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Original Research

An investigation of factors affecting changes in health behaviours during the COVID-19 pandemic in a UK population–based cohort study

V.S. Braithwaite, S.J. Sharp, A. Koulman, N.J. Wareham [a], K.L. Rennie [*, a]

MRC Epidemiology Unit, University of Cambridge School of Clinical Medicine, Institute of Metabolic Science, Cambridge Biomedical Campus, CB2 0QQ, United Kingdom

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ABSTRACT

Objectives: The COVID-19 pandemic has led to changes in behaviours, which may have different health effects in population subgroups. We investigated whether within-individual changes in health behaviours from before to during the pandemic differ by socio-economic deprivation, age or sex.
Study design: Prospective cohort study.
Methods: Participants were recruited from the existing UK Fenland cohort study with measurements of health behaviours twice prepandemic (2005 to February 2020) and three times during the pandemic (July 2020 to April 2021). Health behaviours included daily servings of fruit and vegetables, units of alcohol consumed per week, smoking status, sleep duration and total and domain-specific physical activity energy expenditure. Sociodemographic information (English indices of multiple deprivation, education, occupation and ethnicity) and COVID-19 antibody status were also collected. Participants were grouped into three categories based on their English indices of multiple deprivation score: most, middle and least deprived.
Results: Participants were included if they had completed at least one measurement during the pandemic and one prepandemic ($n = 3212$). Fruit and vegetable consumption, total physical activity energy expenditure and smoking prevalence decreased during the pandemic compared with prepandemic, whereas average sleep duration increased and alcohol consumption did not change. Decreases in fruit and vegetable intake and physical activity energy expenditure were most pronounced in the most deprived group compared with the least deprived group and were greater in women than men.
Conclusions: Socio-economic inequalities in health behaviours have worsened during the pandemic. As the country emerges from the COVID-19 pandemic, strategies to reduce health inequalities need to be put at the forefront of recovery plans.

Introduction

The COVID-19 pandemic has given rise to unprecedented restrictions on people's lives and has resulted in more than 380 million confirmed cases and 5.6 million deaths worldwide[1] as of January 2022. The pandemic has had differential health, social and economic effects on different groups in society.[2] As with most patterns of disease, the most deprived groups in the United Kingdom were affected particularly by the pandemic. Direct effects included higher risk of avoidable death from COVID-19 for those aged <75 years, which was substantially greater for those living in the most deprived areas of England compared with those in the least deprived areas during 2020.[3,4] This pattern was also reported in other countries, for example, in the United States where people living in a more deprived area had a higher risk of COVID-19 hospitalisation.[5]

In addition to the differential direct effects that the virus itself had on health, there were also a range of indirect effects of both the pandemic and the associated non-pharmaceutical interventions that were likely to impact groups in society differentially. For example, those from more deprived groups were more likely to experience loss of income and unemployment during the pandemic

* Corresponding author.
E-mail address: Kirsten.Rennie@mrc-epid.cam.ac.uk (K.L. Rennie).
[a] Joint senior authors.

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compared with less deprived groups and were therefore more likely to feel the associated negative impact that loss of income has on health behaviours, health and well-being.[2] A systematic review including 87 studies reported that health behaviours including poor diet, alcohol consumption and physical inactivity had been exacerbated in the first year of the pandemic.[6] However, a high proportion of the studies were cross-sectional, and the review did not assess how these health behaviours differed between socioeconomic groups or with deprivation measures.

The aim of this study was to investigate changes in health behaviours during the pandemic compared with before the pandemic and whether these changes were influenced by deprivation. The health behaviours of interest were self-reported fruit and vegetable consumption, alcohol consumption, smoking status, sleep duration, and physical activity (PA) energy expenditure. Data were collected prospectively in participants of the Fenland cohort study, the United Kingdom, at five different time points over 2005–2021 using the same measurement instruments. The first two time points were before the pandemic, and the other three were during the pandemic. Specifically, we aimed to investigate whether health behaviours differed between before the pandemic and during the COVID-19 pandemic by deprivation group.

Methods

Study design

The Fenland cohort study was established in 2005; participants were recruited from general practice sampling frames in Cambridgeshire (http://www.mrc-epid.cam.ac.uk/research/studies/fenland-study/; $n \sim 46{,}000$). All participants were invited to Phase 1 (P1), Phase 2 (P2) and then to the Fenland COVID-19 substudy. A total of 12,435 people took part in P1 of the study (P1: 2005–2015) and 7795 in P2 of the study (P2: 2014–2020). P2 clinical visits were stopped at the start of the COVID-19 pandemic, and P2 ended early. A substudy of the Fenland cohort, the Fenland COVID-19 study was conducted remotely. Participants were recruited between July and October 2020 and followed up at three time points over a period of 6 months from enrolment date to April 2021 (C0, C3 and C6).[7] For the present study, participants were included if they had (1) taken part in the Fenland COVID-19 study, (2) had diet and PA data from at least the first time point during the pandemic (C0) (3) and had data from at least one prepandemic time point (P1 and/or P2).

Ethics and patient and participant involvement

Ethics approvals for Phases 1 and 2 were obtained from Cambridge East Research Ethics committee on 11 May 2004 and 5 July 2014, respectively. Written informed consent was obtained from all participants, and participants were made aware that they were able to request to leave the study at any point. For the Fenland COVID-19 substudy, ethical approval was obtained from South West Cornwall and Plymouth Research Ethics committee on 30 June 2020. Consent for the Fenland COVID-19 substudy was completed online. The Fenland cohort participant panel was involved in the planning, conducting and reporting of the Fenland COVID-19 study as part of patient and public involvement.

Setting and participants

Participants born between 1950 and 1975 were originally recruited from general practice registers, a population-based sampling frame across Cambridgeshire, United Kingdom. Inclusion and exclusion criteria have been described.[7] As part of the Fenland COVID-19 substudy, participants who were known to be still alive and had not withdrawn previously from the study, who had a valid email or telephone number, were approached via phone call, email or text message ($n = 11{,}469$) and asked whether they would like to participate. There was no specific exclusion criterion for the substudy.

Deprivation

The English indices for multiple deprivation 2019 (IMD) were derived from participants' current address available at the start of the Fenland COVID-19 study.[8] IMD measures relative levels of area deprivation among the 32,844 Lower Layer Super Output Area (LSOAs) in England and is calculated based on seven domains of deprivation, which includes income, employment, health deprivation and disability, education and skills training, crime, barriers to housing and services and living environment.[8]

Participants were grouped into three categories based on national IMD tertiles whereby Group 1 (most deprived) included IMD ranks from 1 to 10,947, Group 2 (middle) included IMD ranks from 10,948 to 21,896, and Group 3 (least deprived) included ranks from 21,897 to 32,844.

Outcome variables

Five different health behaviours were investigated; fruit and vegetable consumption, alcohol consumption, smoking status, sleep duration and PA measured using the same measurement instruments at all the five study time points.

Diet

Habitual dietary patterns over the previous 4 weeks were obtained using a validated food frequency questionnaire.[9] Individuals were asked how frequently they consumed servings of specific fruit or vegetables: never or less than once a month, 1–3 times per month, once a week, 2–4 times per week, 5–6 times per week, once a day, 2–3 times per day, 4–5 times per day, or 6 or more times per day. For computational purposes, we used the midpoint of food frequencies reported in ranges and 0 for people reporting ‘never or less than once a month’. Total daily reported servings of fruit and vegetables were calculated by adding the number of reported servings of different types of fruit and vegetables consumed. Adequate fruit or vegetable consumption was categorised as consuming 5 or more servings of fruit or vegetables a day based on National Health Service (NHS) recommendations.[10]

Participants reported frequency of intake of different types of alcohol, which was converted into units of alcohol; a small glass of wine (125 mL) was defined containing 1.36 units of alcohol, a half pint (192 mL) of beer, lager or cider as 1.4 units, a small glass (50 mL) of port, sherry, vermouth or liqueur as 0.8 units, and a single measure of spirits (23 mL) as 0.9 units of alcohol. Total units of alcohol consumed per week were then calculated by adding the number of units of different types of alcoholic beverages consumed per week. Excessive alcohol consumption was categorised as consuming 14 or more units of alcohol per week based on NHS recommendations.[10]

Smoking status

At P1, P2 and C0, participants were asked whether they currently smoked, had smoked in the past or had never smoked.

Time spent sleeping

Reported sleep duration was ascertained by asking participants to record the average time that they went to bed and woke up over the last 4 weeks on weekdays and on weekends, and a weighted average per day was calculated.[11] This question was only introduced halfway through Phase 1, and therefore, data are not available on all participants at Phase 1.

Physical activity

Recent PA over the previous 4 weeks was determined using the validated Recent Physical Activity Questionnaire (RPAQ).[12] The RPAQ is a self-completion questionnaire designed to assess physical activity in four domains: at home, at work, commuting and during leisure time over the previous 4 weeks. RPAQ has been validated against doubly labelled water and accelerometry for the assessment of physical activity energy expenditure (PAEE) in adults. The electronic web-based version of RPAQ was used for this study. Reported frequency and duration were used to compute time spent in specific activities, which was multiplied by energy costs of each activity taken from the reported metabolic equivalent of tasks from the physical activity compendium[13] to calculate activity-specific PAEE, which were summated by domain and across all domains as total PAEE. If reported time spent in activities was >18 h (assuming 6 h sleep), all reported durations of activity were scaled back to 18 h. PAEE was expressed in KJ/kg/day.

Baseline characteristics

Age at Phase 1 of the study was used in analyses, and four categories were used in subgroup analyses (30–40, 40–50, 50–60 and 60+ years). Highest educational attainment was classified using international standards[14] (lower secondary education, upper secondary education or postsecondary non-tertiary education and Bachelor's degree or equivalent level), and ethnicity and occupation were self-reported during Phase 1 of the study. The degree level category included having a university degree, and no differentiation was made for those with further degree qualifications (such as Master's or PhD). Self-reported ethnicity was reported in 17 categories. As most participants identified as 'White', ethnicity was categorised as 'White' and 'not White'. Self-reported occupation was categorised into three occupation groups:[15] Group 1, routine manual and service, semi-routine and technical; Group 2, middle or junior managers, clerical and intermediate; Group 3, traditional professional, modern professional and senior managers.[16]

Height in centimetres and weight in kilograms were measured by a trained member of the study team at P1 and P2, and weight was also self-reported at C0 in those participants who had access to weighing scales at home. Body mass index (BMI) (weight in kilogram/height in square metres) was calculated; overweight (including obese participants) was defined as BMI $\geq$25 kg/m^2, and obesity was defined as $\geq$30 kg/m^2. BMI at C0 was calculated using height measured from P2. To ascertain whether participants had been exposed to the SARS-CoV-2 virus before and during the Fenland COVID-19 substudy period, participants completed remote blood sample collections at three time points (C0, C3 and C6). Participants collected blood from their upper arm or thigh using self-administered OneDraw devices and the dried blood spot samples were posted back to the MRC Epidemiology Laboratory, University of Cambridge, UK. The samples were analysed for SARS-CoV-2 immunoglobulin G antibodies using commercial enzyme-linked immunosorbent assay.[7] The study focussed on seropositivity. Therefore, all negative results and borderline results were classed as not seropositive.

Statistical analysis and data handling

Statistical analysis was performed using Stata version 14 (Statacorp LLC, Texas, USA).[17] Skewed variables were summarised using median and interquartile range, normally distributed variables using mean and standard deviation (SD) and categorical variables with *n* (%).

Analyses at each time point

To test for associations between IMD groupings 1 and 3 and each outcome variable, a Wilcoxon rank-sum test was used, and Chi-squared test was used for categorical variables. To test for a trend across IMD grouping, (1-3) non-parametric rank tests were used.

Assessing the effect of the pandemic overall and within subgroups

A two-level random intercepts linear (for all outcomes except smoking) or logistic (for smoking) regression model was used to investigate whether health behaviours differed between during pandemic (at least C0 time point, and C3 and/or C6 if completed) and prepandemic (P1 and/or P2) time points. The model was adjusted for age at Phase 1, time to follow-up from Phase 1, season (spring/summer/autumn/winter) and sex. Continuous outcomes were log transformed to address non-normality of the residuals. The pandemic effect was reported as a ratio of geometric means (RGM) of the outcome (>1 implies an increase, <1 implies a decrease) comparing during vs. prepandemic, overall and stratified by (1) IMD group,(2) gender and (3) age group (30–40, 40–50, 50–60 and 60+ years). The interaction with each of these variables was tested by including the relevant parameters in the model and applying a Wald test.

Sensitivity analysis

To assess the effect of using occupation as an individual marker of deprivation rather than IMD, which is a group level marker, analyses were repeated using the three occupation groups as the exposure variable instead of IMD group.

To assess the impact of COVID-19 infection on changes in health behaviour, the analyses were repeated after removing participants who were seropositive for COVID-19 at any of the three time points measured during the pandemic (C0, C3 or C6).

Role of the funding source

The funders were not involved in the study design, collection analysis or interpretation of the data in the writing of the report or the decision to submit the paper for publication.

Results

Of the 12,435 participants originally recruited in the Fenland cohort, 11,469 participants were contactable and invited to take part in the COVID-19 substudy, of whom 4031 (35%) consented to participate. This analysis included 3231 (80%) participants who had completed both a food frequency questionnaire and RPAQ questionnaire at C0 (Fig. 1 and Supplementary Fig. 1). Those participants included in this analysis were compared with participants originally recruited in the Fenland cohort who did not take part in the COVID-19 substudy and were not included in the analysis ($n = 3231$ vs. $n = 9204$). A higher proportion of those in the analysis group were women than Fenland cohort participants not in the analysis (57.5% vs. 52.5%); they were also older (mean [SD]: 49.3 [7.3] vs. 48.3 [7.6]), more likely to be in the highest occupation group (traditional professional, modern professional, or higher managerial; 65.6% vs. 48.8%), have a Bachelor's degree or equivalent (47.8% vs. 32.1%) and less likely to be in the most deprived IMD group (15.7% vs. 26.2%).

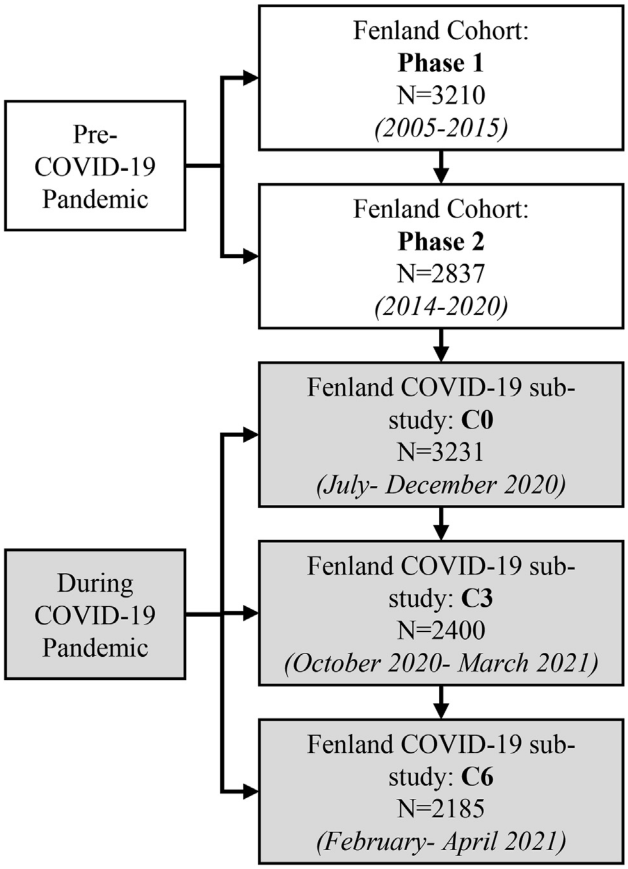

Fig. 1. Participant flow diagram. Participants were included in the present study if they had completed health behaviour questionnaires at C0 (Fenland COVID-19 sub-study, baseline), $n = 3231$. The flowchart indicates the number of participants who were included from the prepandemic time points (Phase 1: $n = 3210$ and Phase 2: $n = 2837$, shaded white) and during the pandemic (baseline C0: $n = 3231$, C3: $n = 2400$ and C6: $n = 2185$, shaded grey), and the dates during which the health behaviours were measured.

Baseline characteristics

Of the 3231 participants included, 58% were women, and 98% of participants were White (Table 1). At Phase 1 (P1: baseline), participants had a mean (SD) age of 49.3 (7.3) years, 48% had a Bachelor's degree or equivalent, and 66% reported traditional professional, modern professional or higher managerial as their occupation (Group 3). At baseline, 16% of participants were in the most deprived IMD group, 35% in the middle deprived group and 49% in the least deprived group. When stratifying by IMD group, participants in the most deprived group (Group 1) were on average 4 kg heavier than those in the least IMD deprived group and were more likely to be overweight (65% vs 52%) or obese (24% vs 15%) than those in the least IMD deprived group ($P < 0.0001$ for all). The mean time interval from P1 to the first time point during the pandemic (C0) was 9.8 years (SD 2.3), range (5.5–15.7 years). The mean time interval was higher in the most deprived IMD group compared with the middle and least deprived groups (most deprived: 10.2 years [SD 2.3], middle: 9.6 years [SD 2.3], 9.9 years [SD 2.3] and least deprived: 9.9 years [SD 2.3], respectively, $P < 0.001$).

At baseline, participants in the most deprived IMD group ate fewer portions of fruit and vegetables per day, consumed fewer units of alcohol per week and were more likely to smoke compared with the least deprived IMD group (Health behaviours in Table 1). At baseline, the average reported sleep duration and total PA was similar across IMD groups, although the most deprived IMD group expended more PA at work and home and less PA during leisure time compared with the least deprived IMD group.

Change in health behaviours before and during the COVID-19 pandemic

Fruit and vegetable consumption was estimated to have decreased by 12% during the pandemic compared with before the pandemic (RGM: 0.88 [95% confidence interval: 0.87–0.90]; $P < 0.0001$). In relation to the primary hypothesis, this decrease was greatest in the most deprived IMD group (RGM: 0.86 [0.82–0.91]; P interaction = 0.02), and in women (RGM: 0.86 [0.84–0.88]; P interaction < 0.0001). Fruit and vegetable intake decreased among all age groups but more so in the youngest (those aged 30–40 years at P1: baseline) and oldest (60+ years) age groups (P interaction = 0.05; Fig. 2A, Supplementary Table 1).

Reported alcohol consumption did not differ significantly overall before compared with during the pandemic. However, men tended to report an increase in alcohol consumption, and women tended to report a decrease (P interaction = 0.03), and those in the youngest age group (30–40 years at P1: baseline) reported a 9% increase in alcohol consumption during the pandemic compared with before the pandemic (RGM: 1.09 [0.98–1.21]; P interaction = 0.007).

The average sleep duration increased overall by 3% during the pandemic compared with before the pandemic (RGM: 1.03 [1.02–1.03]; $P < 0.0001$). Sleep duration increased more so in men (P interaction < 0.0001) but did not differ significantly by IMD or age group.

Total PAEE decreased overall by 17% (RGM: 0.83 [0.81–0.86], $P < 0.0001$). In relation to the primary hypothesis, this decrease was greatest in the most and middle deprived IMD groups (RGM: 0.81 [0.73–0.90] and 0.81 [0.77–0.86], P interaction = 0.04), in women (RGM: 0.80 [0.77–0.84]; P interaction < 0.0001) and in the over 60 s (RGM: 0.76 [0.65–0.91]; P interaction = 0.13).

Smoking decreased during the pandemic (odds ratio [95% confidence interval]: 0.45 [0.22–0.92]; $P = 0.03$) compared with before the pandemic. Because of the small number of participants who smoked (3.6% during the pandemic), it was not possible to perform stratified analyses for this outcome of the primary hypothesis.

Participants who worked at each time point

The percentage of participants who reported they were working at the different time points decreased from 92% at baseline (P1) to 60% by C6 (Supplementary Table 3). This decrease was similar among the three IMD groups. This did not distinguish between those who continued to work in their workplace and those who were working from home.

Sensitivity analysis: occupation

The use of occupation group in place of IMD in the multilevel mixed-effects generalised linear model was very similar in terms of the interpretation of the results with the exception of two minor differences in the statistical significance of interaction terms in the models for change in total PAEE (Supplementary Table 2). The biggest difference was for a model investigating domain-specific PAEE at home, for which there was a highly statistical interaction between occupational grouping and the term for the pandemic ($P < 0.0001$), which was not evident at all in a model for the same outcome exploring the potential interaction between IMD and the pandemic ($P = 0.99$). The direction of the interaction was that

Table 1
Characteristics of participants of the Fenland Study at Phase 1 ($n = 3231$) by indices for multiple deprivation category (1: most deprived [$n = 508$, 16%], 2: middle [$n = 1132$, 35%], 3: least deprived [$n = 1591$, 49%]).

Characteristics	All ($n = 3231$)	IMD category 1: most deprived	IMD category 2: middle	IMD category 3: least deprived	Test for trend[a], *P*-value
Age (y), mean (SD)	49.3 (7.3)	49.2 (7.3)	49.4 (7.2)	49.2 (7.3)	0.68
Sex, *n* (%)					
Female	1858 (57.5)	286 (56.3)	651 (57.5)	921 (57.9)	0.49
Male	1373 (42.5)	222 (43.7)	481 (42.5)	670 (42.1)	
Occupation, *n* (%)					
Technical, semi-routine and routine	478 (15.3)	136 (27.4)	187 (16.9)	155 (10.1)	0.0001
Lower managerial and intermediate occupations	597 (19.1)	113 (22.8)	218 (19.8)	266 (17.4)	
Traditional and modern professional and higher managerial	2054 (65.6)	247 (49.8)	697 (63.3)	1110 (72.5)	
Education[a], *n* (%)					
Bachelor's degree or equivalent	1501 (47.8)	126 (26.1)	495 (44.3)	880 (56.3)	0.0001
Upper secondary/non-tertiary education	1351 (43.0)	281 (58.3)	489 (44.7)	581 (37.2)	0.0001
Lower secondary	288 (9.2)	75 (15.6)	110 (10.1)	103 (6.6)	0.0001
Ethnicity, *n* (%)					
White	3071 (97.9)	493 (99.4)	1079 (97.5)	1499 (97.9)	0.05
Not White	64 (2.1)	3 (0.6)	28 (2.5)	33 (2.1)	
Anthropometry					
Weight (kg), mean (SD)	76.8 (15.7)	79.8 (17.6)	76.9 (15.4)	75.7 (15.1)	0.0001
Height (cm), mean (SD)	170.5 (9.2)	169.9 (9.2)	170.5 (9.2)	170.7 (9.3)	0.09
BMI (kg/m^2), mean (SD)	26.3 (4.6)	27.5 (4.9)	26.4 (4.6)	25.9 (4.4)	0.0001
≥BMI 25 kg/m^2[a], *n* (Y%)	1808 (55.9)	331 (65.2)	646 (57.1)	831 (52.3)	0.0001
≥BMI 30 kg/m^2[a], *n* (Y%)	563 (17.4)	122 (24.0)	205 (18.1)	236 (14.8)	0.0001
Health behaviours					
Fruit and vegetable (servings/day), median (IQR)	7.4 (5.4–10.1)	7.1 (5.1–10.1)	7.6 (5.4–10.1)	7.5 (5.5–9.9)	0.07
Alcohol consumption (units/week), median (IQR)	5.5 (1.4–10.3)	4.8 (0.7–8.9)	4.9 (1.3–9.5)	5.9 (2.0–11.8)	0.0001
Current smoker, *n* (%)	238 (12.6)	53 (16.4)	94 (13.8)	91 (10.4)	0.0001
Ever smoker, *n* (%)	1365 (42.4)	244 (48.1)	498 (44.1)	625 (39.5)	0.0001
Sleep (hours/day), median (IQR)	8.0 (7.5–8.5)	8.0 (7.5–8.5)	8.0 (7.5–8.4)	8.0 (7.6–8.5)	0.53
Total PAEE (kJ/kg/day), median (IQR)	26.6 (19.1–37.5)	26.8 (18.5–38.3)	26.2 (18.9–37.4)	26.7 (19.4–37.4)	0.8
PAEE at work (kJ/kg/day), median (IQR)	12.5 (9.2–16.4)	13.3 (10.5–18.1)	12.6 (9.2–16.5)	12.4 (9.0–15.2)	0.0001
PAEE at home (kJ/kg/day), median (IQR)	2.6 (0.85–6.4)	2.9 (0.77–7.5)	2.6 (0.85–6.5)	2.6 (0.89–6.2)	0.6
PAEE at leisure (kJ/kg/day), median (IQR)	7.2 (2.9–13.6)	6.1 (1.9–11.9)	7.1 (2.6–13.5)	7.5 (3.3–14.1)	0.06
PAEE during commute (kJ/kg/day), median (IQR)	1.0 (0.34–3.1)	0.81 (0.27–1.8)	1.0 (0.34–2.9)	1.0 (0.41–3.1)	0.05

BMI, body mass index (kg/m^2); IMD, English indices for multiple deprivation 2019; IQR, interquartile range; PAEE, physical activity energy expenditure; SD, standard deviation.
[a] Education level available for 3140 participants.

particularly among those reporting lower managerial and intermediate-level occupations, there was a statistically significant reduction in activity at home during the pandemic, which was not seen in other occupational groups.

Sensitivity analysis: COVID-19 seropositivity

Overall, 14% of participants were seropositive for COVID-19 antibodies at one or more of the three time points during the early waves of the pandemic from July 2020 to April 2021. This percentage did not differ significantly by IMD (IMD Group 1: 14% vs Group 3: 13%; $P < 0.47$). Excluding participants who were seropositive for COVID-19 antibodies at C0, C3 or C6 ($n = 428$) made little difference to the models for change in health behaviour pre- and post-pandemic (Supplementary Fig. 2A–C).

Discussion

Main findings

Our study confirmed the primary hypothesis that observed inequalities in some health behaviours further increased during the pandemic; fruit and vegetable consumption and total PAEE declined more so in the most deprived group compared with the least deprived group during the pandemic relative to prepandemic health behaviours. The average sleep duration increased during the pandemic, but this did not differ by deprivation group.

Socio-economic inequalities in health behaviours existed before the pandemic in this population-based cohort study in which participants from more deprived areas were more likely to be smokers and to report eating fewer portions of fruit and vegetables. Overall, obesity prevalence was 1.6-fold higher in the participants from the most deprived areas (24%) compared with those from the least deprived areas (15%).

We found that changes in health behaviours during the pandemic differed by gender and age. Women reported a greater decrease in fruit and vegetable consumption and total PAEE compared with men, and the decline in total PAEE was most pronounced in those aged > 60 years; this finding is in line with other studies that have reported a greater decrease in self-reported PA in older age groups during the pandemic.[18,19] We did not have information on the types of work people were doing and whether this was from home or in the workplace, which could have impacted their total PAEE. However, we did find that activity from commuting was higher in the most deprived group during the pandemic (Supplementary Table 1), which suggests that they were more likely to be in the workplace than working at home.

Limitations and strengths of the study

This study was embedded in an existing prospective cohort and had repeated data on health behaviours from before the COVID-19 pandemic as well as during the pandemic using the same measurement tools at all time points. This study design therefore diminished recall or measurement bias and allowed for direct comparison of health behaviours across the five time points. Other published studies assessing change in health behaviours in relation to the pandemic have not collected prepandemic data prospectively

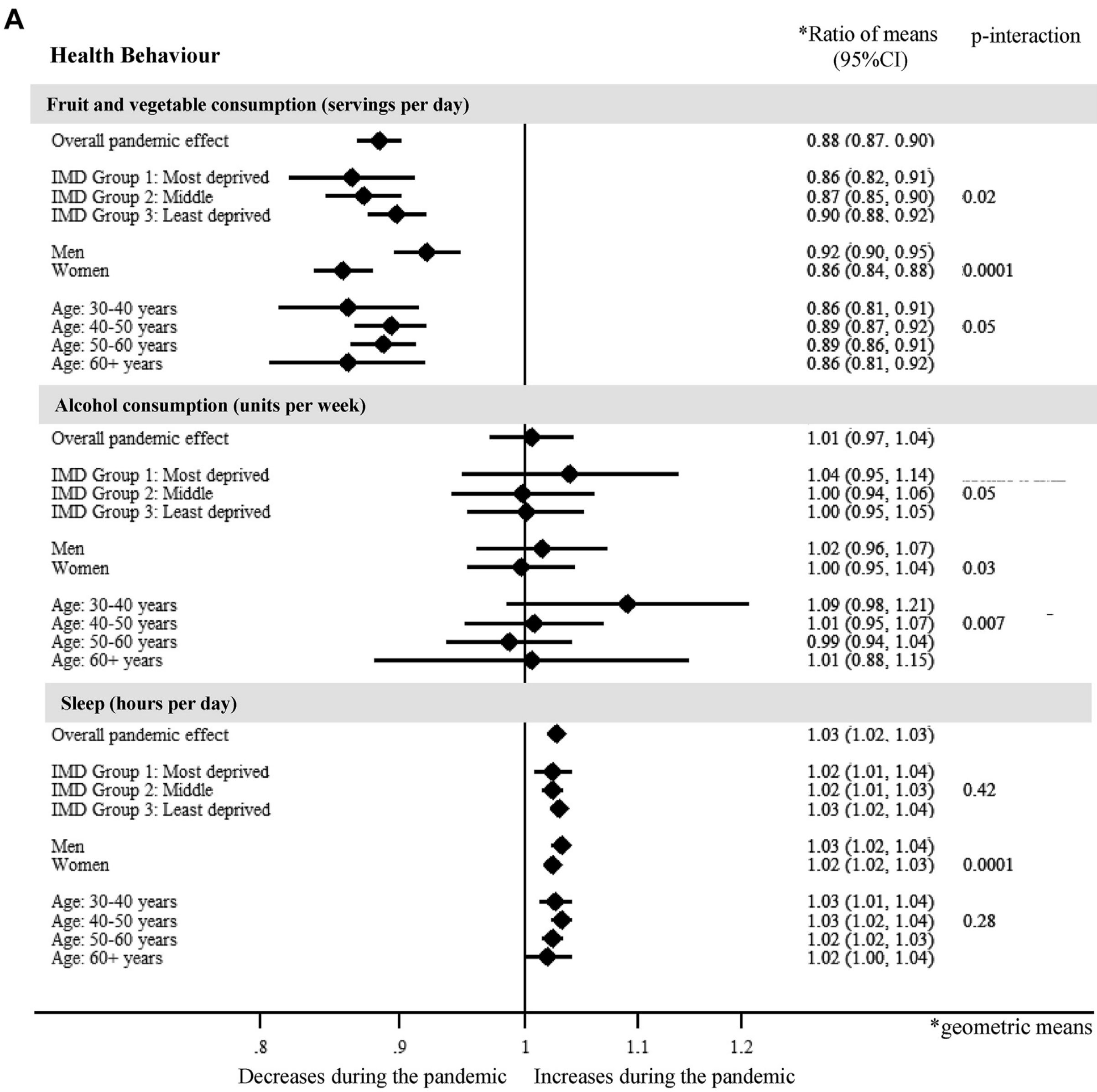

Fig. 2. (A–C) Effect of the pandemic on health behaviours, overall and within subgroups. The effect of the pandemic (during vs. pre) is presented as the ratio of geometric means (95% confidence intervals). A ratio <1 indicates that the health behaviour declined during the pandemic compared with before the pandemic, and a ratio >1 indicates that the health behaviour increased during the pandemic compared with before the pandemic. A ratio of 1 indicates no difference.

and therefore had to rely on participant recall of prior behaviour, which is open to bias.[18,20–31]

Other strengths of this study were the availability of two time measurement time points prepandemic. Models were adjusted for age at Phase 1 and time to follow-up from Phase 1, thus allowing consideration of the rate of change of health behaviours with age under normal circumstances. We also considered the effect of seasonality by adjusting for the season at each time point in the analyses, unlike other studies.[20,21] It is well established that certain health behaviours differ by season, for example, reported fruit and vegetable consumption is known to be lower in the winter. As Phases 1 and 2 of the cohort study recruited participants across several complete years, we were able to account for the effect of the season when assessing changes in health behaviour. This would otherwise have been an issue as the three measurements during the pandemic were largely taken in the autumn and winter months.

The study was able to compare the results using both a group level indicator of deprivation (IMD), a multifaceted marker of area deprivation that considers income, employment, education, health, crime, housing and living environment and an individual marker of socio-economic status, namely, occupation. Sensitivity analysis indicated that the two measurements of social inequalities produced broadly similar results, with the exception of total PAEE, largely due to the domain-specific PAEE at home, where there were distinct differences between men and women. This is in line with previous studies that have shown that IMD concordance with occupation type is reasonable.[32]

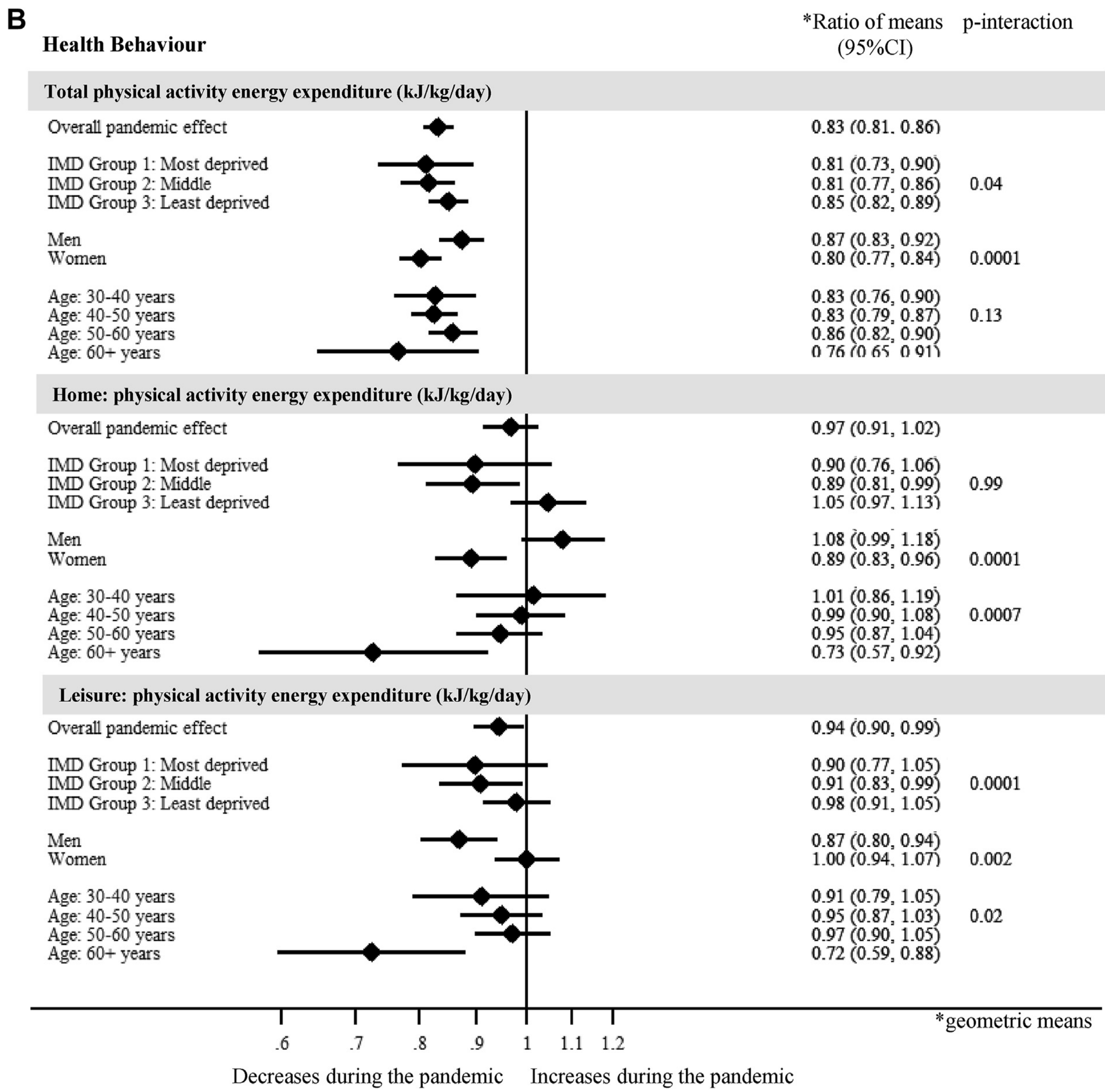

Fig. 2. (continued)

A limitation of this study was that recruitment was undertaken via telephone and email, which may exclude some population groups who do not have access to a telephone or email. This study was conducted in an established and well-characterised cohort, which provided information on socio-demographic characteristics of all participants so that differences could be investigated between those who were included in this study of prepandemic and during pandemic health behaviours and those who did not participate. Those who consented to take part in the study were less likely to come from deprived areas and more likely to have a higher education level and be in the highest occupation group. This cohort study recruited from across Cambridgeshire, where there is low ethnic diversity in the study population, which reflects the low ethnic diversity of the region; we were unable to comment on ethnic differences and changes in health behaviours as a result of the pandemic. In addition, the time from baseline to follow-up was slightly longer in the most deprived group compared with the least deprived group; however, time to follow-up was adjusted for as a covariate in the statistical models.

Implications of the study and future research

Previous studies have shown that health behaviours in adults are often mirrored in their children,[33] so it is likely that the change in health behaviours seen in adults in this study could affect other family members too and not only their own personal health. Therefore, the effect of the pandemic on health behaviour may extend beyond the population subgroup that we studied here. Whether those effects are temporary or long-lasting remains to be determined.

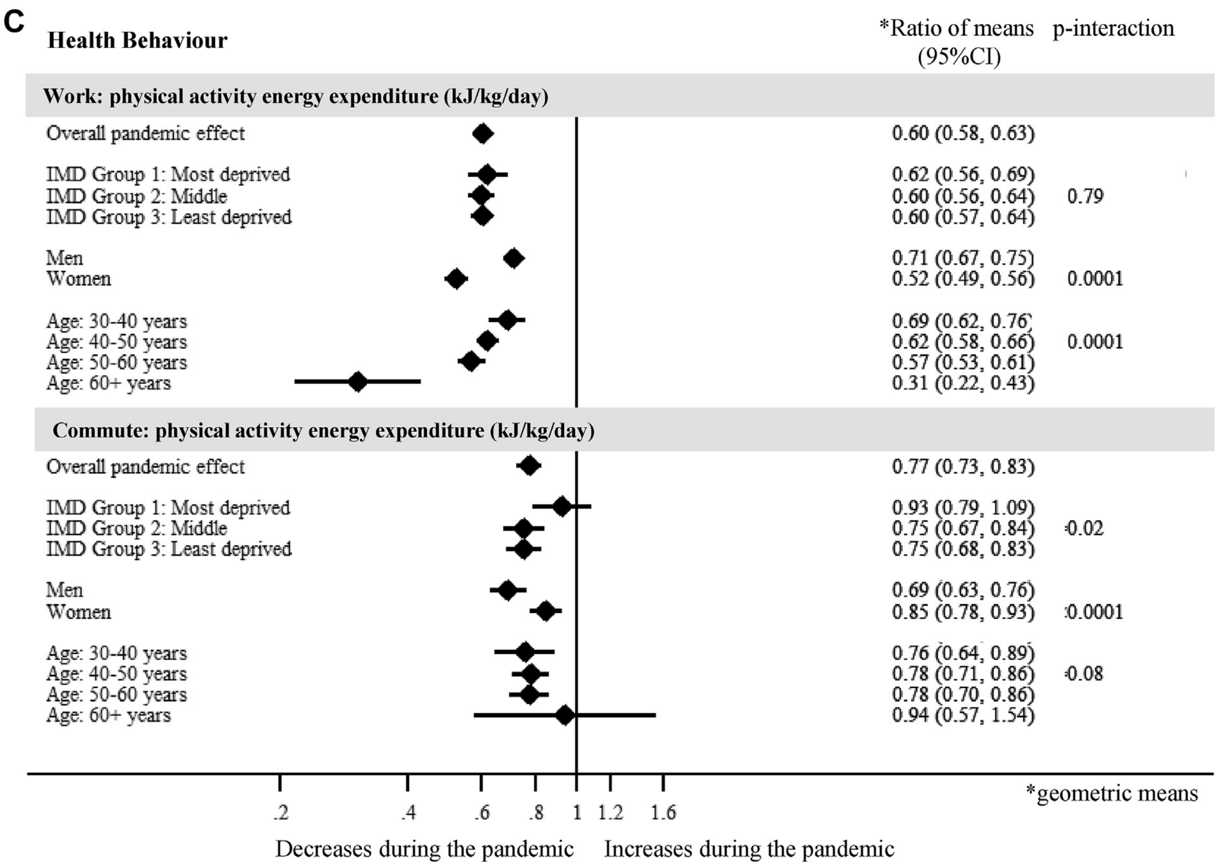

Fig. 2. (continued)

The study suggests that strategies to reduce health inequalities need to be at the forefront of local and national government recovery plans, not just in continued support for disadvantaged groups during the pandemic, like enhanced access to fresh fruit and vegetables, for example, but also through more long-term approaches, which seek to make systematic efforts to reduce inequalities.

Conclusions

The study has shown that socio-economic inequalities in health behaviours, particularly fruit and vegetable consumption and total PAEE, have worsened during the pandemic. As the country emerges from the COVID-19 pandemic, strategies to reduce inequalities need to be put at the forefront of recovery plans.

Author statements

Ethical approval

Ethics approvals for Phases 1 and 2 were obtained from Cambridge East Research Ethics committee on 11 May 2004 and 5 July 2014, respectively. Written informed consent was obtained from all participants, and participants were made aware that they were able to request to leave the study at any point. For the Fenland COVID-19 substudy, ethical approval was obtained from South West Cornwall and Plymouth Research Ethics committee on 30 June 2020. Consent for the Fenland COVID-19 substudy was completed online. The Fenland cohort participant panel was involved in the planning, conducting and reporting of the Fenland COVID-19 study as part of patient and public involvement.

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Competing interests

None declared.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2022.08.005.

References

1. World Health Organization. *WHO coronavirus (COVID-19) dashboard*. Available from: 2021, https://covid19.who.int/.
2. World Health Organization. *Health inequity and the effects of COVID-19. Assessing, responding to and mitigating the socioeconomic impact on health to build a better future*. Available from: 2020, https://apps.who.int/iris/bitstream/handle/10665/338199/WHO-EURO-2020-1744-41495-56594-eng.pdf.
3. Office for National Statistics. *Socioeconomic inequalities in avoidable mortality in England: 2020*. Available from: https://www.ons.gov.uk/

peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/bulletins/socioeconomicinequalitiesinavoidablemortalityinengland/2020.
4. Office for National Statistics. *Deaths involving COVID-19 by local area and socioeconomic deprivation: deaths occurring between 1 March and 31 May 2020*. Office for National Statistics; 2020.
5. Gu T, Mack JA, Salvatore M, Sankar SP, Valley TS, Singh K, et al. Characteristics associated with racial/ethnic disparities in COVID-19 outcomes in an academic health care system. *JAMA Network Open* 2020;**3**(10).
6. Daniels NF, Burrin C, Chan T, Fusco F. A systematic review of the impact of the first year of COVID-19 on obesity risk factors: a pandemic fueling a pandemic? *Curr Dev Nutr* 2022;**6**(4).
7. Koulman A, Rennie K, Parkington D, Tyrrell C, Catt M, Gkrania-Klotsas E, et al. The development, validation and application of remote blood sample collection in telehealth programmes. *Journal of Telemedicine and Telecare* 2022. First published online May 10, 2022. https://doi.org/10.1177/1357633X221093434.
8. Ministry of Housing. *Communities and Local Government. English indices of deprivation 2019 National statistics*. Available from: https://www.gov.uk/government/statistics/english-indices-of-deprivation-2019.
9. Bingham SA, Welch AA, McTaggart A, Mulligan AA, Runswick SA, Luben R, et al. Nutritional methods in the European prospective investigation of cancer in Norfolk. *Public Health Nutrition* 2007;**4**(3):847–58.
10. National Health Service. *Live well*. 2018 Available from: https://www.nhs.uk/live-well/.
11. Leng Y, Wainwright NW, Cappuccio FP, Surtees PG, Luben R, Wareham N, et al. Self-reported sleep patterns in a British population cohort. *Sleep medicine* 2014;**15**(3):295–302.
12. Golubic R, May AM, Benjaminsen Borch K, Overvad K, Charles M-A, Diaz MJT, et al. Validity of electronically administered recent physical activity questionnaire (RPAQ) in ten European countries. *PLOS ONE* 2014;**9**(3):e92829.
13. Ainsworth BE, Haskell WL, Herrmann SD, Meckes N, Bassett D, Tudor-Locke C, et al. 2011 Compendium of physical activities: a second update of codes and MET values. *Medicine and science in sports and exercise* 2011;**43**(8):1575–81.
14. UNESCO Institute for Statistics. *International standard classification of education*. 2011. Available from: http://uis.unesco.org/sites/default/files/documents/international-standard-classification-of-education-isced-2011-en.pdf.
15. Barrett P, Imamura F, Brage S, Griffin SJ, Wareham NJ, Forouhi NG. Sociodemographic, lifestyle and behavioural factors associated with consumption of sweetened beverages among adults in Cambridgeshire, UK: the Fenland Study. *Public Health Nutr* 2017;**20**(15):2766–77.
16. Office for National Statistics. *The National statistics Socio-economic classification (NS-SEC rebased on SOC2010)*, **3**. Basingstoke: ONS; 2013.
17. StataCorp. *Stata Statistical software: release 14*. College Station: TSL; 2015.
18. Eek F, Larsson C, Wisén A, Ekvall Hansson E. Self-perceived changes in physical activity and the relation to life satisfaction and rated physical capacity in Swedish adults during the COVID-19 pandemic – a cross sectional study. *International journal of environmental research and public health* 2021;**18**(2).
19. Harrison E, Monroe-Lord L, Carson AD, Jean-Baptiste AM, Phoenix J, Jackson P, et al. COVID-19 pandemic-related changes in wellness behavior among older Americans. *BMC Public Health* 2021;**21**(1):755.
20. Ammar A, Brach M, Trabelsi K, Chtourou H, Boukhris O, Masmoudi L, et al. Effects of COVID-19 home confinement on eating behaviour and physical activity: results of the ECLB-COVID19 international online survey. *Nutrients* 2020;**12**(6).
21. Panagiotidis P, Rantis K, Holeva V, Parlapani E, Diakogiannis I. Changes in alcohol use habits in the general population, during the COVID-19 lockdown in Greece. *Alcohol and Alcoholism* 2020;**55**(6):702–4.
22. Manthey J, Kilian C, Carr S, Bartak M, Bloomfield K, Braddick F, et al. Use of alcohol, tobacco, cannabis, and other substances during the first wave of the SARS-CoV-2 pandemic in Europe: a survey on 36,000 European substance users. *Subst Abus Treat Prev Policy* 2021;**16**(1):36.
23. Neill E, Meyer D, Toh WL, van Rheenen TE, Phillipou A, Tan EJ, et al. Alcohol use in Australia during the early days of the COVID-19 pandemic: initial results from the COLLATE project. *Psychiatry and clinical neurosciences* 2020;**74**(10):542–9.
24. Naughton F, Ward E, Khondoker M, Belderson P, Marie Minihane A, Dainty J, et al. Health behaviour change during the UK COVID-19 lockdown: findings from the first wave of the C-19 health behaviour and well-being daily tracker study. *British journal of health psychology* 2021;**26**(2):624–43.
25. Ruiz MC, Devonport TJ, Chen-Wilson C-H, Nicholls W, Cagas JY, Fernandez-Montalvo J, et al. A cross-cultural exploratory study of health behaviors and wellbeing during COVID-19. *Frontiers in Psychology* 2021;**11**(3897).
26. Vancini RL, Camargo-Neto L, de Lira CAB, Andrade MS, Viana RB, Nikolaidis PT, et al. Physical activity and sociodemographic profile of Brazilian people during COVID-19 outbreak: an online and cross-sectional survey. *International journal of environmental research and public health* 2020;**17**(21):7964.
27. Al-Domi H, Al-Dalaeen A, Al-Rosan S, Batarseh N, Nawaiseh H. Healthy nutritional behavior during COVID-19 lockdown: a cross-sectional study. *Clin Nutr ESPEN* 2021;**42**:132–7.
28. Đogaš Z, Lušić Kalcina L, Pavlinac Dodig I, Demirović S, Madirazza K, Valić M, et al. The effect of COVID-19 lockdown on lifestyle and mood in Croatian general population: a cross-sectional study. *Croatian medical journal* 2020;**61**(4):309–18.
29. Kaufman-Shriqui V, Navarro DA, Raz O, Boaz M. Multinational dietary changes and anxiety during the coronavirus pandemic-findings from Israel. *Israel journal of health policy research* 2021;**10**(1):28.
30. Alharbi AS, Alshahrani SM, Alsaadi MM, Al-Jahdali HH, Wali SO, BaHammam AS. Sleep quality and insomnia during the COVID-19 lockdown among the Saudi public: a cross-sectional study. *Saudi medical journal* 2021;**42**(4):384–90.
31. Zajacova A, Jehn A, Stackhouse M, Denice P, Ramos H. Changes in health behaviours during early COVID-19 and socio-demographic disparities: a cross-sectional analysis. *Canadian Journal of Public Health* 2020;**111**(6):953–62.
32. Ingleby FC, Belot A, Atherton I, Baker M, Elliss-Brookes L, Woods LM. Assessment of the concordance between individual-level and area-level measures of socio-economic deprivation in a cancer patient cohort in England and Wales. *BMJ open* 2020;**10**(11):e041714.
33. Tabacchi G, Petrigna L, Battaglia G, Navarra G, Palma A, Bellafiore M. An interaction path of mothers' and preschoolers' food- and physical activity-related aspects in disadvantaged Sicilian urban areas. *International journal of environmental research and public health* 2021;**18**(6).