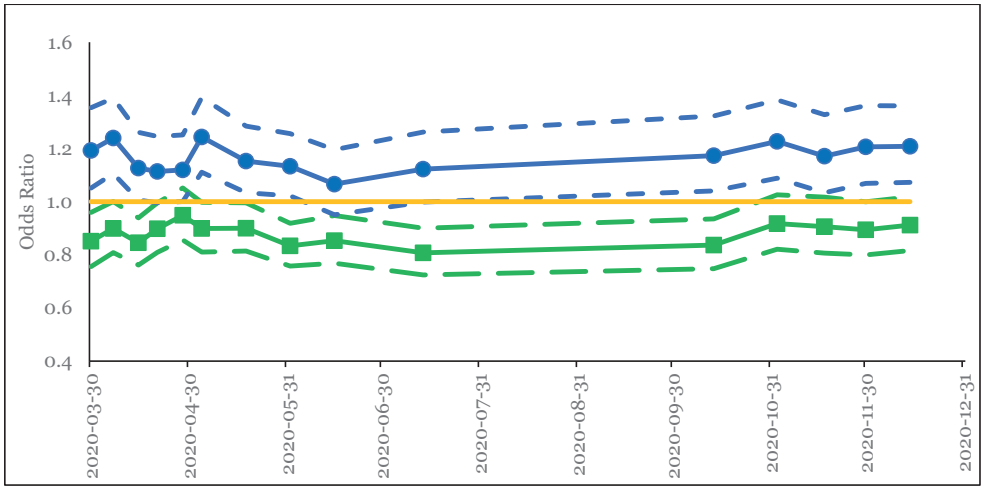
size as for education. Low income is associated with significantly lower odds of increased MVPA (ORs = 0.85) and the high income group having significantly higher chances of increased MVPA (OR = 1.17).

Figure 6.4: Model 1 outcomes for decreased MVPA by income level, odds ratios



Legend: the firm lines with markers show the odds ratios for low education (green) and high education (blue), with middle education (yellow) the reference (OR = 1). The markers are the actual estimated odds ratios for the 15 measurement moments. The dashed lines show the confidence intervals.

Figure 6.5: Model 1 outcomes for increased MVPA by income level, odds ratios



Legend: see Figure 6.4

Table 6.5: Model outcomes of the RE logistic panel data analysis (Model 2) for decreased MVPA and increased MVPA for income

	Decreased MVPA		Increased MVPA	
Variable	**OR (CI)**	**P-value**	**OR (CI)**	**P-value**
Sex	**1.09** (1.01 - 1.17)	0.018	**1.36** (1.25 - 1.47)	0.000
Age	**0.96** (0.94 - 0.99)	0.003	0.99 (0.96 - 1.02)	0.583
Age2	1.00 (1.00 - 1.00)	0.100	1.00 (1.00 - 1.00)	0.732
Income				
Low	1.05 (0.97 - 1.13)	0.246	**0.85** (0.78 - 0.92)	0.000
Middle	ref.		ref.	
High	0.94 (0.87 - 1.02)	0.113	**1.17** (1.07 - 1.28)	0.001
Living alone	**1.23** (1.12 - 1.35)	0.000	0.93 (0.83 - 1.03)	0.159
Child	**1.18** (1.06 - 1.33)	0.003	1.10 (0.97 - 1.25)	0.148
Smoker	**1.42** (1.26 - 1.60)	0.000	**0.63** (0.55 - 0.72)	0.000
PA at baseline (minutes per week)				
0-50	n.a		**0.65** (0.58 - 0.74)	0.000
50-100	**0.77** (0.70 - 0.85)	0.000	**0.52** (0.47 - 0.57)	0.000
100-150	ref.		ref.	
150-180	**1.17** (1.08 - 1.28)	0.000	**0.02** (0.02 - 0.02)	0.000
>180	**33.08** (30.00 - 36.48)	0.000	n.a.	
Time dummies	Incl.		Incl.	
constant	0.58 (0.29 - 1.20)	0.143	2.06 (0.91 - 4.68)	0.085

6.4 Discussion

This study is the first to investigate the socioeconomic differences in physical activity behavior during the Covid-19 pandemic over a longer period. Using unique, large, population-based panel data, it was possible not only to document these difference but also follow the trends in the socioeconomic gradient in physical activity behavior over a 9-month period.

We found that, a large proportion of the population decreased their amount of MVPA in the first few weeks after the first Covid-19 measures were introduced. This effect was more or less similar for all socioeconomic groups. However, from May 2020 onwards, a clear socioeconomic gradient emerged, with low-educated individuals having significantly higher odds of decreasing MVPA, than high-educated individuals, ceteris paribus. Also, for increased MVPA, a strong positive socioeconomic gradient was observed. This finding was consistent throughout the whole measurement period. In addition, smoking, living alone or having little children living at home were also factors that significantly increased socioeconomic inequalities in MVPA. The socioeconomic gradient in MVPA change that we observed is consistent with the gradient in MVPA level, that was found before the Covid-19 pandemic, both in this study many others (Giles-Corti and Donovan, 2002; Wilson et al., 2004).

The model outcomes show that socioeconomic differences are relatively stable over time. In the Summer of 2020, many Covid-19 containment measures were relaxed, but this seems to have had a limited effect on the socioeconomic differences in MVPA behavior that was

established during the preceding period with severe measures. In November 2020, when new measures reduced the opportunities to practice sports and physical activities, socioeconomic inequalities in MVPA increased even more. The evidence from this study suggests that in the long run, when the Covid-19 pandemic is contained, socioeconomic inequalities in MVPA levels may remain significantly larger than before theCovid-19 pandemic.

Our analysis has several limitations. First, our study depends on subjective reporting of MVPA instead of more reliable observation measurement methods (e.g. with accelerometers). However, research shows a strong correlation between questionnaire and accelerometer MVPA measurements, especially when time interval levels are used, as was the case in the current study (Hart et al., 2011). Second, for the baseline measurement, respondents were asked about the amount of MVPA they performed "before the Covid-19 crisis", which lacks specificity. Respondents may have interpreted this question as the amount of MVPA in a specific week or as an average week before the first Covid-19 measures were taken. Also, they could be referring to a week immediately before the corona crisis (March 2020) or for instance the same week exactly a year before the time-point. In all cases, each time-point would include seasonal, as well as weather effects. The lack of clarity is somewhat problematic for both internal consistency of the data and interpretation of the outcomes. Third, MVPA is operationalized as ordinal categories. This means that changes within a category will go unnoticed, while equally small changes across categories (e.g. going from 45 to 55 min MVPA per week) will be reported as MVPA changes. Nevertheless, this issue likely has very limited effect on our results because we have a large sample, from 15 time-points and our results seem very robust to various sensitivity analyses. Fourth, for the lowest (0–50 min./week) and highest (>180 min) baseline MVPA categories, it is only possible to change behavior in one direction. This limits the possibilities and data available for e.g. multinomial logistic regression analysis. Therefore, we have chosen for separate regression analysis for increased and decreased MVPA and use the baseline MVPA categories as controls. Fifth, the study panel was not perfectly representative of the general population of the northern part of the Netherlands. Although we control for several demographic and socioeconomic variables, this may also be an indication (but not necessarily so) of selection bias in the dependent variables (changes in MVPA). In addition, other factors, such as the respondent's physical or mental health status, were possible confounders of the associations with MVPA, but due to a lack of data we could not control for them. Similar research on Covid-19-related changes in MVPA behavior showed decreased MVPA was relatively more prevalent in the Netherlands (RIVM, 2021) than in our data, while a study for Flanders study (Constandt et al., 2020) found the opposite. Moreover, the relatively small number of low-SES respondents might lower the predicting power of our analysis. This might be partly due to the online set-up of the survey (e.g. the absence of persons that cannot afford a computer). Sixth, although panel data were used to determine socioeconomic differences in MVPA over time, changes over time

in the SES variables and covariates themselves were not measured in the Lifelines Covid-19 survey. Although there might have been changes in, for example, the income levels during the pandemic, we believe this bias would be relatively small because most of the variables that we use cannot change dramatically over a 9-month period and employment and income was protected by the economic measures implemented by the Dutch government. Finally, because our study included only demographic and lifestyle covariates, it is possible that the model estimates suffer from omitted variable bias, such as being infected by the Covid-19 virus. Although this study examines the extend of socioeconomic differences in MVPA behavior, it did not investigate the underlying mechanisms. Future research should look into mediating factors such as psychological, environmental, infrastructural or social aspects, that were known to be important for explaining socioeconomic differences in MVPA behavior before the Covid-19 crisis (Yen and Li, 2019; Brug et al., 2017).

6.5 Conclusion

Before the Covid-19 pandemic, socioeconomic inequalities in doing PA were substantial. This research shows that because of this pandemic and the measures to contain the virus, the gap in MVPA between low and high SES groups has widened. Low SES group were much more likely to decrease MVPA and less likely to increase MVPA during the Covid-19 crisis, compared with higher SES groups. This gradient accounts for both education and income. Alarmingly, the findings were persistent over a long period, and included a period when many Covid-19 containing measures that harmed PA opportunities were lifted. This means that after the Covid-19 crisis, socioeconomic inequalities in PA behavior may still be larger than before the pandemic. Our findings show that there is a need for public health policies to increase efforts to stimulate PA with a focus on the low SES groups. The Covid-19 may not only coincide with, but also intensify, an ongoing global health and social crisis of physical inactivity and sedentary behavior.

Appendix

Table A6.1: Measurements of MVPA in the Lifelines Covid-19 study, with start date of the inquiry, 2020

Measurement	Inquiry date
1	2020-03-31
2	2020-04-07
3	2020-04-14
4	2020-04-21
5	2020-04-28
6	2020-05-04
7	2020-05-18
8	2020-06-01
9	2020-06-15
10	2020-07-13
11	2020-10-12
12	2020-11-02
13	2020-11-16
14	2020-11-30
15	2020-12-14

Figure A6.1: Flow chart of data selection