Use of wearable sensors to assess compliance of asthmatic children in response to lockdown measures for the COVID-19 epidemic

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Research Article

Keywords: COVID-19, SARS-CoV-2, lock-down, physical activity, Global Positioning System, schoolchildren, asthma

DOI: https://doi.org/10.21203/rs.3.rs-37518/v1

Abstract

Between March and April 2020, Cyprus and Greece health authorities enforced three escalated levels of public health interventions to control the COVID-19 pandemic. We quantified compliance of asthmatic schoolchildren from both countries to intervention levels, using wearable sensors to continuously track personal location and physical activity. Changes in 'fraction time spent at home' and 'total steps/day' were assessed with a mixed-effects model adjusting for confounders. We observed significant mean increases in 'fraction time spent at home' in Cyprus and Greece, during each intervention level by 41.4% and 14.3% (level 1), 48.7% and 23.1% (level 2) and 45.2% and 32.0% (level 3), respectively. Physical activity in Cyprus and Greece demonstrated significant mean decreases by -2,531 and -1,191 (level 1), -3,638 and -2,337 (level 2) and -3,644 and -1,961 (level 3) total steps/day, respectively. We also report significant independent effects of weekends and age on fraction time spent at home and weekends, age, humidity and gender on physical activity. We suggest that wearable technology provides objective, continuous, real-time location and activity data making possible to inform in a timely manner public health officials on compliance to various tiers of public health interventions during a pandemic.

Introduction

Following several coronavirus outbreaks during the last years [1], a novel coronavirus named SARS-CoV–2 (COVID–19) presented in Wuhan, China in December 2019, causing severe pneumonia with high fatality rates, especially, amongst the elderly and people with comorbidities [2]. The virus rapidly spread all over the world and on the 11th of March 2020, WHO characterized COVID–19 outbreak as a pandemic [3].

In the absence of an effective vaccine or specific antiviral drugs against COVID–19 [4], public health interventions implemented at the community or national level are essentially the only strategy to control the pandemic. Non-pharmaceutical interventions may range from simple isolation of disease carriers, quarantine of contacts and hand hygiene measures to travel restrictions, ban of mass gatherings, social distancing and finally to complete lock-down and community quarantine (cordon sanintaire) [5–7]. During the first peak of the pandemic, affected countries chose different levels of interventions based, among others, on national risk assessments of estimated number of patients and capacity for hospitalization and critical care support [8, 9]. The evolution of the pandemic over the last months demonstrated that timely interventions were effective to delay the spread of COVID–19 [10, 11], as it was also shown in previous flu and SARS epidemics [12–14].

The compliance of the population to non-pharmaceutical interventions plays a catalytic role in the successful containment of the virus [15]. However, monitoring and understanding population's compliance to behavioural changes requested by interventions during an emerging pandemic is difficult [16–18]. In the context of complete lockdown measures, where citizens are advised to reduce their mobility and stay at home, wearable sensors measuring physical activity levels and time spent at home may help quantifying compliance. The aim of our study was to quantify mobility changes in response to COVID−19 lockdown measures of schoolchildren with asthma in Cyprus and Greece by continuously tracking their location and activity using wearable sensors.

Results

Participants' characteristics

A total of 108 (57% males) asthmatic children, 53 in Cyprus and 55 in Crete-Greece, with an average age of 9.2 years were enrolled in the study and contributed data between February 3 and April 26, 2020. All children had a physician's diagnosis of asthma, while 53% also reported wheezing episode(s) during the past 12 months, 45% unscheduled medical visit(s) for asthma, 26% emergency room visits for asthma, and 20% daily preventive anti-asthma medication during the past 12 months (Table 1). For the February 3 to April 26, 2019 study period, we measured mobility for 39 and 52 asthmatic children (59% males) in Cyprus and Greece, respectively, with an average age of 9.3 years.

Unadjusted analysis

Overall, in both countries there were significant changes in the observed fraction time spent at home and total steps/day with introduction of public health intervention levels. The observed mean fraction time spent at home among asthmatic children in Cyprus and Greece during baseline period was 43.8% (95%CI: 40.5–47.1%) and 52.4% (95%CI: 49.4–55.4%) respectively. In Cyprus, the observed fraction time spent at home significantly increased to 88.9% (95%CI: 85.7–92.1%) during level 1, to 95.5% (95%CI: 93.8–97.2%) during level 2 and 94.1% (95%CI: 92.5–95.7%) during level 3 of interventions. In Greece, introduction of level 1 public health interventions was characterized by an increase in the observed fraction time spent at home to 71.4% (95%CI: 60.4–82.5%), while during level 2 and 3 interventions the fraction time spent at home increased further to 84.9% (95%CI: 80.3–89.4%) and 89.6% (95%CI: 87.0–92.3%) respectively (Table 2, Figure 2). In Cyprus, the observed total steps/day reduced significantly with introduction of each level of public health interventions from 8,996 (95%CI: 8,567–9,425) at baseline, to 6,499 (95%CI: 5,832–7,166) at level 1, 6,248 (95%CI: 5,683–6,812) at level 2 and 6,270 (95%CI: 5,814–6,727) at level 3. Similarly, in Greece, the observed total steps/day reduced with each level of public health interventions from 8,527 (95%CI: 8,145–8,908) at baseline, to 6,864 (95%CI: 5,689–8,040) at level 1, 5,533 (95%CI: 4,769–6,297) at level 2 and 5,439 (95%CI: 5,051–5,829) at level 3 (Table 2, Figure 2). This pattern was in sharp contrast to the normal mobility pattern of the asthmatic children cohorts in Cyprus and Greece during the first study period of February 3 to April 26, 2019, where the fraction time spent at home and total steps per day were quite stable throughout the same weeks of the year (Figure 3).

Adjusted Analyses

Based on the mixed effects model, after controlling for several confounders, the adjusted mean increase in time-fractions spent at home in Cyprus were: 41.4% (95%CI: 34.5–48.2%, p_{value}<0.001) during level 1, 48.7% (95%CI: 42.0–55.5%, p_{value}<0.001) during level 2, and 45.2% (95%CI: 39.3–51.2%, p_{value}<0.001) during level 3 of interventions, (Table 3). There was no significant increase between level 2 and 3 periods (p_{value} = 0.298), while the increase between level 1 and 2 periods was almost significant (p_{value} = 0.055). In Greece, the adjusted mean changes in fraction time spent at home were more gradual and moderate, increasing by 14.3% (95%CI: 2.2–26.3%, p_{value} = 0.02) during level 1, 23.1% (95%CI: 11.2–34.9%, p_{value}<0.001) during level 2, and 32.0% (95%CI: 24.8–39.3%, p_{value}<0.001) during level 3 interventions, (Table 4). The changes between levels 1 and 2 as well as levels 2 and 3 were not statistically significant.

In Cyprus, physical activity, expressed in total steps per day, demonstrated an adjusted mean decrease of –2,531 (95%CI: –3,364, –1,698, p_{value}<0.001) during level 1, –3,638 (95%CI: –4,521, –2,755, p_{value}<0.001) during level 2, and –3,644 (95%CI: –4,428, –2,859, p_{value}<0.001) during level 3, (Table 3). The decreases in total steps per day for levels 1 and 2 were statistically significant (p_{value} = 0.019), but not for levels 2 and 3 (p_{value} = 0.954). In Greece, the adjusted mean decrease of physical activity during level 1 period was –1,191 (95%CI: –2,641, –259, p_{value} = 0.108) steps per day. During level 2 and 3 periods the corresponding decreases were –2,337 (95%CI: –3,679, –995, p_{value} = 0.001) and –1,961 (95%CI: –2,933, –990, p_{value}<0.001) steps/day, (Table 4). The differences in total steps decreases per day between levels 1 and 2 (p_{value} = 0.212) and levels 2 and 3 (p_{value} = 0.576) did not reach statistical significance.

In the cohort of asthmatic children in Cyprus, we found that fraction time spent at home was significantly higher during weekends as compared to weekdays (10.9%, 95%CI: 8.0, 13.8%) and with every year of increasing age (1.4%, 95%CI: 0.2, 2.6%). Furthermore, total steps per day were significantly lower during weekends (–1,002, 95%CI: –1,374, –630), with increasing age (–378, 95%: –615, –143), increasing humidity (–29, 95%CI: –42, –15) and in year 2020 as compared to year 2019 (–1,560, 95%CI: –2,796, –324). Finally, total steps per day were significantly higher in males as compared to females (1,024, 95%CI: 53, 1,944), (Table 3). In asthmatic children in Greece, the fraction of time spent at home was also found to be significantly higher during weekends as compared to weekdays (8.32%, 95%CI: 5.2, 11.4%), while steps per day were significantly lower during weekends (–1,212, 95%CI: –1,615, –809) and in year 2020 as compared to year 2019 (–2,791, 95%CI: –4,090, –1,492), (Table 4). In asthmatic children in Cyprus, we found significant interaction effects of weekends across all levels of interventions on both the fraction time spent indoors (level 0: 10.9% compared to level 1: –22.8%, p_{value}: <0.001, level 2: –13.0%, p_{value}: 0.047 and level 3: –18.6%, p_{value}: <0.001) and total steps per day (level 0: –1002 compared to level 1: 1863, p_{value}: 0.006, level 2: 1180, p_{value}: 0.181 and level 3: 1359, p_{value}: <0.023), Table 3. In asthmatic children in Greece we found significant interaction effect for weekends only on total steps per day (level 0: –1212 compared to level 1: 149, p_{value}: 0.919, level 2: 3704, p_{value}: 0.005 and level 3: 1434, p_{value}: 0.036), Table 4.

Discussion

In this study, we have assessed changes in mobility of asthmatic children in Cyprus and Greece in response to public health interventions for the COVID−19 pandemic using GPS tracking, pedometer and heart rate sensors embedded in wearable watches. In asthmatic children in Cyprus, we recorded a steep increase in the fraction of time spent at home from 44% to the very high 95% and a steep decrease in total steps per day from 8,996 to 6,270, demonstrating high compliance to the implemented three levels of interventions. In asthmatic children in Greece, we observed a more gradual, stepwise increase in fraction time spent at home from 52% at baseline to the also high 90% and a similar pattern of gradual decrease of physical activity from 8,527 to 5,439 steps/day. The different pattern of changes in the mobility of asthmatic children in Cyprus and Greece might not be related to differences in their compliance to interventions but more so to the actual measures taken at each level. In fact, the content of intervention measures in the case of Greece was slightly different to those in Cyprus and escalated to include personal transport and movement restrictions only in level 3 period, whereas during level 2 period there was only ban of public gatherings and closure of shops and worship places. In the case of Cyprus, personal mobility restrictions were implemented from level 2 measures and only became stricter (only one movement per day) in level 3, although the corresponding changes in fraction time spent at home and steps per day between level 2 and level 3 periods were not significant.

The successful management of the pandemic spread in Cyprus and Greece is probably due to the early introduction of lock-down measures in both countries by March 25 and 23, 2020 respectively, and the high compliance of vulnerable groups, and possibly the general population, who spent the majority of their time at home. The effectiveness of lock-down measures to reduce transmission of COVID−19 in several European countries including Greece was previously reported by Imperial College in London [19]. A recent modelling study evaluated the impact of the sequence of restrictions posed to mobility and human-to-human interactions on the virus transmission in Italy and found that they have reduced transmission by 45%[20]. As of 26 April 2020, 1.43 and 1.22 deaths per 100,000 population were reported for Cyprus and Greece, which places them among the countries with the lowest mortality rates for COVID−19 in the EU/EEA and UK [21].

It is well documented that wearable technology is a reliable, objective tool for monitoring numerous diseases and estimating adherence to medication [22]. However, to the best of our knowledge, there are no previous studies examining compliance to public health interventions using wearable devices. Previous reports on adherence to public health interventions during epidemics were based on telephone or mailed interviews and questionnaires [16–18, 23]. These conventional tools have inherent limitations such as non-response, recall biases, lack of validation of self-reports, influence by concerns about being recognized as breaching quarantine and low-level spatio-temporal information. In contrast, the use of wearable devices provides objective, continuous, real-time location and activity data making possible to timely inform public health officials on the results of various tiers of public health interventions and ensure adequate decision making in escalating or de-escalating interventions.

By using a mixed effects model, we were able to find independent quantitative effects of several factors on location of participants at home (weekends, increasing age) and their physical activity (weekends, increasing age, humidity and gender). We also found an interaction effect of weekends on higher fraction of time spent at home and lower physical activity, which was reversed during the implementation of intervention measures in both countries. The change of participants behavior in both countries and the increase in their mobility on weekends during the enforcement of the lockdown measures requires further investigation. The independent effect of age on increasing fraction time spent at home and lower physical activity and female gender on lower physical activity in asthmatic children in Cyprus, agree with previous studies that reported lower physical activity in asthmatic girls [24] and older asthmatic children [25]. Year 2020 has been associated with lower physical activity in asthmatic children in both countries, which may relate to a systematic effect of either the recording devices used or implication of environmental factors we have not accounted for in the analysis.

The paradigm of our study supports that in a public health emergency, it is possible to employ wearable technology in a greater sample of the general population and enable rapid measurements of how the public reacts to a particular set of interventions. GPS and physical activity data for example are collected anonymously by telephone companies from their smartphone customers and theoretically may provide information about population's attitude and adherence to interventions taken in pandemics, natural disasters, etc. However, this kind of monitoring raises important ethical issues, as it could be considered as limiting individual freedoms and rights [26]. In our case, monitoring of these patients with wearable devices was already established as part of the ongoing MEDEA project that started much before the spread of COVID–19, and thus we had obtained timely ethical approval and written consent from participants. In the case of pandemics, where decisions and measures are taken within days or even hours, it is extremely difficult to obtain fast-track consent from individuals to record their attitudes with wearable technology.

An important limitation of wearable technology is the loss of signal of GPS tracking, especially in indoor environments, which introduces the challenge of how to treat missing values. As a response, automated microenvironment classification algorithms that include spatial and temporal buffering have been developed and validated, especially for air pollution exposure studies [27] and provide an effective way to account for missing location data.

Conclusion

In conclusion, for the first time we implemented novel wearable technology methods to assess personal compliance to public health interventions aiming to contain the spread of a novel, highly contagious virus such as SARS-CoV–2. The successful implementation of public health interventions in Cyprus and Greece, which minimized COVID–19 related mortality in both countries, was reflected in the sharp mobility reductions recorded in the participants of our study early in the course of the outbreak. Wearable devices provide objective, continuous, real-time data that may timely inform public health officials on compliance to various tiers of public health interventions and ensure informed decision-making and strategic planning in the containment of epidemics, both at national and cross-national levels.

Materials And Methods

Study Setting

Asthmatic children were recruited from primary schools in Cyprus and Crete-Greece and were enrolled in the ongoing LIFE-MEDEA public health intervention project (Clinical.Trials.gov Identifier: NCT03503812). The LIFE-MEDEA project aims to evaluate the efficacy of behavioral recommendations to reduce exposure to particulate matter during desert dust storm (DDS) events and thus mitigate disease-specific adverse health effects in vulnerable groups of patients. Details of the study protocol and methods are presented in Supplementary File 1. In order to assess adherence to recommendations, participants are equipped with a wearable device (smartwatch) with several sensors. Participants are instructed to wear the smartwatch throughout the study period, during both DDS and non-DDS days. During non-DDS days, all participants carry out their usual daily activities. The first MEDEA study period took place during February-June 2019, while the second study period during February-June 2020 is currently underway.

Study populations and recruitment

In the asthma panel study the target population were children aged from 6 to 11 years with mild to moderate persistent asthma. The eligibility criteria included a physician's diagnosis of asthma and at least one of the following: daily preventative asthma medication, wheezing episodes and/or unscheduled medical visits for asthma during the past 12 months. Basic demographic and clinical information from all participants was collected during the recruitment process. Study approvals were obtained from Ethics and National authorities (Supplementary File) and guardians of all participants provided written informed consent.

Physical activity and GPS tracking

Physical activity and global positioning system (GPS) data were recorded between February 3 and April 26, 2020 in Cyprus and Greece using the smartwatch and were extracted to assess the participants' mobility during the enforcement of COVID–19 lock down measures. The EMBRACE^{TM} smartwatch (Embrace Tech LTD, Cyprus) was used for data collection. The smartwatch works as a stand-alone device and is equipped with multiple sensors such as pedometer, GPS and heart rate as well as an embedded sim-card for Wi-Fi data transfer. The software is capable of synchronizing the sensors, so the data are transferred to the cloud with the same timestamp. Data on GPS coordinates and steps/time unit, and heart rate are collected per 5-min intervals. Data synchronization with a cloud-based database is performed automatically when the smartwatch contacts the Wi-Fi network inside the participants' home. For each participant we recorded the total number of steps per day during a 24-hour period. In addition, we defined the fraction of time spent at home as the ratio of time with GPS signal within a 100 m radius around the participant's residence divided by 24 hours. The 100 m radius was defined as the maximum barrier to account for the accuracy of GPS signal in commercially available GPS receivers [28]. As signal accuracy in urban and especially indoor environments, is further blocked or bounced repeatedly off buildings prior to being received [29], we also classified 5-min intervals with no GPS signal as either "at-home" or "out-home" depending on the signal of the most recent valid GPS recording. Lastly, days where participants did not wear the smartwatch, were identified by absence of heart rate measurements and were excluded from subsequent analysis. We also excluded from the analysis, GPS and pedometer data for DDS days in Cyprus (5 days during February-April 2020 and 4 days during February-April 2019) and Crete-Greece (1 day during February-April 2020 and 2 days during February-April 2019) that may had further influenced the mobility of the participants.

Public health (non-pharmaceutical) interventions in Cyprus and Greece

Data collection period spans for 12 weeks from February 3 to April 26, 2020 and was divided into four levels based on the implemented public health interventions in each country. In Cyprus, the first COVID–19 cases were identified on March 9, 2020 and the study period is divided to: i) level 0 (baseline)—no public health interventions (Weeks 1–5: February 3, 2020 - March 12, 2020), ii) level 1—social distancing measures, ban of public events with >75 people, bars, restaurants and schools closed (Weeks 6–7: March 13, 2020—March 24, 2020), iii) level 2—all retail shops and worship places were closed, and mobility restrictions were implemented, except for subsistence and health needs (3 permissions per person per day) (Week 8: March 25, 2020—March 31, 2020), iv) level 3—stringent lockdown with only one mobility permission per person per day (Weeks 9–12: April 01, 2020—April 26, 2020) (Figure 1). In Greece, the first COVID–19 case was identified on February 26, 2020 and the study period is divided to: i) level 0 (baseline)—no public health interventions (Weeks 1–5: February 03, 2020—March 10, 2020), ii) level 1—social distancing measures, ban of all public events, bars, restaurants and schools closed (Week 6: March 11, 2020—March 15, 2020), iii) level 2—all retail shops and worship places closed, ban of gatherings of >10 people (Week 7: March 16, 2020—March 22, 2020), iv) level 3—mobility restrictions except for subsistence and health needs (no daily limit) (Weeks 8–12: March 23, 2020-April 26, 2020) (Figure 1).

Statistical analysis

Basic demographics and clinical characteristics of the asthmatic children were summarized using mean (standard deviation) for continuous variables and percentages for categorical variables. In an unadjusted analysis, the mean fraction time spent at home and mean total steps per day were compared between the different periods of public health interventions using ANOVA, while graphs were constructed in order to demonstrate the weekly variation in mobility before and during the implementation of public health interventions in Cyprus and Greece. Furthermore, the course of fraction time spent at home and total steps per day in asthmatic children participating in the second MEDEA study period during February - April 2020 and the same parameters' course in asthmatic children participating in the first MEDEA study period during February - April 2019 are displayed in separate graphs for Cyprus and Greece.

The changes in the daily levels of fraction time spent at home and total steps were further explored in a mixed effect model, which included a fixed effect term for the level of public health interventions and a random intercept for each participant. The mixed effect model was adjusted for the effect of age, gender, temperature, humidity, year, and weekend on mobility. In addition, sine and cosine functions were included to control for monthly variability in our data. Finally, for each included parameter, we used an interaction term to test for differential change of mobility across the levels of interventions measures.

All statistical comparisons were performed using STATA 12 (StataCorp, TX) and a p-value lower than 0.05 was considered as statistically significant.

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Declarations

Acknowledgments

We are grateful to all LIFE-MEDEA participants, their families and school teachers for their cooperation.

Funding

This study was supported by the European Union LIFE project MEDEA (LIFE16 CCA/CY/000041).

Author Contributions

PK: Conceptualization, Project administration, Methodology, Software, Data curation, Visualisation, Formal analysis,Writing-Original draft preparation; *AM:* Methodology, Data curation, Visualisation, Formal analysis, Writing-Original draft preparation; *PA:* Data curation, Visualisation, Writing-Original draft preparation; *EG:* Data curation, Visualisation, Writing - Review & Editing; *EM:* Data curation, Writing - Review & Editing; *HD:* Project administration, Data curation, Writing - Review & Editing; *AM:* Data curation, Visualisation, Writing - Review & Editing*; PK:* Data curation, Visualisation, Writing - Review & Editing; *SA:* Data curation, Visualisation, Writing - Review & Editing; *HZ:* Software, Writing - Review & Editing; *SIP:* Conceptualization, Methodology, Writing - Review & Editing; *PK:* Conceptualization, Methodology, Software, Writing - Review & Editing; *GKN:* Conceptualization, Methodology; Software, Formal analysis, Writing - Review & Editing; *PKY:* Conceptualization, Methodology; Writing - Review & Editing, Funding acquisition, Supervision.

Declaration of competing interests:

The authors declare they have no actual or potential competing financial interests

Tables

Table 1: Basic demographic and clinical characteristics of asthmatic children in Cyprus and Greece

Parameter	Asthmatic children (Cyprus, n=53)	Asthmatic children (Greece, n=55)
Demographic		
M (%)	35 (66%)	27 (49%)
Age, years*	9.3 (1.7)	9.11 (1.8)
Weight, kg*	39.3 (19.0)	35.9 (9.6)
Height, cm*	137.2 (21)	134.8 (10.2)
BMI, kg/m^2*	20.3 (8.3)	19.5 (3.3)
Asthma eligibility criteria		
Physician diagnosis of Asthma	53 (100%)	55 (100%)
Wheezing episodes	35 (66%)	22 (40%)
	10 (19%)	12 (22%)

Daily preventive medication		
Unscheduled physician visits for Asthma	34 (64%)	15 (27%)
ER† visits for Asthma	10 (19%)	18 (33%)

*Values are presented as Mean (Standard Deviation). †ER: Emergency Department

Table 2: Observed fraction time spent at home and total steps per day across levels of intervention, values are presented as mean (95% Confidence Interval)

Intervention		Parameter	Statistical Significance		Parameter	Statistical Significance	
		Fraction time spent at home	Compared to baseline	Compared to previous level	Steps per day	Compared to baseline	Compared to previous level
Asthmatic children (Cyprus) (n=53)	Baseline (Level 0)	43.8% (40.5%; 47.1%)	-	-	8996 (8567; 9425)	-	-
	Level 1	88.9% (85.7%; 92.1%)	<0.001	<0.001	6499 (5832; 7166)	<0.001	<0.001
	Level 2	95.5% (93.8%; 97.2%)	<0.001	0.151	6248 (5683; 6812)	<0.001	0.999
	Level 3	94.1% (92.5%; 95.7%)	<0.001	0.999	6270 (5814; 6727)	<0.001	0.999
		Fraction time spent at home			Steps per day		

Asthmatic children (Greece) **(n=55)**	**Baseline** **(Level 0)**	52.4% (49.4%; 55.4%)	-	-	8527 (8145; 8908)	-	-
	Level 1	71.4% (60.4%; 82.5%)	0.003	0.003	6864 (5689; 8040)	0.060	0.060
	Level 2	84.9% (80.3%; 89.4%)	<0.001	0.357	5533 (4769; 6297)	<0.001	0.613
	Level 3	89.6% (87.0%; 92.3%)	<0.001	0.999	5439 (5051; 5829)	<0.001	0.999

Table 3: Fraction time spent at home and total steps per day in response to interventions for Covid-19 among asthmatic children in Cyprus.

	Fraction time spent at home		Total Steps per day	
Parameter	*β* coefficient (95% CI)	Compared to baseline	*β* coefficient (95% CI)	Compared to baseline
Baseline (Level 0) (intercept)	47.1% (18.2%; 76.0%)	-	13520 (9123-17917)	-
Level 1	41.4% (34.5%; 48.2%)	<0.001*	-2531 (-3364;-1698)	<0.001*
Level 2	48.7% (42.0%; 55.5%)	<0.001†	-3638 (-4521;-2755)	<0.001‡
Level 3	45.2% (39.3%; 51.2%)	<0.001§	-3644 (-4428;-2859)	<0.001§
Gender (male)	1.7% (-3.2%; 6.5%)	0.502	1024 (53;1944)	0.039
Age (per year increase)	1.4% (0.2%; 2.6%)	0.019	-378 (-615; -143)	0.002

Year (2020)	-0.6% (-6.4%; 5.1%)	0.826	-1560 (-2796; -324)	0.013
Weekend	10.9% (8.0%; 13.8%)	<0.001	-1002 (1374; -630)	<0.001
Temperature (per degree C^0 increase)	-0.03% (-0.07%; 0.15%)	0.909	58.0 (-6; 122)	0.075
Humidity (per % increase	0.04% (-0.07%; 0.15%)	0.539	-29 (-42; -15)	<0.001
Interaction term	**β coefficient (95% CI)**	**Compared to baseline**	**β coefficient (95% CI)**	**Compared to baseline**
Weekend # Level 1	-22.8% (-33.8%; -11,8%)	<0.001	1870 (539; 3202)	0.006
Weekend # Level 2	-13.0% (-25.9%; -0.1%)	0.047	1196 (-535; 2927)	0.176
Weekend # Level 3	-18.6% (-27.4%; -9,8%)	<0.001	1361 (191; 2531)	<0.001

*p<0.001, compared to previous level. †p=0.055, compared to the previous level. ‡p=0.021, compared to the previous level.

- p>0.05, compared to the previous level.

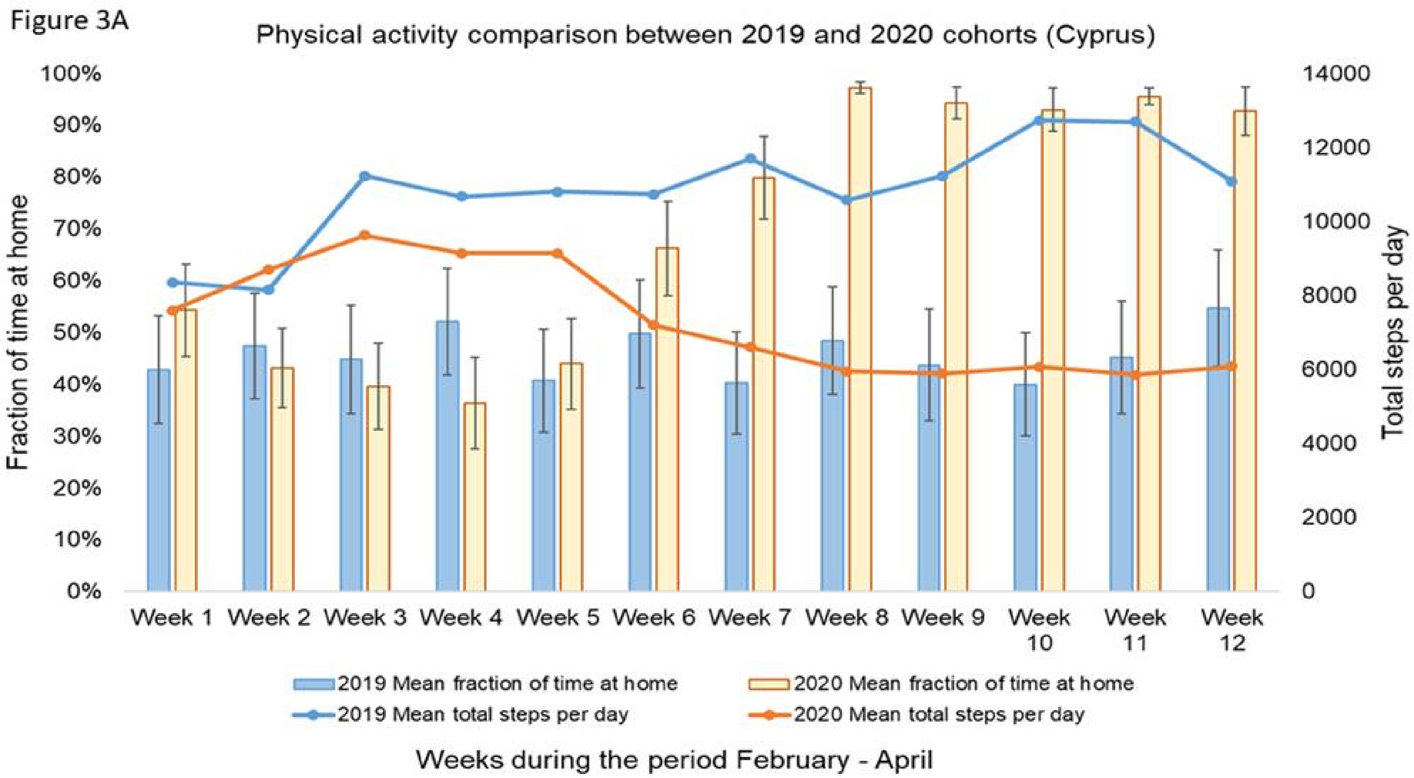
Table 4: Fraction time spent at home and total steps per day in response to interventions for Covid-19 among asthmatic children in Greece

	Fraction time spent at home		Total Steps per day	
Parameter	**β coefficient (95% CI)**	**Compared to baseline**	**β coefficient (95% CI)**	**Compared to baseline**
Baseline (Level 0) (intercept)	74.6% (52.3%; 97.0%)	-	13342 (9182; 17501)	-
Level 1	14.3% (2.2%; 26.3%)	0.020*	-1191 (-2641; -259)	0.108†
Level 2	23.1% (11.2%; 34.9%)	<0.001†	-2337 (-3679; -995)	0.001†
Level 3	32.0% (24.8%; -39.3%)	<0.001†	-1961 (-2933; -990)	<0.001†
Gender (male)	2.2% (-3.4%; 7.7%)	0.442	1064 (-63; 2191)	0.064
Age (per year increase)	-1.0% (-2.6%; 0.5%)	0.191	57 (-257; 370)	0.722
Year (2020)	-0.7% (-7.9%; 6.6%)	0.859	-2791 (-4090; -1492)	<0.001

Weekend	8.32% (5.2%; 11.4%)	<0.001	-1212 (1615; -809)	<0.001
Temperature (per degree C^0 increase)	-0.6% (-1.3%; 0.0%)	0.059	21 (-64; 107)	0.628
Humidity (per % increase)	-0.1% (-0.2%; 0.0%)	0.061	-2 (-16; 12)	0.763
Interaction term	**β coefficient (95% CI)**	**Compared to baseline**	**β coefficient (95% CI)**	**Compared to baseline**
Weekend # Level 1	-12.7% (-37.2%; -11,8%)	0.310	149 (-2739; 3037)	0.006
Weekend # Level 2	-9.5% (-32.5%; 13.5%)	0.416	3704 (1115; 6292)	0.005
Weekend # Level 3	-9.6% (-19.8%; 0.5%)	0.063	1433 (96; 2772)	0.036

*p=0.020, compared to previous level. †p>0.05, compared to the previous level.

Figures



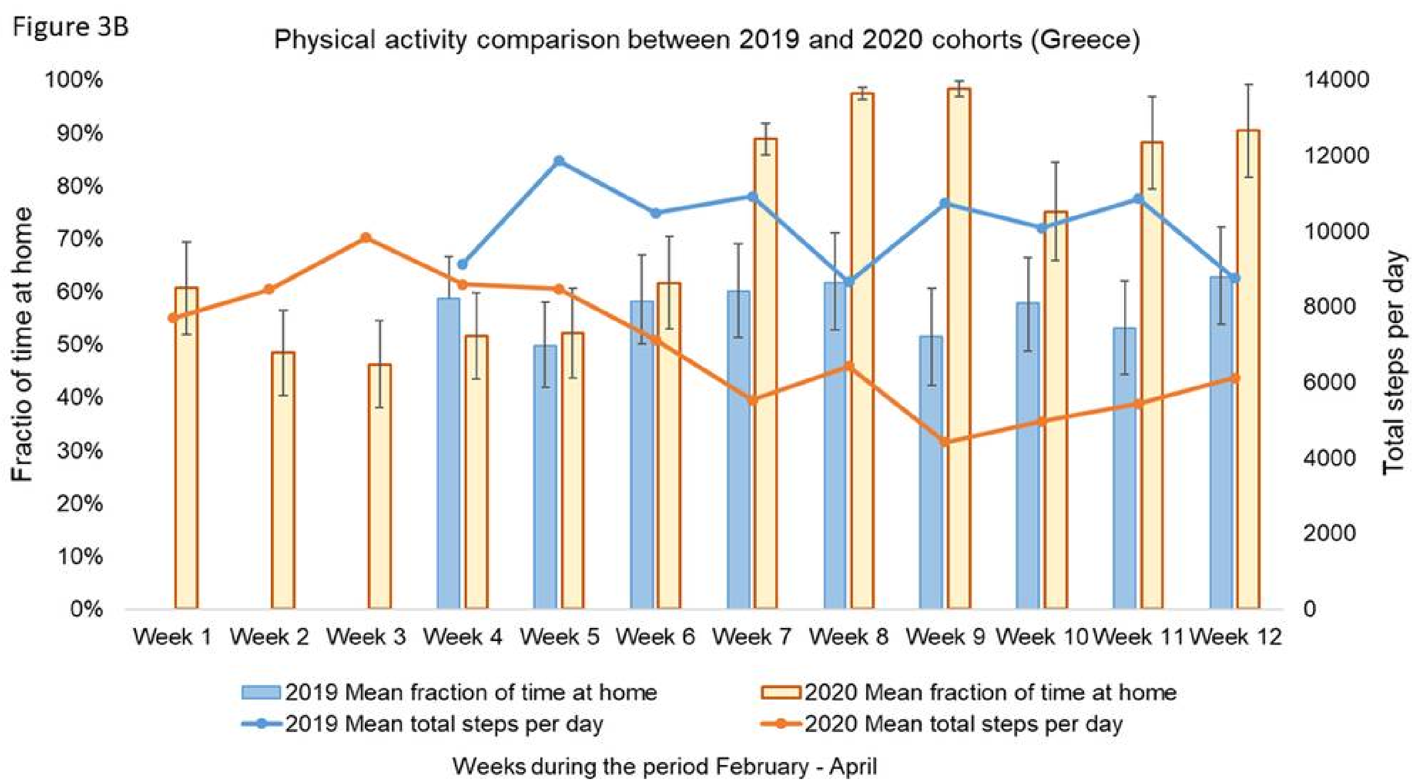
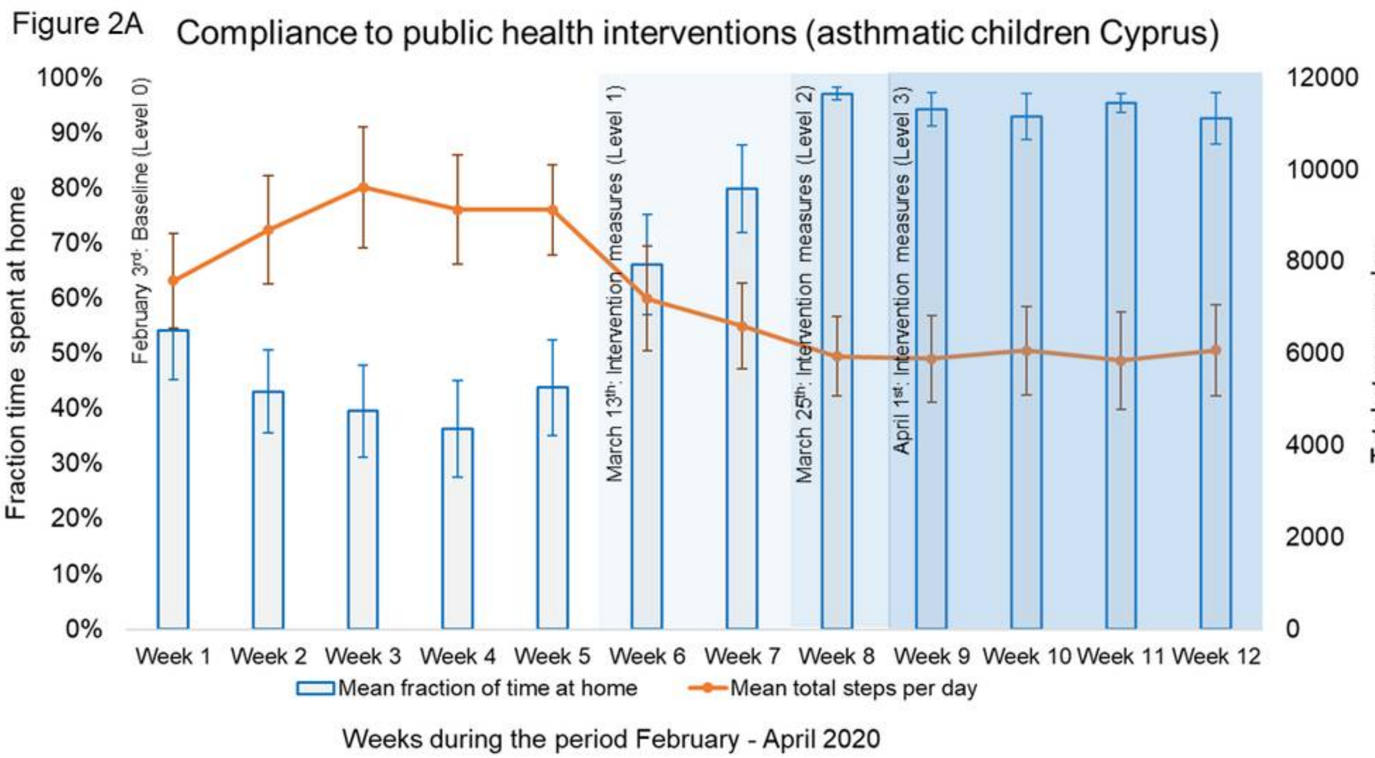


Figure 1

Comparison of mobility of asthmatic children recorded in February-April 2019 and February-April 2020 in Cyprus and Crete. Weekly averages of fraction time spent at home and steps/day during the same period of 2019 and 2020 in Cyprus (3A) and Greece (3B) (February-April).



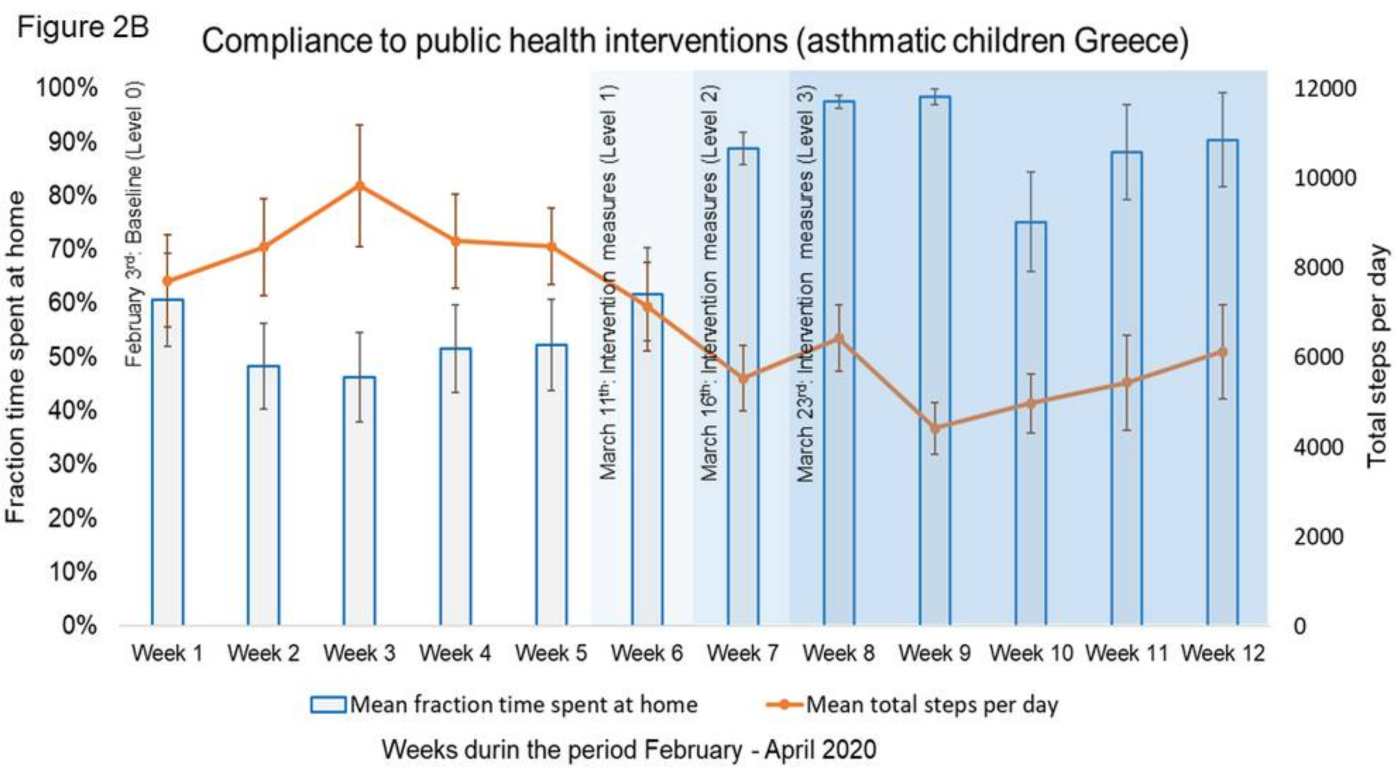


Figure 2

Changes in mobility in response to public health interventions among asthmatic children. Weekly averages of fraction time spent at home and steps/day, before and during three levels of public health interventions in asthmatic children in Cyprus (2A) and Greece (2B).

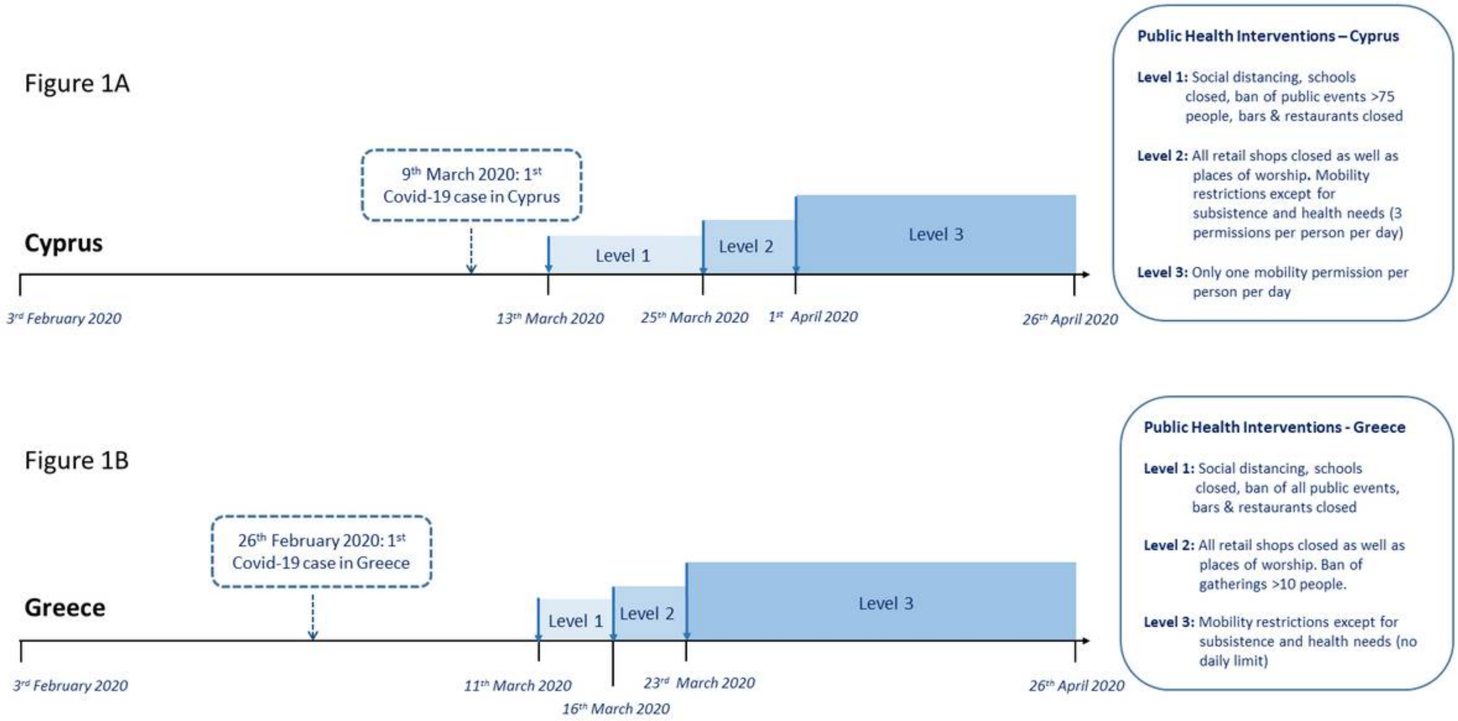


Figure 3

Timeline of public health interventions in Cyprus and Greece. Timeline of the study recordings in relation to introduction of public health interventions in Cyprus (1A) and Greece (1B) during March-April 2020.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementaryInformation.pdf