

# BMJ Open

BMJ Open is committed to open peer review. As part of this commitment we make the peer review history of every article we publish publicly available.

When an article is published we post the peer reviewers' comments and the authors' responses online. We also post the versions of the paper that were used during peer review. These are the versions that the peer review comments apply to.

The versions of the paper that follow are the versions that were submitted during the peer review process. They are not the versions of record or the final published versions. They should not be cited or distributed as the published version of this manuscript.

BMJ Open is an open access journal and the full, final, typeset and author-corrected version of record of the manuscript is available on our site with no access controls, subscription charges or pay-per-view fees (<http://bmjopen.bmj.com>).

If you have any questions on BMJ Open's open peer review process please email [info.bmjopen@bmj.com](mailto:info.bmjopen@bmj.com)

# BMJ Open

## The impact of airplane noise on mental and physical health. A quasi-experimental analysis.

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2021-057209
Article Type:	Original research
Date Submitted by the Author:	13-Sep-2021
Complete List of Authors:	Wang, Scarlett; New York University, Wagner School of Public Service Glied, Sherry; New York University, Wagner School of Public Service Williams, Sharifa; Nathan S Kline Institute for Psychiatric Research, Center for Research on Cultural and Structural Equity in Behavioral Health Will, Brian; Queens Quiet Skies Muennig, Peter; Columbia University Mailman School of Public Health, Global Research Analytics for Population Health
Keywords:	MENTAL HEALTH, EPIDEMIOLOGY, Cardiac Epidemiology < CARDIOLOGY, PUBLIC HEALTH

SCHOLARONE™  
Manuscripts



I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our [licence](#).

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which [Creative Commons](#) licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

- 1  
2  
3 1 Title Page  
4  
5 2 The impact of airplane noise on mental and physical health. A quasi-experimental analysis.  
6  
7

8 3  
9  
10 4 Scarlett Sijia Wang, MPH, MS  
11 5 Corresponding author.  
12 6 Associate Research Scientist  
13 7 Robert F. Wagner Graduate School of Public Service  
14 8 Email: [scarlett@nyu.edu](mailto:scarlett@nyu.edu)  
15 9 New York University  
16 10 295 Lafayette St.  
17 11 Second Floor  
18 12 New York, NY 10012

19 13  
20 14 Sherry Glied, PHD  
21 15 Dean  
22 16 Robert F. Wagner Graduate School of Public Service  
23 17 New York University  
24 18 295 Lafayette St.  
25 19 Second Floor  
26 20 New York, NY 10012

27 21  
28 22 Sharifa Z. Williams, DrPH, MS  
29 23 Research Scientist  
30 24 Nathan S. Kline Institute for Psychiatric Research  
31 25 Center for Research on Cultural and Structural Equity in Behavioral Health  
32 26 Division of Social Solutions and Services Research  
33 27 140 Old Orangeburg Road, Bldg. 35,  
34 28 Orangeburg, NY 10962-1159

35 29  
36 30 Brian Will  
37 31 (Mr. Will passed away prior to the submission of the manuscript.)  
38 32

39 33 Peter Muennig, MD, MPH  
40 34 Professor  
41 35 Mailman School of Public Health  
42 36 Columbia University  
43 37 722 West 168th St.  
44 38 ARB 4th Floor  
45 39 New York, NY 10032  
46 40

47  
48  
49  
50  
51  
52  
53  
54 41  
55  
56  
57  
58  
59  
60

1  
2  
3 43 The impact of airplane noise on mental and physical health. A quasi-experimental analysis.  
4

5 44 **Abstract**

6  
7  
8 45 **Objectives.** Historically, departures at New York City's La Guardia airport (LGA) flew over a  
9  
10 46 large sports complex. During the US Open tennis games, flights were diverted to fly over a  
11  
12 47 heavily populated foreign-born neighborhood for roughly two weeks out of the year so that the  
13  
14 48 tennis match was not disturbed (the "TNNIS" departure). In 2012, the use of the TNNIS  
15  
16 49 departure became year-round to better optimize flight patterns around the metropolitan area.

17 50 **Methods.** We exploited exogenously-induced spatial and temporal variation in flight patterns in  
18  
19 51 order to examine difference-in-difference effects of this new aircraft noise on the health of  
20  
21 52 individual residents in the community relative to individuals residing within a demographically  
22  
23 53 similar community that was not impacted. We used individual-level Medicaid records, focusing  
24  
25 54 on conditions associated with noise: sleep disturbance, psychological stress, mental illness,  
26  
27 55 substance use, and cardiovascular disease.  
28  
29  
30  
31

32  
33 56 **Results.** We found that increased exposure to airplane noise was associated with a significant  
34  
35 57 increase in insomnia across all age groups, but particularly in children ages 5-17 (OR = 1.64).  
36  
37 58 Cardiovascular disease increased significantly both among 18-44-year-old (OR = 1.45) and 45-  
38  
39 59 64-year-old Medicaid recipients (OR = 1.15). Substance use and mental health-related  
40  
41 60 emergency department visits also increased. For ages 5-17 RR= 4.11 (95% CI= 3.28, 5.16); for  
42  
43 61 ages 18-44 RR = 2.46 (95% CI = 2.20, 2.76); and for ages 45-64, RR = 1.48 (95% CI = 1.31,  
44  
45 62 1.67).  
46  
47  
48

49 63 **Conclusion.** This study demonstrates that increased cardiovascular disease, substance use/mental  
50  
51 64 health emergencies, and insomnia among local residents are the externalities of this decision.  
52  
53

54 65  
55  
56  
57  
58  
59  
60

1  
2  
3 **66 What is already known about this subject?**  
4

5  
6 67 Previous work demonstrated adverse health effect associated with airplane noise,  
7  
8 68 including cardiovascular disease and insomnia.  
9

10 **69 What are the new findings?**  
11

12 70 This study exploits exogenous variation in exposure to airplane noise longitudinally in a  
13  
14 71 case and control community in New York City using individual-level Medicaid records. Our  
15  
16 72 more granular and higher quality data suggest that the increased airplane noise was associated  
17  
18 73 with increases in insomnia, substance use/mental health emergencies, and cardiovascular disease.  
19  
20  
21  
22 74

23  
24 **75 How might it impact on policy in the foreseeable future?**  
25

26 76 As air traffic increases, policy makers should consider avoiding residential areas when  
27  
28 77 designing new airports.  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

1  
2  
3 78 When aircraft enter urban airspace, they traditionally approach and depart over areas that  
4  
5 79 are less populated, such as waterways, parks, or areas with warehouses or manufacturing.<sup>1</sup>  
6  
7  
8 80 However, as air traffic increases over time, the airspace used for traditional routes of arrivals and  
9  
10 81 departures has become crowded.<sup>2</sup> To handle this increase in traffic, landings and departures must  
11  
12 82 sometimes be altered to optimize flight patterns.<sup>2</sup> Almost invariably, these new flight patterns  
13  
14 83 require routing aircraft over populated areas that were not previously exposed to aircraft noise.

15  
16  
17 84 Noise, and aircraft noise in particular, is associated with a number of health problems,  
18  
19 85 particularly sleep disturbances, mental illness, and substance use.<sup>3-8</sup> The sleep disturbances and  
20  
21 86 psychological stress associated with aircraft noise are, in turn, thought to produce a cascade of  
22  
23 87 biological effects that result in premature aging via endocrinologic changes.<sup>9-14</sup>

24  
25  
26 88 Noise is thought to produce stress by activating the central nervous system and by  
27  
28 89 interfering with sleep.<sup>3,6,8,15,16</sup> This stress produces predictable changes in biochemical pathways  
29  
30 90 in human and animal studies that accelerate the rate of aging.<sup>14,17,18</sup> This accelerated aging  
31  
32 91 process has been linked to the premature onset of age-related diseases, including cardiovascular  
33  
34 92 disease.<sup>9,19,20</sup>

35  
36  
37  
38 93 While the pathways linking poor sleep and psychological stress to premature aging and  
39  
40 94 chronic disease are understood, few studies have examined interventions that alter noise  
41  
42 95 exposure in human populations.<sup>21</sup> Most of our knowledge about the health impact of aircraft  
43  
44 96 noise in humans is based upon associational studies.<sup>7</sup> These studies suffer from a number of  
45  
46 97 limitations. On one hand, people who live near airports may self-select, such that those who are  
47  
48 98 less sensitive to noise can take advantage of lower home prices on purchases or rentals for  
49  
50 99 homes.<sup>13,19,20</sup> On the other hand, those who live near airports tend to have lower than average  
51  
52 100 income, a major risk factor for premature disease and death.<sup>19,22-24</sup> There is limited evidence

1  
2  
3 101 based of the impact of aircraft noise on premature aging and health based on experimental or  
4  
5 102 quasi-experimental analysis.<sup>12,13,23,25</sup>  
6  
7

8 103 Flight pattern changes afford a unique opportunity for studying the health impact of  
9  
10 104 aircraft noise in humans. In the past decade, flight patterns have shifted, and these shifts have  
11  
12 105 increasingly been accompanied by resident complaints.<sup>26</sup> As they do so, it becomes possible to  
13  
14 106 identify areas that are impacted by new aircraft noise.  
15  
16

17 107 We conducted a longitudinal case/control study of one well-documented flight pattern  
18  
19 108 change in New York City. LaGuardia Airport is one of 3 major airports in the greater New York  
20  
21 109 City area. One of its departure patterns utilizes Flushing Meadows Park, a route known as the  
22  
23 110 "Whitestone Climb."<sup>24</sup> Because it is over greenspace, the Whitestone Climb has little impact on  
24  
25 111 humans living in nearby dwellings. However, this park is also the location of the US Open  
26  
27 112 Tennis match. During games, a seldom-used departure route called the "Flushing Climb" (now  
28  
29 113 called TNNIS) was used so that the tennis games were not disturbed by aircraft noise. The  
30  
31 114 TNNIS climb routes aircraft over densely populated Flushing, Queens, greatly increasing the  
32  
33 115 exposure of residents to noise on the ground.<sup>24</sup>  
34  
35  
36  
37

38 116 A Freedom of Information Act (FOIA) request by a local group opposed to airplane noise  
39  
40 117 in Queens demonstrated that flight patterns using the TNNIS climb have increased to year-round  
41  
42 118 use since 2012. Before that time, the use of the TNNIS climb was rare outside of the US Open.<sup>27</sup>  
43  
44

45 119 Previous work found that the year-round use of the TNNIS climb was costly, both in  
46  
47 120 terms of money and lives.<sup>24</sup> However, this economic analysis was primarily based on  
48  
49 121 associational data. Using data on flight patterns over Flushing obtained using the FOIA as well  
50  
51 122 as Medicaid utilization data, we conducted a quasi-experimental analysis of the health impacts of  
52  
53 123 the airplane noise associated with this new route.  
54  
55  
56  
57  
58  
59  
60



## 124 **Methods**

### 125 **Data**

126 The data used in this study are New York City Medicaid claims prepared by the New  
127 York University Health Evaluation and Analytics Lab. The data include Medicaid member  
128 demographic information, address history, eligibility, medical services, and diagnostic  
129 information. The database consists of Medicaid fee for service claims and managed care  
130 encounters; both are comparable in quality.<sup>28</sup>

### 131 *A priori* specifications and hypotheses

132 We hypothesized that exposure to airplane noise would increase health care utilization,  
133 insomnia, mood disorder, anxiety, depression, and cardiovascular disease depending upon the  
134 age group.<sup>3,6,8,9,12,13</sup> Specifically, exposure to airplane noise would produce sleep disorders across  
135 all age groups,<sup>29</sup> would lead to emotional or behavioral disturbances including substance abuse,  
136 mood disorder, depression, and developmental disorders among young adults aged 18 to < 45  
137 years who tend to be more at risk of these stress-associated disorders,<sup>30</sup> and would produce or  
138 exacerbate cardiovascular disease among older adults aged 45 and over when heart disease  
139 begins to increase in prevalence.<sup>31</sup> Noise studies suggest wide-ranging  
140 psychoneuroendocrinological effects (allostatic load) producing hypertension, hyperglycemia,  
141 and hypercholesterolemia.<sup>3,6,8,9,12,13,30,31</sup> These biological changes are linked to cardiovascular  
142 disease, a correlate of exposure to airplane noise as well as other forms of nighttime  
143 noise.<sup>7,10,11,32</sup>

### 144 **Study Design**

145 We used individual-level data at the member-cohort level for the analysis. We selected  
146 samples of Medicaid members residing in each of the two neighborhoods at two points in time.

1  
2  
3 147 The pre-cohort was defined as Medicaid recipients living in the study neighborhoods between  
4  
5 148 2019-2011 (pre cohort) and 2013-2016 (post cohort). 64% of the Flushing pre cohort and 63% of  
6  
7 149 the Sunset Park pre cohort were also in the post cohort. We used the difference-in-difference  
8  
9  
10 150 models to analyze the results.

## 11 151 Exposure

12  
13  
14 152 To determine exposure, we used data extracted under a FOIA request for flight patterns  
15  
16 153 over Flushing, Queens, New York and from Part 150 Study Technical Advisory Committee  
17  
18 154 Meeting No. 8 documents.<sup>33</sup> These documents were derived from a 2014 study conducted and  
19  
20 155 funded by the Port Authority of NY & NJ (Port Authority) in partnership with the Federal  
21  
22 156 Aviation Administration (FAA). In these documents the Port Authority presents estimated noise  
23  
24 157 exposure in geographies surrounding La Guardia Airport. Exposure is quantified using the  
25  
26 158 Integrated Noise Model in DNL (day-night average sound level) units. We also visually  
27  
28 159 inspected changes in sound related to aircraft flight over sound monitors on the ground in  
29  
30  
31 160 Flushing using Flight Aware, a publicly-available flight tracking website.<sup>34</sup>

32  
33 161 These geographic regions or corridors were stratified according to intensity of noise  
34  
35 162 exposure over a 24-hour period. We divided census tracts into > 60 DNL, 55-60 DNL, and <55  
36  
37 163 DNL (Figure 1). We aggregated census tracts and for regions of Flushing, Queens with noise  
38  
39 164 exposure levels of 55 DNL or greater after 2012.<sup>19</sup> These tracts after 2012 are therefore identified  
40  
41 165 as the treatment condition in this quasi-experimental analysis.

42  
43 166 Flushing, Queens is a vibrant, predominantly immigrant neighborhood.<sup>24</sup> It is  
44  
45 167 increasingly populated by Asians immigrants, particularly those of Chinese descent. The English  
46  
47 168 proficiency in 2018 was 49%, and the population was 54% Asian and 26% white. While the

1  
2  
3 169 neighborhood ranked as one of the poorest, the rates of education are higher than average and the  
4  
5 170 rates of crime, obesity, and hypertension are much lower than New York City as a whole.<sup>24</sup>  
6

7  
8 171 Sunset Park in Brooklyn, New York was identified as an appropriate control  
9  
10 172 neighborhood as the neighborhood (1) did not experience a change in exposure to aircraft noise  
11  
12 173 after 2012 when the TNNIS climb began frequent use, and (2) is similar to Flushing with respect  
13  
14 174 to the distribution of sociodemographic and economic characteristics.<sup>35,36</sup> Like Flushing, Sunset  
15  
16 175 Park is increasingly populated by those of Chinese descent with 32% of the population  
17  
18 176 identifying as Asian and 23% identifying as white. About 48% of the residents were born outside  
19  
20 177 of the United States and the English proficiency in 2018 was 51%.<sup>25</sup> Sunset Park also has high  
21  
22 178 poverty rates with relatively low rates of crime, obesity, and hypertension, and high levels of  
23  
24 179 education relative to New York City as a whole.<sup>24</sup> Census tracts in Sunset Park were matched to  
25  
26 180 those identified in Flushing based on race, foreign-born status, and age distribution.  
27  
28  
29

### 30 31 181 Key outcomes

32  
33 182 We used International Classification for Disease revision (ICD-9 and ICD-10) codes as  
34  
35 183 well as Clinical Classifications Software (CCS) codes for diagnostic groups to identify the  
36  
37 184 following conditions of interest: insomnia (ICD-9 = 3270, 78052 or ICD-10 = G470),  
38  
39 185 cardiovascular disease (CCS = 109 – 113), alcohol use disorder (CCS=660), substance use  
40  
41 186 disorder (CCS = 661), anxiety (CCS = 651), depression (ICD-9 = 311 or ICD-10 = F33), mood  
42  
43 187 disorder (CCS = 657), and disorders usually diagnosed in infancy, childhood adolescence (CCS  
44  
45 188 = 655), which includes autism, childhood emotional disorder, and separation anxiety.  
46  
47  
48

49 189 We linked census tracts of Flushing and Sunset Park to geocoded Medicaid addresses. If  
50  
51 190 a recipient had a Medicaid-registered address within a given census tract, they were assigned to  
52  
53 191 that census tract. Participants were excluded if they had invalid addresses, dual Medicare status,  
54  
55  
56  
57  
58  
59  
60

1  
2  
3 192 did not have a valid date of birth, or were not officially enrolled in Medicaid during the study  
4  
5 193 period (Table 1). Participant samples were then defined as Medicaid recipients in the period  
6  
7  
8 194 2009-2011 (pre-implementation period) and 2013-2015 (the TNNIS use period) and who resided  
9  
10 195 within census tracts in Flushing and Sunset Park.

11  
12 196 For these identified records, indicator variables were created to identify type of medical  
13  
14 197 claims inpatient, outpatient, and emergency department (ED) visits as well as prescription drugs,  
15  
16 198 both overall and for visits related to substance use and mental health disorders (650-663, 670).  
17  
18 199 We additionally obtained information on the age of the subscriber associated with each record.  
19  
20 200 Because we did not have access to Medicare records, and did not include dual eligible  
21  
22 201 participants due to the high likelihood of pre-existing medical conditions and smaller sample  
23  
24 202 size, our sample does not include adults aged 65 or older. Age in years was defined as the  
25  
26 203 calculated age on January 1, 2009 and January 1, 2013, and stratified into three age cohorts, 5-  
27  
28 204 17, 18-44, 45-64 years.

### 205 Statistical analyses

206 Our focus is on the rate of diagnoses for the hypothesized conditions. We first assess  
207 whether there were significant changes in utilization overall between the baseline and TNNIS  
208 use periods and whether the observed changes differed by neighborhood (i.e., exposure) after  
209 considering other changes over time between these neighborhoods. We use Poisson regression  
210 (see equation 1) to model the number of overall and substance use and mental health related  
211 inpatient, emergency department and outpatient visits for those months in which participants  
212 were enrolled in Medicaid.

213 For our primary analyses, we use logistic regression (see equation 2) to examine the odds  
214 of receiving a diagnosis for the hypothesized conditions. Before implementing these regression

1  
2  
3 215 analyses, we examined trends in socio-demographic characteristics as well as trends in Medicaid  
4  
5 216 enrollment to ensure that no divergent patterns were noted around 2012. Because racial  
6  
7 217 composition varied somewhat between the two neighborhoods (Table 1), we controlled for race  
8  
9 218 in our analyses to ensure that compositional changes by race did not influence the analysis. We  
10  
11 219 also stratified by age so that we could better test our *a priori* hypotheses by condition. For  
12  
13 220 chronic diseases, i.e. cardiovascular disease, we adopted a longer follow-up period 2008-  
14  
15 221 2011(pre-implementation) and 2013-2016 (TNNIS implementation) to allow for lag time in  
16  
17 222 disease manifestation.

$$21 223 \log(E(Y | \mathbf{x})) = \alpha + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_1 x_2 + \beta_4 x_3, \quad (1)$$

22 224 where  $Y = \text{number of Medicaid claims for condition of interest}$

23 225  $\text{offset} = \text{number of Medicaid enrollment months}$

$$24 226$$

$$25 227 \log\left(\frac{p}{1-p}\right) = \alpha + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_1 x_2 + \beta_4 x_3, \quad (2)$$

26 228 where  $p$   
27  
28  
29  
30  
31  
32  
33  
34  
35  
36 228 =  $\Pr(Y = 1)$  is the probability of  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

229 Here,  $x_1$ , was the indicator for neighborhood exposure condition (Sunset Park=0 vs  
230 Flushing=1);  $x_2$ , indicated implementation period (pre-implementation=0 vs TNNIS  
231 implementation=1); and  $x_3$ , race/ethnicity group membership (Asian=1, Black=2, Hispanic=3,  
232 White=4 [reference], Other=5, Unknown=6).

### 233 Patient and Public Involvement

234 The research question was inspired by the work of a non-profit community organization  
235 called Queens Quiet Skies that works to mitigate airplane noise. One of the coauthors of the  
236 paper was a member of this organization and obtained the Freedom of Information Act requests

237 for Federal Aviation Administration documents. These documents were used to identify the  
238 treatment census tracts and measuring the level of airplane noise exposure.

## 239 **Results**

240 Participants were generally similar across both groups over the two points in time (Table  
241 1), but health care utilization varied over time by age group and treatment status.

242 The increased use of the TNNIS climb occurred in 2012.<sup>27</sup> Prior to that date the climb  
243 was only used for the US Open or unexpected weather/runway repairs.<sup>27</sup> We were only able to  
244 obtain data on TNNIS departures after the New York Port Authority's Fiscal Year 2013 because  
245 the Port Authority indicated that the earlier data had been lost. There were roughly 1,278 TNNIS  
246 departures/year on average during US Open events in the 2013-2019 period, providing a point of  
247 reference. Since 2013, the total annual number of TNNIS climbs ranged from between 9,349 and  
248 29,676, with an average of 18,653/year. The DNL figures (Figure 1) reflect the average noise  
249 exposure by census tract across the 2013-2019 period, and may not reflect the actual change in  
250 aircraft noise in Flushing, NY in the pre-2012 and post-2012 periods.

### 251 Overall medical utilization

252 Table 2 provides results from regression models assessing period-related changes in  
253 medical utilization and diagnoses. The effects of the change in flight patterns on overall  
254 utilization were inconsistent across types of utilization and age. Overall, outpatient visits  
255 increased slightly in Flushing relative to Sunset Park for those aged 18-44 (rate ratio [RR] =  
256 1.04, 95% CI = 1.04, 1.05). Prescription drug claims also increased by a similar amount for this  
257 group (RR = 1.06, 95% CI = 1.06, 1.06). However, outpatient visits and prescription drug use for  
258 children in Flushing aged 5-17 (outpatient RR=0.86, 95% CI = 0.85, 0.87; prescription drug

1  
2  
3 259 claims RR = 0.94, 95% CI = 0.94, 0.95) as well as for older adults 45 – 64 declined (outpatient  
4  
5 260 RR=0.92, 95% CI = 0.92, 0.93; prescription drug claims RR = 0.93, 95% CI = 0.92, 0.93).

6  
7  
8 261 While the general pattern for outpatient visits indicates decreased medical utilization in  
9  
10 262 Flushing compared to Sunset Park over time, emergency department visits in Flushing increased  
11  
12 263 in the post TNNIS period among all age groups. For ages 5-17, the RR was 1.31 (95% CI= 1.24,  
13  
14 264 1.37); for ages 18-44, the RR was 1.45 (95% CI = 1.41, 1.49); and for ages 45-64, the RR was  
15  
16 265 1.16 (95% CI = 1.11, 1.21). Substance use and mental health-related emergency department  
17  
18 266 visits also increased in Flushing in the post period relative to Sunset Park, with rate ratios  
19  
20 267 ranging between 2.5 to 4.1. For ages 5-17 RR= 4.11 (95% CI= 3.28, 5.16); for ages 18-44 RR =  
21  
22 268 2.46 (95% CI = 2.20, 2.76); and for ages 45-64, RR = 1.48 (95% CI = 1.31, 1.67).

23  
24  
25  
26 269 Relative to Sunset Park, inpatient visits in Flushing also show statistically significant  
27  
28 270 increases for overall visits for ages 18-44 (RR=1.05, 95% CI = 1.02, 1.08). However, statistically  
29  
30 271 significant decreases were observed for ages 45-64 (RR=0.93, 95% CI = 0.88, 0.97).

### 31 272 Changes by diagnosis

32  
33  
34  
35 273 Relative to Sunset Park, implementation of the TNNIS climb was associated with  
36  
37 274 increases in insomnia diagnoses, particularly for children. For example, the crude prevalence of  
38  
39 275 insomnia for children increased by 57% from 398 per 100,000 in Flushing, compared to a 6%  
40  
41 276 decrease from 477 per 100,000 in Sunset Park. For children in this age group, the odds ratio  
42  
43 277 (OR) for insomnia was 1.64 (95% CI =1.12, 2.39). For older ages, the effect sizes were  
44  
45 278 somewhat less striking (i.e., for the 18-44 age group, the OR was 1.17 [95% CI = 1.09, 1.26],  
46  
47 279 and for ages 45-64 the OR = 1.1 [95% CI = 1.09, 1.28]).

48  
49  
50  
51 280 Cardiovascular disease diagnoses increased significantly in Flushing relative to Sunset  
52  
53 281 Park in the post-2012 period. For 18-44-year-olds, the crude prevalence of cardiovascular disease

282 increased in both neighborhoods due to aging of the samples, by 83% from 1,955 per 100,000 in  
283 Flushing and by 29% from 1,576 per 100,000 in Sunset Park. The OR for cardiovascular disease  
284 diagnoses in Flushing relative to Sunset Park in this age group was 1.45 (95% CI = 1.30, 1.62).  
285 For 45-64-year-olds, , the crude prevalence increased by 33% from 9,934 per 100,000 in  
286 Flushing and 19% from 9,073 per 100,000 in Sunset Park. For this age group, the OR was 1.15  
287 (95% CI = 1.07, 1.25). Substance use disorder only increased significantly for the 45-64 age  
288 group in Flushing relative to Sunset Park (OR =1.24, 95% CI=1.07, 1.44).

289 Figure 2 shows the monthly prevalence of insomnia and cardiovascular disease diagnoses  
290 for the 45-64 age group. Age is measured at the beginning of each period, January 1, 2009 for  
291 the pre-period and January 1, 2013 for the post period. The numerator is the number of unique  
292 individuals with one or more diagnosis from inpatient, emergency room or outpatient claims and  
293 the denominator is the number of Medicaid-enrolled patients. The trends of both conditions  
294 increased throughout the study periods, because people are getting older, but Flushing showed  
295 increases that were larger in magnitude in the post period relative to Sunset Park.

296 Results for other conditions were more mixed. Clinical depression diagnoses increased  
297 for the two older age groups (ages 18-44 OR = 1.12, 95% CI = 1.02, 1.24; ages 45-64 OR = 1.20,  
298 95% CI = 1.08, 1.33). Broader mood disorder diagnoses, however, only showed statistically  
299 significant increases for the 45-65 age group (OR = 1.10, 95% CI = 1.00, 1.20). For 5-17-year-  
300 olds, developmental disorder diagnoses significantly decreased (OR=0.80, 95% CI = 0.66, 0.97)  
301 in Flushing relative to Sunset Park after the implementation of TNNIS.

302

## 303 Discussion



1  
2  
3 304 We find that increases in airplane noise at DNL levels greater than 55 were associated  
4  
5 305 with increases in insomnia, depression, substance abuse, and cardiovascular disease across most  
6  
7 306 age groups. These diagnoses are generally consistent with our *a priori* hypotheses regarding the  
8  
9 307 relationship between exposure to airplane noise and health.<sup>3,6,8,9,12,13,30,31</sup> Specifically, airplane  
10  
11 308 noise may produce disruptions in sleep and psychological stress, thereby producing  
12  
13 309 neuroendocrine disruptions that lead to mental health disorders and cardiovascular disease.

14  
15  
16  
17 310 Our study was subject to a number of limitations. First, the health effects in a  
18  
19 311 predominantly Chinese-American population may not be generalizable to other populations.  
20  
21 312 Chinese-Americans in New York City are unusually healthy.<sup>37</sup> Medicaid data also present unique  
22  
23 313 challenges. Participants can enter and exit the program, for example. If there are more  
24  
25 314 participants exiting the program in one area relative to another, the observed outcomes will also  
26  
27 315 change. We addressed this problem by adjusting for the months a participant was enrolled in  
28  
29 316 Medicaid within a calendar year, but noise may nevertheless be introduced in the analysis.  
30  
31 317 Finally, it is possible that the change in neighborhood composition over time differed before and  
32  
33 318 after the implementation of year-round TNNIS departures in Flushing relative to Sunset Park.  
34  
35 319 However, we did not observe any trends in the available data that suggested this was the case,  
36  
37 320 and there were no major events in 2012 that clearly serve as an alternative causal factor for either  
38  
39 321 the primary or unexpected findings.

40  
41  
42  
43 322 The biological pathways through which airplane noise impacts health have been  
44  
45 323 elucidated.<sup>9-14</sup> Numerous associational studies suggest that airplane noise produces real-world  
46  
47 324 health impacts, and experimental animal models show a wide range of health impacts associated  
48  
49 325 with noise-induced stress as well.<sup>3-9,11-13,15-18,32</sup> Our study adds quasi-experimental evidence in  
50  
51 326 humans to this substantial body of research showing that increasing airplane noise will have  
52  
53  
54  
55  
56  
57  
58  
59  
60

1  
2  
3 327 detrimental health impacts on communities surrounding airports. The magnitude of our findings  
4  
5 328 is not strictly comparable to those in associational studies because lagged health effects (e.g., the  
6  
7 329 time required for psychological stress to manifest as cardiovascular disease) tend to mute the  
8  
9  
10 330 measured impacts.

11  
12 331 Nevertheless, the magnitude of the impact of airplane noise on the health outcomes we  
13  
14 332 observe are generally in line with associational studies. For instance, an earlier analysis of  
15  
16 333 associational studies of the health impact of aircraft noise in Flushing, NY estimated that aircraft  
17  
18 334 noise would produce a weighted increase in cardiovascular disease of 14% (RR = 1.14, 95% CI  
19  
20 335 = 1.08, 1.22) and a weighted increase in anxiety of 79% (RR = 1.79, 95% CI = 1.0-3.1).<sup>11,24</sup> We  
21  
22 336 observe an odds ratio for cardiovascular disease among 18-64-year-olds in the range of 1.12 to  
23  
24 337 1.40. While the studies examine incident cardiovascular disease and we measure both incident  
25  
26 338 and prevalent cardiovascular disease, it is reasonable to assume that the OR we estimate does not  
27  
28 339 greatly overestimate the adjusted RR computed using associational studies.<sup>38</sup>

29  
30  
31 340 Cost-effectiveness analyses (based partly on earlier associational data) show that the  
32  
33 341 benefits of noise-mitigation strategies (reduced illness and discomfort) tend to outweigh the  
34  
35 342 costs.<sup>24,39</sup> Given that these earlier studies did not include the full range of health outcomes that  
36  
37 343 we measure here, it is likely that these studies understate the already substantial benefits of  
38  
39 344 mitigation strategies.

40  
41  
42 345 Much more comprehensive economic analyses are required to determine the extent to  
43  
44 346 which policymakers may wish to act. The costliest options—building airports far from populated  
45  
46 347 areas and providing high speed transit and freeways—can increase the cost of mitigation by  
47  
48 348 billions of dollars.

49  
50  
51 349

1  
2  
3 **350 Research Ethics Approval**  
4

5 351 This study is approved by the Institutional Review Borad at New York University

6  
7  
8 352 Washington Square under IRB-FY2016-1101.  
9

10 **353 Acknowledgements**  
11

12 354 The authors thank NYU Health Evaluation and Analytics Lab and the New York State  
13  
14 355 Department of Health for making the Medicaid claims data available and gratefully acknowledge  
15  
16 356 the funding for this research from the Robert Wood Johnson Foundation's Policies for Action  
17  
18  
19 357 program.  
20

21 358 Disclaimer: The views and opinions expressed in this article are those of the authors and  
22  
23 359 do not necessarily reflect the official policy or position of the New York State Department of  
24  
25 360 Health. Example of analysis performed within this article are only examples. They should not be  
26  
27  
28 361 utilized in real-world analytic products.  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

Table 1 – Demographics characteristics and outcome prevalence and rates for Flushing, New York and Sunset Park, New York before (earlier than 2012) and after (after 2013) airplane noise increased in Flushing, New York.

Baseline Characteristics	Pre-Period: 2009-2011						Post-Period: 2012-2015					
	Age 5 -17		Age 18-44		Age 45-64		Age 5-17		Age 18-44		Age 45-64	
	Flushing	Sunset Park	Flushing	Sunset Park	Flushing	Sunset Park	Flushing	Sunset Park	Flushing	Sunset Park	Flushing	Sunset Park
Demographics												
Total N	20,120	21,597	57,089	52,016	36,472	18,681	24,552	26,009	76,278	60,774	50,806	24,421
Age (Mean)	11.69	11.12	31.07	29.86	53.44	53.29	11.43	10.71	30.95	30.65	53.99	54.22
Age (STD)	3.94	3.92	8.19	7.54	5.59	5.5	3.94	3.87	7.84	7.5	5.44	5.57
Female (%)	48%	48%	58%	57%	54%	51%	48%	48%	56%	56%	54%	52%
Asian (%)	50%	46%	60%	62%	63%	60%	52%	47%	59%	59%	63%	62%
Black (%)	6%	2%	5%	1%	4%	2%	4%	1%	3%	1%	3%	1%
Hispanic (%)	17%	15%	11%	9%	11%	11%	14%	14%	7%	7%	7%	8%
White (%)	11%	24%	10%	15%	10%	14%	10%	24%	8%	14%	8%	12%
Other (%)	5%	3%	5%	4%	6%	7%	5%	3%	4%	3%	5%	6%
Unknown (%)	12%	11%	10%	8%	6%	5%	14%	12%	20%	16%	13%	11%
Average months on Medicaid per year	9	10	8	8	9	10	9	10	8	9	9	9
Total Medicaid Spending per Person per Year	\$1,911	\$1,904	\$3,818	\$3,954	\$6,754	\$6,076	\$1,783	\$1,972	\$3,398	\$3,114	\$6,520	\$6,115
Prevalence per 100,000												
Insomnia	398	477	4,208	6,096	8,036	9,143	623	450	4,755	5,573	11,034	10,843
Cardiovascular disease*	NA*	NA*	1,955	1,576	9,934	9,073	NA*	NA*	3,575	2,540	13,260	10,786

Downloaded from <http://bmjopen.bmj.com/> on 20 April 2024 by guest. Protected by copyright.

1	Alcohol Use Disorder	NA*	NA*	2,114	1,173	2,470	2,184	NA*	NA*	2,264	1,198	2,870	2,199
2	Substance Use Disorder	NA*	NA*	2,265	1,517	1,799	2,098	NA*	NA*	3,799	2,026	4,250	4,058
3	Anxiety	NA*	NA*	5,124	4,639	6,279	6,279	NA*	NA*	5,726	5,055	7,537	7,416
4	Depression	NA*	NA*	3,782	2,874	6,007	5,867	NA*	NA*	3,191	2,722	5,637	4,656
5	Mood Disorder	NA*	NA*	6,371	4,900	9,399	8,891	NA*	NA*	5,607	4,400	8,375	7,297
6	Disorders diagnosed	1,983	1,394	289	212	170	112	2,480	2,219	307	214	163	188
7	young												
8													
9													
10													
11													
12													
13													
14	Emergency Department	328	216	335	257	288	237	375	188	360	270	332	216
15	Emergency Department	13	20	26	21	31	39	20	7	32	13	45	36
16	(SM)												
17	Inpatient Stays	70	53	267	319	299	245	60	49	231	30	234	190
18	Inpatient Stays (SM)	14	7	43	24	45	32	11	5	37	0	37	21
19													
20													
21													
22													
23													
24	Total Outpatient	3.4	4.1	4.1	4.6	6.7	7.3	3.9	5.2	4.5	3.0	7.6	8.2
25	Outpatient (SM)	0.2	0.2	0.3	0.2	0.4	0.3	0.3	0.3	0.3	0.0	0.5	0.4
26													
27													

Visits per 1,000 per year

Outpatient visits per person per year

\* We adopted a longer follow-up period 2008-2011(pre-implementation) and 2013-2016 (TNNIS implementation) to allow for lag time in disease manifestation

0.1136/bmjopen.2023.057209 on 2 May 2022. Downloaded from http://bmjopen.bmj.com/ on April 18, 2024 by guest. Protected by copyright.

Table 2 – Model Results and 95% Confidence Intervals

	Rate Ratios from the Difference in Difference Poisson Model		
	Age 5 - 17	Age 18 - 44	Age 45 - 64
Inpatient Visits	0.92 (0.83, 1.03)	1.05 (1.02, 1.08)	0.93 (0.88, 0.97)
Emergency Department Visits	1.31 (1.24, 1.37)	1.45 (1.41, 1.49)	1.16 (1.11, 1.21)
Outpatient Visits	0.86 (0.85, 0.87)	1.04 (1.04, 1.05)	0.92 (0.92, 0.93)
Pharmacy Claims	0.94 (0.94, 0.95)	1.06 (1.06, 1.06)	0.93 (0.92, 0.93)
	Rate Ratios from the Difference in Difference Poisson Model Substance Use and Mental Health Related		
	Age 5 - 17	Age 18 - 44	Age 45 - 64
Inpatient Visits	NA*	1.11 (1.01, 1.22)	1.19 (1.04, 1.36)
Emergency Department Visits	4.11 (3.28, 5.16)	2.46 (2.20, 2.76)	1.48 (1.31, 1.67)
Outpatient Visits	1.12 (1.09, 1.16)	0.93 (0.92, 0.95)	0.87 (0.85, 0.89)
	Odds Ratios from the Difference in Difference Logistic Model		
	Age 5 - 17	Age 18 - 44	Age 45 - 64
Insomnia	1.64 (1.12, 2.39)	1.17 (1.09, 1.26)	1.18 (1.09, 1.28)
Cardiovascular Disease**	NA*	1.45 (1.30, 1.62)	1.15 (1.07, 1.25)
Alcohol Use Disorder	NA*	0.97 (0.86, 1.11)	1.16 (0.99, 1.35)
Substance Use Disorder	NA*	0.92 (0.83, 1.03)	1.24 (1.07, 1.44)
Depression	NA*	1.12 (1.02, 1.24)	1.20 (1.08, 1.33)
Anxiety	NA*	1.02 (0.95, 1.10)	1.01 (0.92, 1.11)
Mood Disorder	NA*	1.03 (0.95, 1.10)	1.10 (1.00, 1.20)
Disorders diagnosed young	0.80 (0.66, 0.97)	0.99 (0.72, 1.37)	0.56 (0.31, 1.04)

1  
2  
3  
4  
5 \*These diseases and conditions are rare or difficult to diagnose in children.  
6

7  
8 \*\*We adopted a longer follow-up period 2008-2011(pre-implementation) and 2013-2016  
9  
10 (TNNIS implementation) to allow for lag time in disease manifestation  
11  
12  
13

14  
15 Figure 1 – Intensity of noise exposure over a 24-hour period by census tract. The day night level  
16  
17 (DNL) 55 corridor (outer line) is demarcated separately from the DNL 60 corridor (inner line).  
18  
19  
20

21  
22 Figure 2 – Prevalence of insomnia and cardiovascular disease diagnoses per 100,000 among 45-  
23  
24 64 age group  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

1. Nolan M. *Fundamentals of air traffic control*. Cengage learning; 2010.
2. Prevot T, Homola J, Mercer J, Mainini M, Cabrall C. Initial evaluation of NextGen air/ground operations with ground-based automated separation assurance. *ATM2009, Napa, California*. 2009.
3. Zaharna M, Guilleminault C. Sleep, noise and health: review. *Noise and Health*. 2010;12(47):64.
4. Clark C, Stansfeld SA. The effect of transportation noise on health and cognitive development: A review of recent evidence. *Int J Comp Psychol*. 2007;20(2).
5. Stansfeld S, Haines M, Burr M, Berry B, Lercher P. A review of environmental noise and mental health. *Noise and Health*. 2000;2(8):1.
6. Passchier-Vermeer W, Passchier WF. Noise exposure and public health. *Environ Health Perspect*. 2000;108(Suppl 1):123.
7. Morrell S, Taylor R, Lyle D. A review of health effects of aircraft noise. *Aust N Z J Public Health*. 1997;21(2):221-236.
8. Beutel ME, Jünger C, Klein EM, et al. Noise annoyance is associated with depression and anxiety in the general population-the contribution of aircraft noise. *PLoS One*. 2016;11(5).
9. Münzel T, Schmidt FP, Steven S, Herzog J, Daiber A, Sørensen M. Environmental noise and the cardiovascular system. *J Am Coll Cardiol*. 2018;71(6):688-697.
10. Schmidt FP, Basner M, Kröger G, et al. Effect of nighttime aircraft noise exposure on endothelial function and stress hormone release in healthy adults. *Eur Heart J*. 2013;34(45):3508-3514.
11. Babisch W. Cardiovascular effects of noise. *Noise and Health*. 2011;13(52):201.



12. Maschke C, Harder J, Ising H, Hecht K, Thierfelder W. Stress hormone changes in persons exposed to simulated night noise. *Noise and health*. 2002;5(17):35.
13. Melamed S, Bruhis S. The effects of chronic industrial noise exposure on urinary cortisol, fatigue, and irritability: a controlled field experiment. *J Occup Environ Med*. 1996;38(3):252-256.
14. McEwen BS. Protective and damaging effects of stress mediators. *N Engl J Med*. 1998;338(3):171-179.
15. Basner M, Babisch W, Davis A, et al. Auditory and non-auditory effects of noise on health. *The lancet*. 2014;383(9925):1325-1332.
16. Perron S, Tétreault L-F, King N, Plante C, Smargiassi A. Review of the effect of aircraft noise on sleep disturbance in adults. *Noise and health*. 2012;14(57):58.
17. Xue L, Zhang D, Wang T, Shou X. Effects of high frequency noise on female rat's multi-organ histology. *Noise and Health*. 2014;16(71):213.
18. Ising H, Babisch W, Kruppa B. Noise-induced endocrine effects and cardiovascular risk. *Noise and health*. 1999;1(4):37.
19. Cohen JP, Coughlin CC. Changing noise levels and housing prices near the Atlanta airport. *Growth and Change*. 2009;40(2):287-313.
20. Cohen JP, Coughlin CC. Spatial hedonic models of airport noise, proximity, and housing prices. *Journal of Regional Science*. 2008;48(5):859-878.
21. Kawachi I, Adler NE, Dow WH. Money, schooling, and health: Mechanisms and causal evidence. *Ann N Y Acad Sci*. 2010;1186:56-68.
22. Muennig P, Franks P, Jia H, Lubetkin E, Gold MR. The income-associated burden of disease in the United States. *Soc Sci Med*. 2005;61(9):2018-2026.

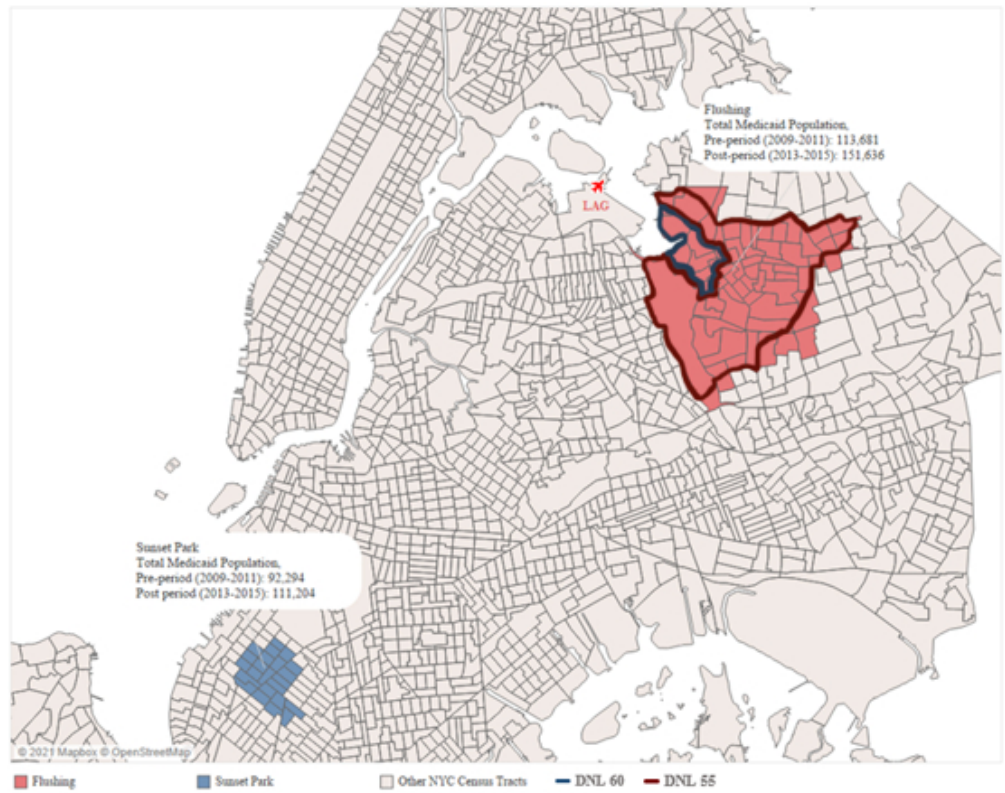
- 1  
2  
3 23. Boes S, Nüesch S, Stillman S. Aircraft Noise, Health, And Residential Sorting: Evidence  
4 From Two Quasi-Experiments. *Health Econ.* 2013;22(9):1037-1051.  
5  
6  
7  
8 24. Zafari Z, Jiao B, Will B, Li S, Muennig PA. The trade-off between optimizing flight  
9 patterns and human health: a case study of aircraft noise in Queens, NY, USA. *Int J*  
10 *Environ Res Public Health.* 2018;15(8).  
11  
12  
13  
14  
15 25. Nüesch S. Aircraft noise, health, and residential sorting: evidence from two quasi-  
16 experiments. *Standardization news: SN.* 2012(6744).  
17  
18  
19 26. Eagan ME, Hanrahan R, Miller R. Implementing performance based navigation  
20 procedures at US airport: Improving community noise exposure. Paper presented at:  
21 INTER-NOISE and NOISE-CON Congress and Conference Proceedings2013.  
22  
23  
24  
25  
26 27. Buckley C. A rumble in the sky and grumbles below. Accessed 11/17/2020. Available  
27 online at: [https://www.nytimes.com/2013/08/26/nyregion/planes-roar-from-above-](https://www.nytimes.com/2013/08/26/nyregion/planes-roar-from-above-creates-a-rumble-on-the-ground.html)  
28 [creates-a-rumble-on-the-ground.html](https://www.nytimes.com/2013/08/26/nyregion/planes-roar-from-above-creates-a-rumble-on-the-ground.html).  
29  
30  
31  
32  
33 28. Mathematica. (2013). Medicaid Managed Care and Integrated Delivery Systems:  
34 Technical Assistance to States and Strengthening Federal Oversight. Washington, DC:  
35 Mathematica Policy Research.  
36  
37  
38  
39  
40 29. Bhaskar S, Hemavathy D, Prasad S. Prevalence of chronic insomnia in adult patients and  
41 its correlation with medical comorbidities. *J Family Med Prim Care.* 2016;5(4):780-784.  
42 doi:10.4103/2249-4863.201153.  
43  
44  
45  
46  
47 30. Bernstein GA, Borchardt CM. Anxiety disorders of childhood and adolescence: A critical  
48 review. *J Am Acad Child Adolesc Psychiatry.* 1991;30(4):519-532.  
49  
50  
51  
52 31. Mensah GA, Brown DW. An overview of cardiovascular disease burden in the United  
53 States. *Health Aff (Millwood).* 2007;26(1):38-48.  
54  
55  
56  
57  
58  
59  
60

- 1  
2  
3 32. Halonen JI, Hansell AL, Gulliver J, et al. Road traffic noise is associated with increased  
4 cardiovascular morbidity and mortality and all-cause mortality in London. *Eur Heart J*.  
5 2015;36(39):2653-2661.  
6  
7  
8  
9  
10 33. Technical Advisory Committee (TAC) meeting 8. Available online at:  
11  
12 [http://www.panynjpart150.com/AdminPages/GetProjectFile.asp?a=LGA&f=LGA%20T](http://www.panynjpart150.com/AdminPages/GetProjectFile.asp?a=LGA&f=LGA%20TAC%20Meeting%20No.%208%20Summary,%20August%2016,%202016.pdf)  
13 [AC%20Meeting%20No.%208%20Summary,%20August%2016,%202016.pdf](http://www.panynjpart150.com/AdminPages/GetProjectFile.asp?a=LGA&f=LGA%20TAC%20Meeting%20No.%208%20Summary,%20August%2016,%202016.pdf) Accessed  
14 6/17/2020.  
15  
16  
17  
18 34. Flight Aware. Live flight tracking. Available online at: <https://flightaware.com>. Accessed  
19 6/20/2020.  
20  
21  
22  
23 35. NYC Health. Community Health Profile: Sunset Park. Available online at:  
24 <https://www1.nyc.gov/assets/doh/downloads/pdf/data/2018chp-bk7.pdf> Accessed  
25 3/2/2020.  
26  
27  
28  
29 36. NYC Health. Community Health Profile: Flushing and Whitestone. Available online at:  
30 <https://www1.nyc.gov/assets/doh/downloads/pdf/data/2018chp-qn7.pdf> Accessed  
31 3/2/2020.  
32  
33  
34  
35 37. Muennig P, Wang Y, Jacobowski A. The health of immigrants to New York City from  
36 Mainland China: Evidence from the New York Health Examination and Nutrition  
37 Survey. *Journal of Immigrant and Refugee Studies* 2012;10:1-7.  
38  
39  
40  
41  
42  
43 38. Knol MJ, Le Cessie S, Algra A, Vandenbroucke JP, Groenwold RH. Overestimation of  
44 risk ratios by odds ratios in trials and cohort studies: alternatives to logistic regression.  
45 *CMAJ*. 2012;184(8):895-899. doi:10.1503/cmaj.101715.  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

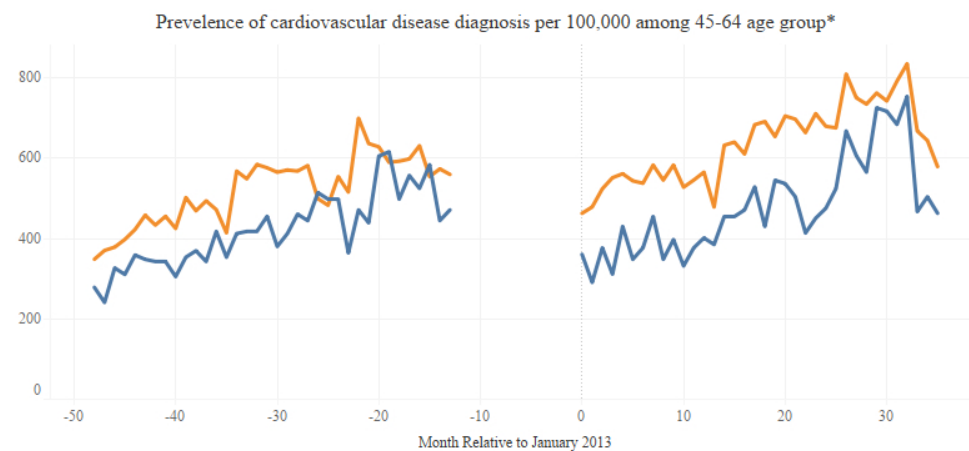
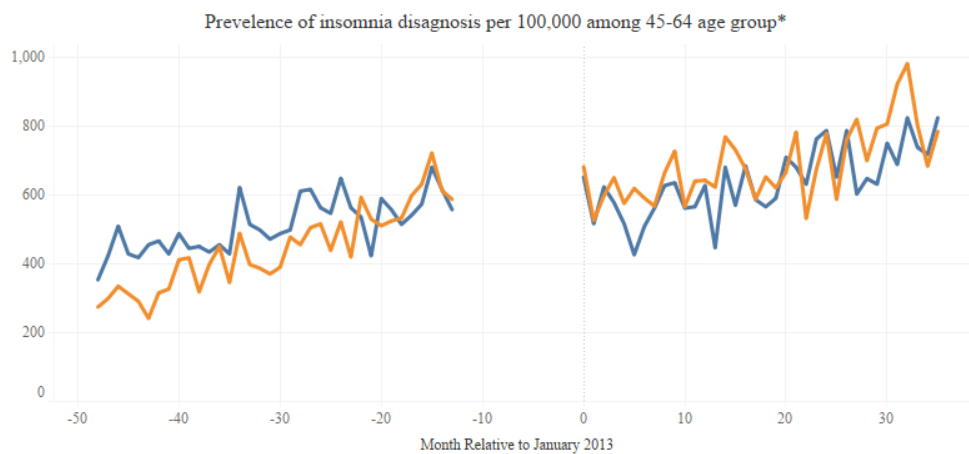
- 1  
2  
3 39. Jiao B, Zafari Z, Will B, Ruggeri K, Li S, Muennig P. The Cost-Effectiveness of  
4 Lowering Permissible Noise Levels Around US Airports. *Int J Environ Res Public*  
5 *Health*. 2017;14(12):1497.  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

For peer review only

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60



117x93mm (120 x 120 DPI)



Exposed: Flushing Control: Sunset Park

\*Age is measured at the beginning of each period, January 1, 2009 for the pre-period and January 1, 2013 for the post-period

211x211mm (96 x 96 DPI)

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

STROBE Statement—Checklist of items that should be included in reports of *cohort studies*

	Item No	Recommendation	Page No
<b>Title and abstract</b>	1	(a) Indicate the study's design with a commonly used term in the title or the abstract (b) Provide in the abstract an informative and balanced summary of what was done and what was found	1
<b>Introduction</b>			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	2-3
Objectives	3	State specific objectives, including any prespecified hypotheses	4
<b>Methods</b>			
Study design	4	Present key elements of study design early in the paper	4-6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4-6
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up (b) For matched studies, give matching criteria and number of exposed and unexposed	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4
Bias	9	Describe any efforts to address potential sources of bias	7, 11
Study size	10	Explain how the study size was arrived at	8, 14- 15
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5-7
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding (b) Describe any methods used to examine subgroups and interactions (c) Explain how missing data were addressed (d) If applicable, explain how loss to follow-up was addressed (e) Describe any sensitivity analyses	7-8
<b>Results</b>			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed (b) Give reasons for non-participation at each stage (c) Consider use of a flow diagram	8, 14- 15
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders (b) Indicate number of participants with missing data for each variable of interest (c) Summarise follow-up time (eg, average and total amount)	8,14- 15
Outcome data	15*	Report numbers of outcome events or summary measures over time	8-11, 14

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

For peer review only



1	Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	8-11, 14-19
2			(b) Report category boundaries when continuous variables were categorized	
3			(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
4				
5				
6				
7				
8				
9	Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9
10				
11	<b>Discussion</b>			
12				
13	Key results	18	Summarise key results with reference to study objectives	11
14	Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	11-12
15				
16	Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12-13
17				
18				
19				
20	Generalisability	21	Discuss the generalisability (external validity) of the study results	11
21				
22	<b>Other information</b>			
23	Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Supplemental material, acknowledgements
24				
25				
26				

\*Give information separately for exposed and unexposed groups.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at <http://www.strobe-statement.org>.

# BMJ Open

## The impact of airplane noise on mental and physical health. A quasi-experimental analysis.

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2021-057209.R1
Article Type:	Original research
Date Submitted by the Author:	22-Dec-2021
Complete List of Authors:	Wang, Scarlett; New York University, Wagner School of Public Service Glied, Sherry; New York University, Wagner School of Public Service Williams, Sharifa; Nathan S Kline Institute for Psychiatric Research, Center for Research on Cultural and Structural Equity in Behavioral Health Will, Brian; Queens Quiet Skies Muennig, Peter; Columbia University Mailman School of Public Health, Global Research Analytics for Population Health
<b>Primary Subject Heading</b>:	Public health
Secondary Subject Heading:	Epidemiology
Keywords:	MENTAL HEALTH, EPIDEMIOLOGY, Cardiac Epidemiology < CARDIOLOGY, PUBLIC HEALTH

SCHOLARONE™  
Manuscripts



I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our [licence](#).

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which [Creative Commons](#) licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

- 1 Title Page
- 2 The impact of airplane noise on mental and physical health. A quasi-experimental analysis.

3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

4 Scarlett Sijia Wang, MPH, MS  
5 Corresponding author.  
6 Associate Research Scientist  
7 Robert F. Wagner Graduate School of Public Service  
8 Email: [scarlett@nyu.edu](mailto:scarlett@nyu.edu)  
9 New York University  
10 295 Lafayette St.  
11 Second Floor  
12 New York, NY 10012

14 Sherry Glied, PHD  
15 Dean  
16 Robert F. Wagner Graduate School of Public Service  
17 New York University  
18 295 Lafayette St.  
19 Second Floor  
20 New York, NY 10012

22 Sharifa Z. Williams, DrPH, MS  
23 Research Scientist  
24 Nathan S. Kline Institute for Psychiatric Research  
25 Center for Research on Cultural and Structural Equity in Behavioral Health  
26 Division of Social Solutions and Services Research  
27 140 Old Orangeburg Road, Bldg. 35,  
28 Orangeburg, NY 10962-1159

30 Brian Will  
31 (Mr. Will passed away prior to the submission of the manuscript.)

33 Peter Muennig, MD, MPH  
34 Professor  
35 Mailman School of Public Health  
36 Columbia University  
37 722 West 168th St.  
38 ARB 4th Floor  
39 New York, NY 10032

41

43 The impact of airplane noise on mental and physical health: a quasi-experimental analysis.

44 **Abstract**

45 **Objectives.** Historically, departures at New York City's La Guardia airport (LGA) flew over a  
46 large sports complex within a park. During the US Open tennis games, flights were diverted to  
47 fly over a heavily populated foreign-born neighborhood for roughly two weeks out of the year so  
48 that the tennis match was not disturbed (the "TNNIS" departure). In 2012, the use of the TNNIS  
49 departure became year-round to better optimize flight patterns around the metropolitan area.

50 **Methods.** We exploited exogenously-induced spatial and temporal variation in flight patterns to  
51 examine difference-in-difference effects of this new exposure to aircraft noise on the health of  
52 individual residents in the community relative to individuals residing within a demographically  
53 similar community that was not impacted. We used individual-level Medicaid records, focusing  
54 on conditions associated with noise: sleep disturbance, psychological stress, mental illness,  
55 substance use, and cardiovascular disease.

56 **Results.** We found that increased exposure to airplane noise was associated with a significant  
57 increase in insomnia across all age groups, but particularly in children ages 5-17 (OR = 1.64).  
58 Cardiovascular disease increased significantly both among 18-44-year-old (OR = 1.45) and 45-  
59 64-year-old Medicaid recipients (OR = 1.15). Substance use and mental health-related  
60 emergency department visits also increased. For ages 5-17 RR= 4.11 (95% CI= 3.28, 5.16); for  
61 ages 18-44 RR = 2.46 (95% CI = 2.20, 2.76); and for ages 45-64, RR = 1.48 (95% CI = 1.31,  
62 1.67).

63 **Conclusion.** We find that increased exposure to airplane noise increases diagnosed  
64 cardiovascular disease, substance use/mental health emergencies, and insomnia among local  
65 residents.

## 66 **Strengths and limitations**

- 67 1. We used a quasi-experimental design to study before and after impacts of a flight pattern  
68 change in two matched zip code clusters within New York City (a difference-in-  
69 difference design).
- 70 2. We used a large insurance claims database that allowed us to capture diagnoses for most  
71 residents in both impacted and unimpacted zip code clusters.
- 72 3. Despite the difference-in-difference design, it is possible that participants self-segregated  
73 after the increase in aircraft noise or that other unmeasured factors influenced the  
74 observed outcomes.
- 75 4. We were unable to compute a dose-response relationship due to the use of aggregated  
76 noise data.
- 77 5. We find that a sudden and dramatic change in aircraft noise increased diagnoses of  
78 insomnia, cardiovascular disease, substance abuse, and mental illness.

## 80 **What is already known about this subject?**

81 Previous work demonstrated adverse health effect associated with airplane noise,  
82 including cardiovascular disease and insomnia using ecological or associational approaches.

## 84 **What are the new findings?**

85 This study exploits exogenous variation in exposure to airplane noise longitudinally in a  
86 case and control community in New York City using individual-level Medicaid records. Our  
87 difference-in-difference design coupled with more granular data suggest that the increased  
88 airplane noise was associated with increases in insomnia, substance use/mental health

1  
2  
3 89 emergencies, and cardiovascular disease may be causal in nature, but additional studies must be  
4  
5 90 done.  
6  
7  
8 91

9  
10 92 **How might it impact on policy in the foreseeable future?**  
11

12 93 As air traffic increases, policy makers should consider conducting analyses on the health  
13  
14 94 impacts of their policy changes and should strive to build airports further from residential areas.  
15  
16  
17 95

18  
19 96 **Authorship Statement**  
20

21 97 Ms. Scarlett Sijia Wang, Dr. Sherry Glied, Dr. Sharifa Z. Williams and Dr. Peter  
22  
23 98 Meunnig approved the final draft and agreed to be accountable for all aspects of the work. Ms.  
24  
25 99 Scarlett Sijia Wang contributed to study design, data linkage, analysis, interpretation of the data,  
26  
27 100 drafting the methods and results sections. Dr. Sherry Glied contributed to the acquisition of data,  
28  
29 101 study design, analysis, and interpretation of data. Dr. Sharifa Z. Williams contributed to data  
30  
31 102 analysis and interpretation of data. Dr. Peter Muennig contributed to study conception, study  
32  
33 103 design, analysis, interpretation of data and drafting the introduction and discussion sections.  
34  
35 104 Though Mr. Brian Will passed away prior to the submission of the manuscript, he had significant  
36  
37 105 contributions in the study conception, the acquisition of data and sample identification.  
38  
39  
40  
41  
42 106

43  
44 107 **Competing Interest**  
45

46 108 At the time of the study, Mr. Brian Will worked at a non-profit organization called  
47  
48 109 Queens Quiet Skies who are a grass-roots group aiming to address airport noise.  
49  
50  
51 110

52  
53 111 **Data Availability**  
54  
55  
56  
57  
58  
59  
60

1  
2  
3 112 We used individual-level claims data that contain protected Patient Health Information  
4  
5 113 (PHI). Therefore, the data cannot be made unavailable publicly as required by the Health  
6  
7  
8 114 Insurance Portability and Accountability Act (HIPPA).  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

For peer review only



1  
2  
3 115 La Guardia's airspace originally utilized departures over areas that were less populated,  
4  
5 116 such as waterways, parks, or areas with warehouses or manufacturing.<sup>1</sup> However, as air traffic  
6  
7 117 increased over time, the airspace used for traditional routes of arrivals and departures became  
8  
9 118 crowded and conflicted with that of a nearby airport, John F. Kennedy.<sup>2</sup> As with La Guardia,  
10  
11 119 other airports sometimes manage increases in traffic by optimizing flight patterns with less  
12  
13 120 regard for the populations on the ground.<sup>2</sup> Almost invariably, these new flight patterns require  
14  
15 121 routing aircraft over populated areas that were not previously exposed to aircraft noise.

16  
17 122 Noise, and aircraft noise in particular, is associated with a number of health problems,  
18  
19 123 particularly sleep disturbances, mental illness, and substance use.<sup>3-8</sup> The sleep disturbances and  
20  
21 124 psychological stress associated with aircraft noise are, in turn, thought to produce a cascade of  
22  
23 125 biological effects that result in premature aging via endocrinologic changes.<sup>9-14</sup>

24  
25 126 Noise is thought to produce stress by activating the central nervous system and by  
26  
27 127 interfering with sleep.<sup>3,6,8,15,16</sup> This stress produces predictable changes in biochemical pathways  
28  
29 128 in human and animal studies that accelerate the rate of aging.<sup>14,17,18</sup> This accelerated aging  
30  
31 129 process has been linked to the premature onset of age-related diseases, including cardiovascular  
32  
33 130 disease.<sup>9,19,20</sup>

34  
35 131 While the pathways linking poor sleep and psychological stress to premature aging and  
36  
37 132 chronic disease are understood, few studies have experimentally examined interventions that  
38  
39 133 alter noise exposure in human populations.<sup>21</sup> Most of our knowledge about the health impact of  
40  
41 134 aircraft noise in humans is based upon associational studies.<sup>7</sup> These studies suffer from a number  
42  
43 135 of limitations. On one hand, people who live near airports may self-select, such that those who  
44  
45 136 are less sensitive to noise can take advantage of lower home prices on purchases or rentals for  
46  
47 137 homes.<sup>13,19,20</sup> On the other hand, those who live near airports tend to have lower than average  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

1  
2  
3 138 income, a major risk factor for premature disease and death.<sup>19,22-24</sup> There is limited evidence  
4  
5 139 based of the impact of aircraft noise on premature aging and health based on experimental or  
6  
7  
8 140 quasi-experimental analysis.<sup>12,13,23,25</sup>  
9

10 141 Flight pattern changes afford a unique opportunity for studying the health impact of  
11  
12 142 aircraft noise in humans. In the past decade, flight patterns have shifted, and these shifts have  
13  
14 143 increasingly been accompanied by resident complaints.<sup>26</sup> As they do so, it becomes possible to  
15  
16 144 identify areas that are impacted by new aircraft noise. In general, the point of maximum noise  
17  
18 145 from an aircraft happens immediately after take-off as the aircraft is on full power. This is the for  
19  
20 146 the experimental group in our study.  
21  
22  
23

24 147 We conducted a longitudinal case/control study of one well-documented flight pattern  
25  
26 148 change in New York City. LaGuardia Airport is one of 3 major airports in the greater New York  
27  
28 149 City area. One of its departure patterns utilizes Flushing Meadows Park, a route known as the  
29  
30 150 "Whitestone Climb."<sup>24</sup> Because it is over greenspace, the Whitestone Climb has little impact on  
31  
32 151 humans living in nearby dwellings. However, this park is also the location of the US Open  
33  
34 152 Tennis match. During games, a seldom-used departure route called the "Flushing Climb" (now  
35  
36 153 called TNNIS) was used so that the tennis games were not disturbed by aircraft noise. The  
37  
38 154 TNNIS climb routes aircraft over densely populated Flushing, Queens, greatly increasing the  
39  
40 155 exposure of residents to noise on the ground.<sup>24</sup>  
41  
42  
43

44 156 A Freedom of Information Act (FOIA) request by a local group opposed to airplane noise  
45  
46 157 in Queens demonstrated that flight patterns using the TNNIS climb have increased to year-round  
47  
48 158 use since 2012. Before that time, the use of the TNNIS climb was rare outside of the US Open.<sup>27</sup>  
49  
50

51 159 Previous work found that the year-round use of the TNNIS climb was costly, both in  
52  
53 160 terms of money and lives.<sup>24</sup> However, this economic analysis was primarily based on  
54  
55  
56  
57  
58  
59  
60

1  
2  
3 161 associational data. Using data on flight patterns over Flushing obtained using the FOIA as well  
4  
5 162 as Medicaid utilization data, we conducted a quasi-experimental analysis of the health impacts of  
6  
7 163 the airplane noise associated with this new route. In the United States, Medicaid is a safety-net  
8  
9  
10 164 health insurance program for the low-income population. In New York State, over five million  
11  
12 165 low-income individuals enrolled in the Medicaid program in 2012.

## 15 166 **Methods**

### 16 167 **Data**

17  
18  
19 168 The data used in this study are New York City Medicaid claims prepared by the New  
20  
21 169 York University Health Evaluation and Analytics Lab. The data include Medicaid member  
22  
23 170 demographic information, address history, eligibility, medical services, and diagnostic  
24  
25 171 information. The database consists of Medicaid fee for service claims and managed care  
26  
27 172 encounters; both are comparable in quality.<sup>28</sup>

### 28 173 *A priori* specifications and hypotheses

29  
30  
31 174 We hypothesized that exposure to airplane noise would increase health care utilization,  
32  
33 175 insomnia, mood disorder, anxiety, depression, and cardiovascular disease depending upon the  
34  
35 176 age group.<sup>3,6,8,9,12,13</sup> Specifically, exposure to airplane noise would produce sleep disorders across  
36  
37 177 all age groups,<sup>29</sup> would lead to emotional or behavioral disturbances including substance abuse,  
38  
39 178 mood disorder, depression, and developmental disorders among young adults aged 18 to 45 years  
40  
41 179 who tend to be more at risk of these stress-associated disorders,<sup>30</sup> and would produce or  
42  
43 180 exacerbate cardiovascular disease among older adults aged 45 and over when heart disease  
44  
45 181 begins to increase in prevalence.<sup>31</sup> Noise studies suggest wide-ranging  
46  
47 182 psychoneuroendocrinological effects (allostatic load) producing hypertension, hyperglycemia,  
48  
49 183 and hypercholesterolemia.<sup>3,6,8,9,12,13,30,31</sup> These biological changes are linked to cardiovascular  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

1  
2  
3 184 disease, a correlate of exposure to airplane noise as well as other forms of nighttime  
4  
5 185 noise.<sup>7,10,11,32</sup>  
6

## 7 186 Study Design

8  
9  
10 187 We used individual-level data at the member-cohort level for the analysis. We selected  
11  
12 188 samples of Medicaid members residing in each of the two neighborhoods at two points in time.  
13  
14 189 The pre-cohort was defined as Medicaid recipients living in the study neighborhoods between  
15  
16 190 2009-2011 (pre cohort) and 2013-2016 (post cohort). 64% of the Flushing pre cohort and 63% of  
17  
18 191 the Sunset Park pre cohort were also in the post cohort. We used the difference-in-difference  
19  
20 192 models to analyze the results.  
21  
22

## 23 193 Exposure

24  
25  
26 194 To determine exposure, we used data extracted under a FOIA request for flight patterns  
27  
28 195 over Flushing, Queens, New York and from Part 150 Study Technical Advisory Committee  
29  
30 196 Meeting No. 8 documents.<sup>33</sup> These documents were derived from a 2014 study conducted and  
31  
32 197 funded by the Port Authority of NY & NJ (Port Authority) in partnership with the Federal  
33  
34 198 Aviation Administration (FAA). In these documents the Port Authority presents estimated noise  
35  
36 199 exposure in geographies surrounding La Guardia Airport. Exposure is quantified using the  
37  
38 200 Integrated Noise Model in DNL (day-night average sound level) units. We also visually  
39  
40 201 inspected changes in sound related to aircraft flight over sound monitors on the ground in  
41  
42 202 Flushing using Flight Aware, a publicly-available flight tracking website and visited the area.<sup>34</sup>  
43  
44 203 This was done to ensure that the estimates from the Port Authority had face validity.  
45  
46  
47  
48

49 204 These geographic regions or corridors were stratified according to intensity of noise  
50  
51 205 exposure over a 24-hour period. We divided census tracts into > 60 DNL, 55-60 DNL, and <55  
52  
53 206 DNL (Figure 1). We aggregated census tracts and for regions of Flushing, Queens with noise  
54  
55  
56  
57  
58  
59  
60

207 exposure levels of 55 DNL or greater after 2012.<sup>19</sup> These tracts after 2012 are therefore identified  
208 as the treatment condition in this quasi-experimental analysis.

209 Flushing, Queens is a vibrant, predominantly immigrant neighborhood.<sup>24</sup> It is  
210 increasingly populated by Asians immigrants, particularly those of Chinese descent. The English  
211 proficiency in 2018 was 49%, and the population was 54% Asian and 26% white. While the  
212 neighborhood ranked as one of the poorest, the rates of education are higher than average and the  
213 rates of crime, obesity, and hypertension are much lower than New York City as a whole.<sup>24</sup>

214 Sunset Park in Brooklyn, New York was identified as an appropriate control  
215 neighborhood as the neighborhood (1) did not experience a change in exposure to aircraft noise  
216 after 2012 when the TNNIS climb began frequent use, and (2) is similar to Flushing with respect  
217 to the distribution of sociodemographic and economic characteristics.<sup>35,36</sup> Like Flushing, Sunset  
218 Park is increasingly populated by those of Chinese descent with 32% of the population  
219 identifying as Asian and 23% identifying as white. About 48% of the residents were born outside  
220 of the United States and the English proficiency in 2018 was 51%.<sup>25</sup> Sunset Park also has high  
221 poverty rates with relatively low rates of crime, obesity, and hypertension, and high levels of  
222 education relative to New York City as a whole.<sup>24</sup> Census tracts in Sunset Park were matched to  
223 those identified in Flushing based on race, foreign-born status, and age distribution.

#### 224 Key outcomes

225 We used International Classification for Disease revision (ICD-9 and ICD-10) codes as  
226 well as Clinical Classifications Software (CCS) codes for diagnostic groups to identify the  
227 following conditions of interest: insomnia (ICD-9 = 3270, 78052 or ICD-10 = G470),  
228 cardiovascular disease (CCS = 109 – 113), alcohol use disorder (CCS=660), substance use  
229 disorder (CCS = 661), anxiety (CCS = 651), depression (ICD-9 = 311 or ICD-10 = F33), mood

230 disorder (CCS = 657), and disorders usually diagnosed in infancy, childhood adolescence (CCS  
231 = 655), which includes autism, childhood emotional disorder, and separation anxiety.

232 We linked census tracts of Flushing and Sunset Park to geocoded Medicaid addresses. If  
233 a recipient had a Medicaid-registered address within a given census tract, they were assigned to  
234 that census tract. Participants were excluded if they had invalid addresses, dual Medicare status,  
235 did not have a valid date of birth, or were not officially enrolled in Medicaid during the study  
236 period (Table 1). Participant samples were then defined as Medicaid recipients in the period  
237 2009-2011 (pre-implementation period) and 2013-2015 (the TNNIS use period) and who resided  
238 within census tracts in Flushing and Sunset Park.

239 For these identified records, indicator variables were created to identify type of medical  
240 claims inpatient, outpatient, and emergency department (ED) visits as well as prescription drugs,  
241 both overall and for visits related to substance use and mental health disorders (650-663, 670).  
242 We additionally obtained information on the age of the subscriber associated with each record.  
243 Because we did not have access to Medicare records, and did not include dual eligible  
244 participants due to the high likelihood of pre-existing medical conditions and smaller sample  
245 size, our sample does not include adults aged 65 or older. Age in years was defined as the  
246 calculated age on January 1, 2009 and January 1, 2013, and stratified into three age cohorts, 5-  
247 17, 18-44, 45-64 years.

248 Statistical analyses

249 Our focus is on the rate of diagnoses for the hypothesized conditions. We first assess  
250 whether there were significant changes in utilization overall between the baseline and TNNIS  
251 use periods and whether the observed changes differed by neighborhood (i.e., exposure) after  
252 considering other changes over time between these neighborhoods. We use Poisson regression

253 (see equation 1) to model the number of overall and substance use and mental health related  
 254 inpatient, emergency department and outpatient visits for those months in which participants  
 255 were enrolled in Medicaid.

256 For our primary analyses, we use logistic regression (see equation 2) to examine the odds  
 257 of receiving a diagnosis for the hypothesized conditions. Before implementing these regression  
 258 analyses, we examined trends in socio-demographic characteristics as well as trends in Medicaid  
 259 enrollment to ensure that no divergent patterns were noted around 2012. Because racial  
 260 composition varied somewhat between the two neighborhoods (Table 1), we controlled for race  
 261 in our analyses to ensure that compositional changes by race did not influence the analysis. We  
 262 also stratified by age so that we could better test our *a priori* hypotheses by condition. For  
 263 chronic diseases, i.e. cardiovascular disease, we adopted a longer follow-up period 2008-  
 264 2011(pre-implementation) and 2013-2016 (TNNIS implementation) to allow for lag time in  
 265 disease manifestation.

$$266 \log(E(Y | \mathbf{x})) = \alpha + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_1 x_2 + \beta_4 x_3, \quad (1)$$

267 where  $Y = \text{number of Medicaid claims for condition of interest}$

268  $\text{offset} = \text{number of Medicaid enrollment months}$

$$270 \log\left(\frac{p}{1-p}\right) = \alpha + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_1 x_2 + \beta_4 x_3, \quad (2)$$

271 where  $p$

$= \Pr(Y = 1)$  is the probability of  
 having Medicaid claim for condition of interest

272 Here,  $x_1$ , was the indicator for neighborhood exposure condition (Sunset Park=0 vs

273 Flushing=1);  $x_2$ , indicated implementation period (pre-implementation=0 vs TNNIS

1  
2  
3 274 implementation=1); and  $x_3$ , race/ethnicity group membership (Asian=1, Black=2, Hispanic=3,  
4  
5 275 White=4 [reference], Other=5, Unknown=6).

## 8 276 Patient and Public Involvement

9  
10 277 The research question was inspired by the work of a non-profit community organization  
11  
12 278 called Queens Quiet Skies that works to mitigate airplane noise. One of the coauthors of the  
13  
14 279 paper was a member of this organization and obtained the Freedom of Information Act requests  
15  
16  
17 280 for Federal Aviation Administration documents. These documents were used to identify the  
18  
19 281 treatment census tracts and measuring the level of airplane noise exposure.

## 22 282 Results

23  
24 283 Participants were generally similar across both groups over the two points in time (Table  
25  
26 284 1), but health care utilization varied over time by age group and treatment status.

27  
28 285 The increased use of the TNNIS climb occurred in 2012.<sup>27</sup> Prior to that date the climb  
29  
30 286 was only used for the US Open or unexpected weather/runway repairs.<sup>27</sup> We were only able to  
31  
32 287 obtain data on TNNIS departures after the New York Port Authority's Fiscal Year 2013 because  
33  
34 288 the Port Authority indicated that the earlier data had been lost. There were roughly 1,278 TNNIS  
35  
36 289 departures/year on average during US Open events in the 2013-2019 period, providing a point of  
37  
38 290 reference. Since 2013, the total annual number of TNNIS climbs ranged from between 9,349 and  
39  
40 291 29,676, with an average of 18,653/year. The DNL figures (Figure 1) reflect the average noise  
41  
42 292 exposure by census tract across the 2013-2019 period, and may not reflect the actual change in  
43  
44 293 aircraft noise in Flushing, NY in the pre-2012 and post-2012 periods.

## 49 294 Overall medical utilization

50  
51 295 Table 2 provides results from regression models assessing period-related changes in  
52  
53 296 medical utilization and diagnoses. The effects of the change in flight patterns on overall  
54  
55  
56  
57  
58  
59  
60



1  
2  
3 297 utilization were inconsistent across types of utilization and age. Overall, outpatient visits  
4  
5 298 increased slightly in Flushing relative to Sunset Park for those aged 18-44 (rate ratio [RR] =  
6  
7  
8 299 1.04, 95% CI = 1.04, 1.05). Prescription drug claims also increased by a similar amount for this  
9  
10 300 group (RR = 1.06, 95% CI = 1.06, 1.06). However, outpatient visits and prescription drug use for  
11  
12 301 children in Flushing aged 5-17 (outpatient RR=0.86, 95% CI = 0.85, 0.87; prescription drug  
13  
14 302 claims RR = 0.94, 95% CI = 0.94, 0.95) as well as for older adults 45 – 64 declined (outpatient  
15  
16 303 RR=0.92, 95% CI = 0.92, 0.93; prescription drug claims RR = 0.93, 95% CI = 0.92, 0.93).

17  
18 304 While the general pattern for outpatient visits indicates decreased medical utilization in  
19  
20 305 Flushing compared to Sunset Park over time, emergency department visits in Flushing increased  
21  
22 306 in the post TNNIS period among all age groups. For ages 5-17, the RR was 1.31 (95% CI= 1.24,  
23  
24 307 1.37); for ages 18-44, the RR was 1.45 (95% CI = 1.41, 1.49); and for ages 45-64, the RR was  
25  
26 308 1.16 (95% CI = 1.11, 1.21). Substance use and mental health-related emergency department  
27  
28 309 visits also increased in Flushing in the post period relative to Sunset Park, with rate ratios  
29  
30 310 ranging between 2.5 to 4.1. For ages 5-17 RR= 4.11 (95% CI= 3.28, 5.16); for ages 18-44 RR =  
31  
32 311 2.46 (95% CI = 2.20, 2.76); and for ages 45-64, RR = 1.48 (95% CI = 1.31, 1.67).

33  
34 312 Relative to Sunset Park, inpatient visits in Flushing also show statistically significant  
35  
36 313 increases for overall visits for ages 18-44 (RR=1.05, 95% CI = 1.02, 1.08). However, statistically  
37  
38 314 significant decreases were observed for ages 45-64 (RR=0.93, 95% CI = 0.88, 0.97).

#### 39 315 Changes by diagnosis

40 316 Relative to Sunset Park, implementation of the TNNIS climb was associated with  
41  
42 317 increases in insomnia diagnoses, particularly for children. For example, the crude prevalence of  
43  
44 318 insomnia for children increased by 57% from 398 per 100,000 in Flushing, compared to a 6%  
45  
46 319 decrease from 477 per 100,000 in Sunset Park. For children in this age group, the odds ratio

320 (OR) for insomnia was 1.64 (95% CI =1.12, 2.39). For older ages, the effect sizes were  
321 somewhat less striking (i.e., for the 18-44 age group, the OR was 1.17 [95% CI = 1.09, 1.26],  
322 and for ages 45-64 the OR = 1.1 [95% CI = 1.09, 1.28]).

323 Cardiovascular disease diagnoses increased significantly in Flushing relative to Sunset  
324 Park in the post-2012 period. For 18-44-year-olds, the crude prevalence of cardiovascular disease  
325 increased in both neighborhoods due to aging of the samples, by 83% from 1,955 per 100,000 in  
326 Flushing and by 29% from 1,576 per 100,000 in Sunset Park. The OR for cardiovascular disease  
327 diagnoses in Flushing relative to Sunset Park in this age group was 1.45 (95% CI = 1.30, 1.62).  
328 For 45-64-year-olds, , the crude prevalence increased by 33% from 9,934 per 100,000 in  
329 Flushing and 19% from 9,073 per 100,000 in Sunset Park. For this age group, the OR was 1.15  
330 (95% CI = 1.07, 1.25). Substance use disorder only increased significantly for the 45-64 age  
331 group in Flushing relative to Sunset Park (OR =1.24, 95% CI=1.07, 1.44).

332 Figure 2 shows the monthly prevalence of insomnia and cardiovascular disease diagnoses  
333 for the 45-64 age group. Age is measured at the beginning of each period, January 1, 2009 for  
334 the pre-period and January 1, 2013 for the post period. The numerator is the number of unique  
335 individuals with one or more diagnosis from inpatient, emergency room or outpatient claims and  
336 the denominator is the number of Medicaid-enrolled patients. The trends of both conditions  
337 increased throughout the study periods, because people are getting older, but Flushing showed  
338 increases that were larger in magnitude in the post period relative to Sunset Park.

339 Results for other conditions were more mixed. Clinical depression diagnoses increased  
340 for the two older age groups (ages 18-44 OR = 1.12, 95% CI = 1.02, 1.24; ages 45-64 OR = 1.20,  
341 95% CI = 1.08, 1.33). Broader mood disorder diagnoses, however, only showed statistically  
342 significant increases for the 45-65 age group (OR = 1.10, 95% CI = 1.00, 1.20). For 5-17-year-

343 olds, developmental disorder diagnoses significantly decreased (OR=0.80, 95% CI = 0.66, 0.97)  
344 in Flushing relative to Sunset Park after the implementation of TNNIS.

345

## 346 Discussion

347 We find that increases in airplane noise at DNL levels greater than 55 were associated  
348 with increases in insomnia, depression, substance abuse, and cardiovascular disease across most  
349 age groups. These diagnoses are generally consistent with our *a priori* hypotheses regarding the  
350 relationship between exposure to airplane noise and health.<sup>3,6,8,9,12,13,30,31</sup> Specifically, airplane  
351 noise may produce disruptions in sleep and psychological stress, thereby producing  
352 neuroendocrine disruptions that lead to mental health disorders and cardiovascular disease.

353 The biological pathways through which airplane noise impacts health have been  
354 elucidated.<sup>9-14</sup> Numerous associational studies suggest that airplane noise produces real-world  
355 health impacts, and experimental animal models show a wide range of health impacts associated  
356 with noise-induced stress as well.<sup>3-9,11-13,15-18,32</sup> Our study adds quasi-experimental evidence in  
357 humans to this substantial body of research showing that increasing airplane noise will have  
358 detrimental health impacts on communities surrounding airports. The magnitude of our findings  
359 is not strictly comparable to those in associational studies because lagged health effects (e.g., the  
360 time required for psychological stress to manifest as cardiovascular disease) tend to mute the  
361 measured impacts.

362 Nevertheless, the magnitude of the impact of airplane noise on the health outcomes we  
363 observe are generally in line with previous work. For instance, an earlier analysis of associational  
364 studies of the health impact of aircraft noise in Flushing, NY estimated that aircraft noise would  
365 produce a weighted increase in cardiovascular disease of 14% (RR = 1.14, 95% CI = 1.08, 1.22)

1  
2  
3 366 and a weighted increase in anxiety of 79% (RR = 1.79, 95% CI = 1.0-3.1).<sup>11,24</sup> We observe an  
4  
5 367 odds ratio for cardiovascular disease among 18-64-year-olds in the range of 1.12 to 1.40. While  
6  
7 368 the studies examine incident cardiovascular disease and we measure both incident and prevalent  
8  
9 369 cardiovascular disease, it is reasonable to assume that the OR we estimate does not greatly  
10  
11  
12 370 overestimate the adjusted RR computed using associational studies.<sup>37</sup>  
13

14  
15 371 In the international literature, the self-reported annoyance, health, health-related quality  
16  
17 372 of life, and cardiovascular disease rates for those who live close to airports is significantly lower  
18  
19 373 than for matched individuals living in quieter areas.<sup>38-40</sup> In this literature, these latter findings are  
20  
21 374 particularly true for noise-sensitive individuals.<sup>38,39</sup> This suggests that self-selection by noise  
22  
23 375 may mute previously observed effects in ecological studies, which control for socio-economic  
24  
25 376 status but not always noise sensitivity. One strength of our study is that the change in aircraft  
26  
27 377 noise was exogenous and moving out of a neighborhood requires time and effort.  
28  
29

30  
31 378 Our study was subject to a number of limitations. First, the health effects in a  
32  
33 379 predominantly Chinese-American population may not be generalizable to other populations.  
34  
35 380 Chinese-Americans in New York City are unusually healthy.<sup>41</sup> Medicaid data also present unique  
36  
37 381 challenges. Participants can enter and exit the program, for example. If there are more  
38  
39 382 participants exiting the program in one area relative to another, the observed outcomes will also  
40  
41 383 change. We addressed this problem by adjusting for the months a participant was enrolled in  
42  
43 384 Medicaid within a calendar year.  
44  
45

46  
47 385 Next, we use DNL as a measure. Frequency of noise exposure may be superior at  
48  
49 386 predicting health outcomes, but frequency data were not available. Finally, it is possible that the  
50  
51 387 change in neighborhood composition over time differed before and after the implementation of  
52  
53 388 year-round TNNIS departures in Flushing relative to Sunset Park. However, we did not observe  
54  
55  
56  
57  
58  
59  
60

1  
2  
3 389 any trends in the available data that suggested this was the case, and there were no major events  
4  
5 390 in 2012 that clearly serve as an alternative causal factor for either the primary or unexpected  
6  
7 391 findings. Moreover, our findings apply only to the zip codes directly under the DNL zones  
8  
9 392 defined by our analysis.

10  
11  
12 393 Cost-effectiveness analyses (based partly on earlier associational data) show that the  
13  
14 394 benefits of noise-mitigation strategies (reduced illness and discomfort) tend to outweigh the  
15  
16 395 costs.<sup>24,42</sup> Given that these earlier studies did not include the full range of health outcomes that  
17  
18 396 we measure here, it is likely that these studies understate the already substantial benefits of  
19  
20 397 aircraft noise mitigation strategies.

21  
22  
23 398 Much more comprehensive quasi-experimental and economic analyses are required to  
24  
25 399 determine the extent to which policymakers may wish to act. The costliest options—building  
26  
27 400 airports far from populated areas and providing high speed transit and freeways—can increase  
28  
29 401 the cost of mitigation by billions of dollars.

30  
31  
32 402

### 33 403 **Research Ethics Approval**

34  
35 404 This study is approved by the Institutional Review Board at New York University  
36  
37 405 Washington Square under IRB-FY2016-1101.

### 38 406 **Acknowledgements**

39  
40 407 The authors thank NYU Health Evaluation and Analytics Lab and the New York State  
41  
42 408 Department of Health for making the Medicaid claims data available and gratefully acknowledge  
43  
44 409 the funding for this research from the Robert Wood Johnson Foundation's Policies for Action  
45  
46 410 program.

1  
2  
3 411 Disclaimer: The views and opinions expressed in this article are those of the authors and  
4  
5 412 do not necessarily reflect the official policy or position of the New York State Department of  
6  
7 413 Health. Example of analysis performed within this article are only examples. They should not be  
8  
9 414 utilized in real-world analytic products.  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

For peer review only

Table 1 – Demographics characteristics and outcome prevalence and rates for Flushing, New York and Sunset Park, New York before (earlier than 2012) and after (after 2013) airplane noise increased in Flushing, New York.

Baseline Characteristics	Pre-Period: 2009-2011						Post-Period: 2012-2015					
	Age 5 -17		Age 18-44		Age 45-64		Age 5-17		Age 18-44		Age 45-64	
	Flushing	Sunset Park	Flushing	Sunset Park	Flushing	Sunset Park	Flushing	Sunset Park	Flushing	Sunset Park	Flushing	Sunset Park
Demographics												
Total N	20,120	21,597	57,089	52,016	36,472	18,681	24,552	26,009	76,278	60,774	50,806	24,421
Age (Mean)	11.69	11.12	31.07	29.86	53.44	53.29	11.43	10.71	30.95	30.65	53.99	54.22
Age (STD)	3.94	3.92	8.19	7.54	5.59	5.5	3.94	3.87	7.84	7.5	5.44	5.57
Female (%)	48%	48%	58%	57%	54%	51%	48%	48%	56%	56%	54%	52%
Asian (%)	50%	46%	60%	62%	63%	60%	52%	47%	59%	59%	63%	62%
Black (%)	6%	2%	5%	1%	4%	2%	4%	1%	3%	1%	3%	1%
Hispanic (%)	17%	15%	11%	9%	11%	11%	14%	14%	7%	7%	7%	8%
White (%)	11%	24%	10%	15%	10%	14%	10%	24%	8%	14%	8%	12%
Other (%)	5%	3%	5%	4%	6%	7%	5%	3%	4%	3%	5%	6%
Unknown (%)	12%	11%	10%	8%	6%	5%	14%	12%	20%	16%	13%	11%
Average months on Medicaid per year	9	10	8	8	9	10	9	10	8	9	9	9
Total Medicaid Spending per Person per Year	\$1,911	\$1,904	\$3,818	\$3,954	\$6,754	\$6,076	\$1,783	\$1,972	\$3,398	\$3,114	\$6,520	\$6,115
Prevalence per 100,000												
Insomnia	398	477	4,208	6,096	8,036	9,143	623	450	4,755	5,573	11,034	10,843
Cardiovascular disease*	NA*	NA*	1,955	1,576	9,934	9,073	NA*	NA*	3,575	2,540	13,260	10,786

Downloaded from <http://bmjopen.bmj.com/> on 20 April 2024 by guest. Protected by copyright.

BMJ Open

1	Alcohol Use Disorder	NA*	NA*	2,114	1,173	2,470	2,184	NA*	NA*	2,264	1,308	2,870	2,199
2	Substance Use Disorder	NA*	NA*	2,265	1,517	1,799	2,098	NA*	NA*	3,799	2,526	4,250	4,058
3	Anxiety	NA*	NA*	5,124	4,639	6,279	6,279	NA*	NA*	5,726	5,055	7,537	7,416
4	Depression	NA*	NA*	3,782	2,874	6,007	5,867	NA*	NA*	3,191	2,722	5,637	4,656
5	Mood Disorder	NA*	NA*	6,371	4,900	9,399	8,891	NA*	NA*	5,607	4,400	8,375	7,297
6	Disorders diagnosed	1,983	1,394	289	212	170	112	2,480	2,219	307	214	163	188
7	young												
8													
9													
10													
11													
12													
13													
14	Emergency Department	328	216	335	257	288	237	375	188	360	247	332	216
15	Emergency Department	13	20	26	21	31	39	20	7	32	14	45	36
16	(SM)												
17	Inpatient Stays	70	53	267	319	299	245	60	49	231	30	234	190
18	Inpatient Stays (SM)	14	7	43	24	45	32	11	5	37	0	37	21
19													
20													
21													
22													
23													
24	Total Outpatient	3.4	4.1	4.1	4.6	6.7	7.3	3.9	5.2	4.5	5.0	7.6	8.2
25	Outpatient (SM)	0.2	0.2	0.3	0.2	0.4	0.3	0.3	0.3	0.3	0.3	0.5	0.4
26													
27													

Outpatient visits per person per year

\* We adopted a longer follow-up period 2008-2011(pre-implementation) and 2013-2016 (TNNIS implementation) to allow for lag time in disease manifestation



Table 2 – Model Results and 95% Confidence Intervals

	Rate Ratios from the Difference in Difference Poisson Model		
	Age 5 - 17	Age 18 - 44	Age 45 - 64
Inpatient Visits	0.92 (0.83, 1.03)	1.05 (1.02, 1.08)	0.93 (0.88, 0.97)
Emergency Department Visits	1.31 (1.24, 1.37)	1.45 (1.41, 1.49)	1.16 (1.11, 1.21)
Outpatient Visits	0.86 (0.85, 0.87)	1.04 (1.04, 1.05)	0.92 (0.92, 0.93)
Pharmacy Claims	0.94 (0.94, 0.95)	1.06 (1.06, 1.06)	0.93 (0.92, 0.93)
	Rate Ratios from the Difference in Difference Poisson Model Substance Use and Mental Health Related		
	Age 5 - 17	Age 18 - 44	Age 45 - 64
Inpatient Visits	NA*	1.11 (1.01, 1.22)	1.19 (1.04, 1.36)
Emergency Department Visits	4.11 (3.28, 5.16)	2.46 (2.20, 2.76)	1.48 (1.31, 1.67)
Outpatient Visits	1.12 (1.09, 1.16)	0.93 (0.92, 0.95)	0.87 (0.85, 0.89)
	Odds Ratios from the Difference in Difference Logistic Model		
	Age 5 - 17	Age 18 - 44	Age 45 - 64
Insomnia	1.64 (1.12, 2.39)	1.17 (1.09, 1.26)	1.18 (1.09, 1.28)
Cardiovascular Disease**	NA*	1.45 (1.30, 1.62)	1.15 (1.07, 1.25)
Alcohol Use Disorder	NA*	0.97 (0.86, 1.11)	1.16 (0.99, 1.35)
Substance Use Disorder	NA*	0.92 (0.83, 1.03)	1.24 (1.07, 1.44)
Depression	NA*	1.12 (1.02, 1.24)	1.20 (1.08, 1.33)
Anxiety	NA*	1.02 (0.95, 1.10)	1.01 (0.92, 1.11)
Mood Disorder	NA*	1.03 (0.95, 1.10)	1.10 (1.00, 1.20)
Disorders diagnosed young	0.80 (0.66, 0.97)	0.99 (0.72, 1.37)	0.56 (0.31, 1.04)

1  
2  
3  
4  
5 \*These diseases and conditions are rare or difficult to diagnose in children.  
6  
7

8 \*\*We adopted a longer follow-up period 2008-2011(pre-implementation) and 2013-2016  
9

10 (TNNIS implementation) to allow for lag time in disease manifestation  
11  
12  
13

14 Figure 1 – Intensity of noise exposure over a 24-hour period by census tract. The day night level  
15 (DNL) 55 corridor (outer line) is demarcated separately from the DNL 60 corridor (inner line).  
16  
17  
18

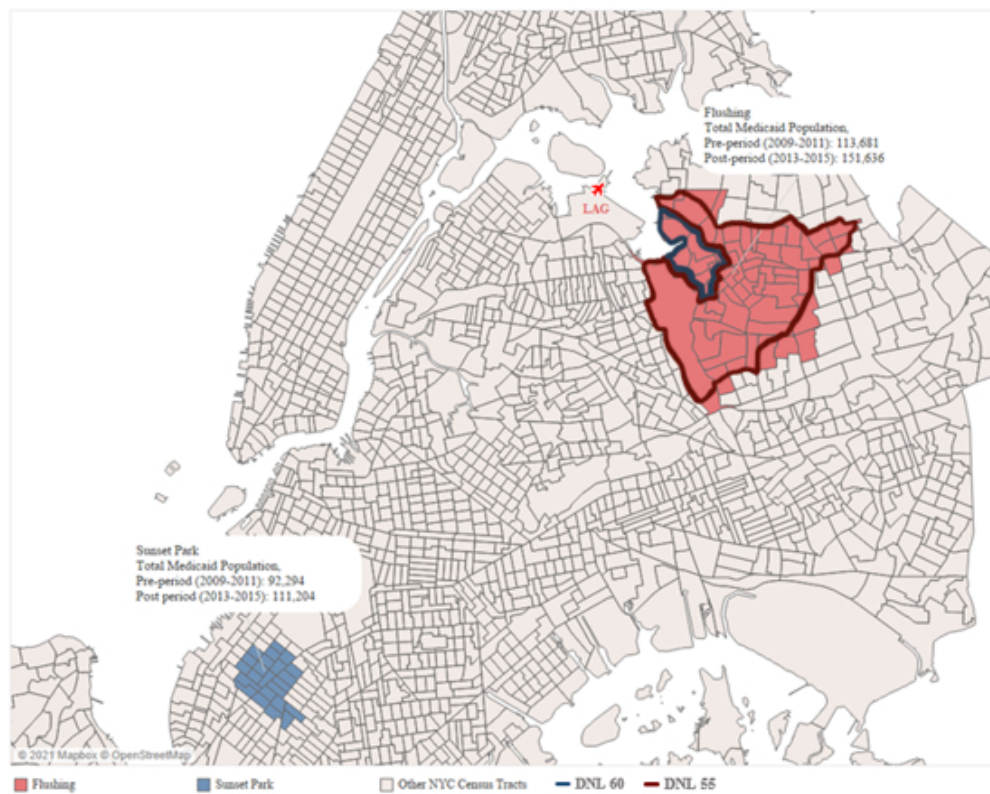
19  
20  
21 Figure 2 – Prevalence of insomnia and cardiovascular disease diagnoses per 100,000 among 45-  
22  
23  
24 64 age group  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

1. Nolan M. Fundamentals of air traffic control: Cengage learning; 2010.
2. Prevot T, Homola J, Mercer J, Mainini M, Cabrall C. Initial evaluation of NextGen air/ground operations with ground-based automated separation assurance. *ATM2009, Napa, California* 2009.
3. Zaharna M, Guilleminault C. Sleep, noise and health: review. *Noise and Health* 2010; **12**(47): 64.
4. Clark C, Stansfeld SA. The effect of transportation noise on health and cognitive development: A review of recent evidence. *Int J Comp Psychol* 2007; **20**(2).
5. Stansfeld S, Haines M, Burr M, Berry B, Lercher P. A review of environmental noise and mental health. *Noise and Health* 2000; **2**(8): 1.
6. Passchier-Vermeer W, Passchier WF. Noise exposure and public health. *Environ Health Perspect* 2000; **108**(Suppl 1): 123.
7. Morrell S, Taylor R, Lyle D. A review of health effects of aircraft noise. *Aust N Z J Public Health* 1997; **21**(2): 221-36.
8. Beutel ME, Jünger C, Klein EM, et al. Noise annoyance is associated with depression and anxiety in the general population-the contribution of aircraft noise. *PLoS One* 2016; **11**(5).
9. Münzel T, Schmidt FP, Steven S, Herzog J, Daiber A, Sørensen M. Environmental noise and the cardiovascular system. *J Am Coll Cardiol* 2018; **71**(6): 688-97.
10. Schmidt FP, Basner M, Kröger G, et al. Effect of nighttime aircraft noise exposure on endothelial function and stress hormone release in healthy adults. *Eur Heart J* 2013; **34**(45): 3508-14.
11. Babisch W. Cardiovascular effects of noise. *Noise and Health* 2011; **13**(52): 201.
12. Maschke C, Harder J, Ising H, Hecht K, Thierfelder W. Stress hormone changes in persons exposed to simulated night noise. *Noise and health* 2002; **5**(17): 35.
13. Melamed S, Bruhis S. The effects of chronic industrial noise exposure on urinary cortisol, fatigue, and irritability: a controlled field experiment. *J Occup Environ Med* 1996; **38**(3): 252-6.
14. McEwen BS. Protective and damaging effects of stress mediators. *N Engl J Med* 1998; **338**(3): 171-9.
15. Basner M, Babisch W, Davis A, et al. Auditory and non-auditory effects of noise on health. *The lancet* 2014; **383**(9925): 1325-32.
16. Perron S, Tétreault L-F, King N, Plante C, Smargiassi A. Review of the effect of aircraft noise on sleep disturbance in adults. *Noise and health* 2012; **14**(57): 58.
17. Xue L, Zhang D, Wang T, Shou X. Effects of high frequency noise on female rat's multi-organ histology. *Noise and Health* 2014; **16**(71): 213.
18. Ising H, Babisch W, Kruppa B. Noise-induced endocrine effects and cardiovascular risk. *Noise and health* 1999; **1**(4): 37.
19. Cohen JP, Coughlin CC. Changing noise levels and housing prices near the Atlanta airport. *Growth and Change* 2009; **40**(2): 287-313.
20. Cohen JP, Coughlin CC. Spatial hedonic models of airport noise, proximity, and housing prices. *Journal of Regional Science* 2008; **48**(5): 859-78.
21. Kawachi I, Adler NE, Dow WH. Money, schooling, and health: Mechanisms and causal evidence. *Ann N Y Acad Sci* 2010; **1186**: 56-68.
22. Muennig P, Franks P, Jia H, Lubetkin E, Gold MR. The income-associated burden of disease in the United States. *Soc Sci Med* 2005; **61**(9): 2018-26.

23. Boes S, Nüesch S, Stillman S. Aircraft Noise, Health, And Residential Sorting: Evidence From Two Quasi-Experiments. *Health Econ* 2013; **22**(9): 1037-51.
24. Zafari Z, Jiao B, Will B, Li S, Muennig PA. The trade-off between optimizing flight patterns and human health: a case study of aircraft noise in Queens, NY, USA. *Int J Environ Res Public Health* 2018; **15**(8).
25. Nüesch S. Aircraft noise, health, and residential sorting: evidence from two quasi-experiments. *Standardization news: SN* 2012; (6744).
26. Eagan ME, Hanrahan R, Miller R. Implementing performance based navigation procedures at US airport: Improving community noise exposure. INTER-NOISE and NOISE-CON Congress and Conference Proceedings; 2013: Institute of Noise Control Engineering; 2013. p. 1577-86.
27. Buckley C. A rumble in the sky and grumbles below. Accessed 11/17/2020. Available online at: <https://www.nytimes.com/2013/08/26/nyregion/planes-roar-from-above-creates-a-rumble-on-the-ground.html>.
28. Mathematica. (2013). Medicaid Managed Care and Integrated Delivery Systems: Technical Assistance to States and Strengthening Federal Oversight. Washington, DC: Mathematica Policy Research.
29. Bhaskar S, Hemavathy D, Prasad S. Prevalence of chronic insomnia in adult patients and its correlation with medical comorbidities. *J Family Med Prim Care*. 2016;5(4):780-784. doi:10.4103/2249-4863.201153.
30. Bernstein GA, Borchardt CM. Anxiety disorders of childhood and adolescence: A critical review. *J Am Acad Child Adolesc Psychiatry* 1991; **30**(4): 519-32.
31. Mensah GA, Brown DW. An overview of cardiovascular disease burden in the United States. *Health Aff (Millwood)* 2007; **26**(1): 38-48.
32. Halonen JI, Hansell AL, Gulliver J, et al. Road traffic noise is associated with increased cardiovascular morbidity and mortality and all-cause mortality in London. *Eur Heart J* 2015; **36**(39): 2653-61.
33. Technical Advisory Committee (TAC) meeting 8. Available online at: <http://www.panynjpart150.com/AdminPages/GetProjectFile.asp?a=LGA&f=LGA%20TAC%20Meeting%20No.%208%20Summary,%20August%2016,%202016.pdf> Accessed 6/17/2020.
34. Flight Aware. Live flight tracking. Available online at: <https://flightaware.com>. Accessed 6/20/2020.
35. NYC Health. Community Health Profile: Sunset Park. Available online at: <https://www1.nyc.gov/assets/doh/downloads/pdf/data/2018chp-bk7.pdf> Accessed 3/2/2020.
36. NYC Health. Community Health Profile: Flushing and Whitestone. Available online at: <https://www1.nyc.gov/assets/doh/downloads/pdf/data/2018chp-qn7.pdf> Accessed 3/2/2020.
37. Knol MJ, Le Cessie S, Algra A, Vandenbroucke JP, Groenwold RH. Overestimation of risk ratios by odds ratios in trials and cohort studies: alternatives to logistic regression. *CMAJ*. 2012;184(8):895-899. doi:10.1503/cmaj.101715.
38. Welch D, Shepherd D, McBride D. Health-related quality of life is impacted by proximity to an airport in noise sensitive people. INTER-NOISE and NOISE-CON Congress and Conference Proceedings; 2016: Institute of Noise Control Engineering; 2016. p. 5003-10.
39. Shepherd D, McBride D, Dirks KN, Welch D. Annoyance and health-related quality of life: a cross-sectional study involving two noise sources. *J Environ Prot (Irvine, Calif)* 2014; **2014**.

- 1  
2  
3 40. Bronzaft AL, Dee Ahern K, McGinn R, O'Connor J, Savino B. Aircraft noise: A potential  
4 health hazard. *Environ Behav* 1998; **30**(1): 101-13.  
5  
6 41. Muennig P, Wang Y, Jacobowski A. The health of immigrants to New York City from  
7 Mainland China: Evidence from the New York Health Examination and Nutrition Survey. *Journal*  
8 *of Immigrant and Refugee Studies* 2012; **10**: 1-7.  
9  
10 42. Jiao B, Zafari Z, Will B, Ruggeri K, Li S, Muennig P. The Cost-Effectiveness of Lowering  
11 Permissible Noise Levels Around US Airports. *Int J Environ Res Public Health* 2017; **14**(12): 1497.  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

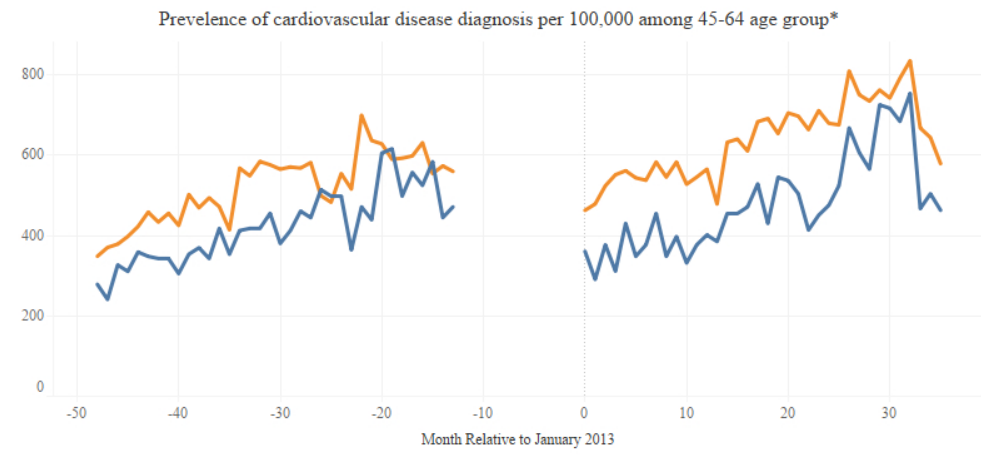
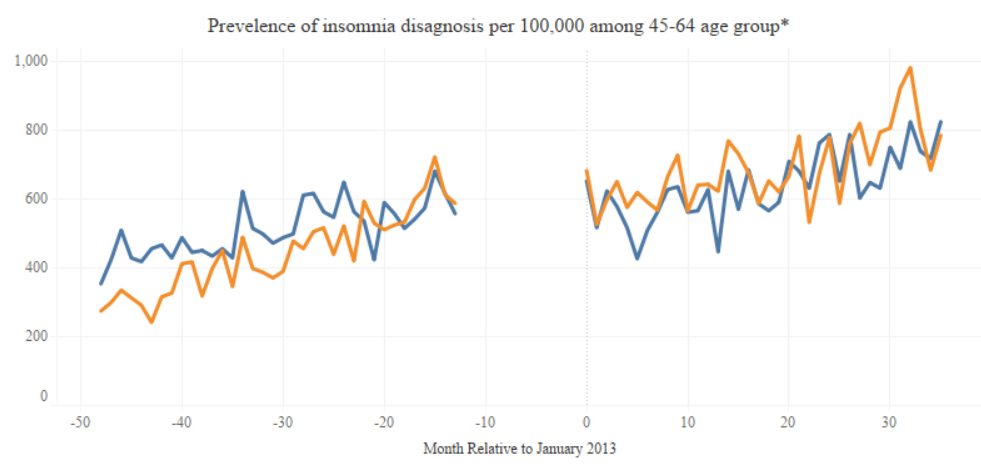
For peer review only



117x93mm (120 x 120 DPI)

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60



Exposed: Flushing Control: Sunset Park  
 \*Age is measured at the beginning of each period, January 1, 2009 for the pre-period and January 1, 2013 for the post-period

211x211mm (96 x 96 DPI)

- 1  
2  
3 1 Title Page  
4  
5 2 The impact of airplane noise on mental and physical health. A quasi-experimental analysis.  
6  
7

8 3  
9  
10 4 Scarlett Sijia Wang, MPH, MS  
11 5 Corresponding author.  
12 6 Associate Research Scientist  
13 7 Robert F. Wagner Graduate School of Public Service  
14 8 Email: [scarlett@nyu.edu](mailto:scarlett@nyu.edu)  
15 9 New York University  
16 10 295 Lafayette St.  
17 11 Second Floor  
18 12 New York, NY 10012

19 13  
20 14 Sherry Glied, PHD  
21 15 Dean  
22 16 Robert F. Wagner Graduate School of Public Service  
23 17 New York University  
24 18 295 Lafayette St.  
25 19 Second Floor  
26 20 New York, NY 10012

27 21  
28 22 Sharifa Z. Williams, DrPH, MS  
29 23 Research Scientist  
30 24 Nathan S. Kline Institute for Psychiatric Research  
31 25 Center for Research on Cultural and Structural Equity in Behavioral Health  
32 26 Division of Social Solutions and Services Research  
33 27 140 Old Orangeburg Road, Bldg. 35,  
34 28 Orangeburg, NY 10962-1159

35 29  
36 30 Brian Will  
37 31 (Mr. Will passed away prior to the submission of the manuscript.)  
38 32

39 33 Peter Muennig, MD, MPH  
40 34 Professor  
41 35 Mailman School of Public Health  
42 36 Columbia University  
43 37 722 West 168th St.  
44 38 ARB 4th Floor  
45 39 New York, NY 10032  
46 40

47  
48  
49  
50  
51 41  
52  
53  
54  
55  
56  
57  
58  
59  
60



43 The impact of airplane noise on mental and physical health: ~~a~~-A quasi-experimental analysis.

#### 44 Abstract

45 **Objectives.** Historically, departures at New York City's La Guardia airport (LGA) flew over a  
46 large sports complex within a park. During the US Open tennis games, flights were diverted to  
47 fly over a heavily populated foreign-born neighborhood for roughly two weeks out of the year so  
48 that the tennis match was not disturbed (the "TNNIS" departure). In 2012, the use of the TNNIS  
49 departure became year-round to better optimize flight patterns around the metropolitan area.

50 **Methods.** We exploited exogenously-induced spatial and temporal variation in flight patterns ~~in~~  
51 ~~order to~~to examine difference-in-difference effects of this new exposure to aircraft noise on the  
52 health of individual residents in the community relative to individuals residing within a  
53 demographically similar community that was not impacted. We used individual-level Medicaid  
54 records, focusing on conditions associated with noise: sleep disturbance, psychological stress,  
55 mental illness, substance use, and cardiovascular disease.

56 **Results.** We found that increased ~~ex~~posure to airplane noise was associated with a significant  
57 increase in insomnia across all age groups, but particularly in children ages 5-17 (OR = 1.64).  
58 Cardiovascular disease increased significantly both among 18-44-year-old (OR = 1.45) and 45-  
59 64-year-old Medicaid recipients (OR = 1.15). Substance use and mental health-related  
60 emergency department visits also increased. For ages 5-17 RR= 4.11 (95% CI= 3.28, 5.16); for  
61 ages 18-44 RR = 2.46 (95% CI = 2.20, 2.76); and for ages 45-64, RR = 1.48 (95% CI = 1.31,  
62 1.67).

63 **Conclusion.** ~~This study demonstrates~~We find that increased exposure to airplane noise increases  
64 diagnosed cardiovascular disease, substance use/mental health emergencies, and insomnia  
65 among local residents ~~are the externalities of this decision~~.

For peer review only

66

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

## 67 Strengths and ~~liminations~~limitations

68 1. Even though ~~w~~We used a quasi-experimental design, the study is an ecological study, and  
69 therefore we cannot prove causality directly, which is a limitation of the study to study  
70 before and after impacts of a flight pattern change in two matched zip code clusters  
71 within New York City (a difference-in-difference design).

72 1.2. One strength of the study is the use ~~We used of a large-sealed insurance claims~~  
73 database that allowed us to capture diagnoses, as well as providing sufficient stastical  
74 power for most residents in both impacted and unimpacted zip code clusters.

75 3. Despite the difference-in-difference design, it is possible that participants self-segregated  
76 after the increase in aircraft noise or that other unmeasured factors influenced the  
77 observed outcomes.

78 4. Another limitation of the study is the lack of ~~We were unable to compute a dose-response~~  
79 relationship due to the use of ~~aggregated~~aggregated noise data.

80 5. A third limitation of the study is the lack of pre-2012 airplane departure data, despite our  
81 persistent effort to request. We find that a sudden and dramatic change in aircraft noise  
82 increased diagnoses of insomnia, cardiovascular disease, substance abuse, and mental  
83 illness.

84  
85 ~~6. One strength of the study is the use of a large-sealed insurance claims database that~~  
86 ~~allowed us to capture diagnoses, as well as providing sufficient stastical power.~~

87 ~~Another strength of the study is the use of a quasi-experiental design and the difference in~~  
88 ~~difference method. Though we cannot prove causality directly, we were able to~~  
89 ~~demonstrate the magnitude of change.~~

1  
2  
3 90 **What is already known about this subject?**  
4

5 91 Previous work demonstrated adverse health effect associated with airplane noise,  
6  
7  
8 92 including cardiovascular disease and insomnia using ecological or associational approaches.  
9

10 93  
11  
12 94 **What are the new findings?**  
13

14 95 This study exploits exogenous variation in exposure to airplane noise longitudinally in a  
15  
16  
17 96 case and control community in New York City using individual-level Medicaid records. Our  
18  
19 97 difference-in-difference design coupled with more granular ~~and higher quality~~ data suggest that  
20  
21  
22 98 the increased airplane noise was associated with increases in insomnia, substance use/mental  
23  
24 99 health emergencies, and cardiovascular disease may be causal in nature, but additional studies  
25  
26 100 must be done.  
27

28 101

29 102

30  
31 103 **How might it impact on policy in the foreseeable future?**  
32

33 104 As air traffic increases, policy makers should consider ~~avoiding residential areas when~~  
34  
35  
36 105 designing new airports ~~conducting analyses on the health impacts of their policy changes and~~  
37  
38  
39 106 should strive to build airports further from residential areas.  
40  
41

42 107

43  
44 108 **Authorship Statement**

45  
46  
47 109 Ms. Scarlett Sijia Wang, Dr. Sherry Glied, Dr. Sharifa Z. Williams and Dr. Peter  
48  
49 110 Meunnig approved the final draft and agreed to be accountable for all aspects of the work. Ms.  
50  
51 111 Scarlett Sijia Wang contributed to study design, data linkage, analysis, interpretation of the data,  
52  
53 112 drafting the methods and results sections. Dr. Sherry Glied contributed to the acquisition of data,  
54  
55

1  
2  
3 113 [study design, analysis, and interpretation of data. Dr. Sharifa Z. Williams contributed to data](#)  
4  
5 114 [analysis and interpretation of data. Dr. Peter Muennig contributed to study conception, study](#)  
6  
7  
8 115 [design, analysis, interpretation of data and drafting the introduction and discussion sections.](#)  
9  
10 116 [Though Mr. Brian Will passed away prior to the submission of the manuscript, he had significant](#)  
11  
12 117 [contributions in the study conception, the acquisition of data and sample identification.](#)  
13  
14

### 15 118

### 16

### 17 119 **Competing Interest**

### 18

19 120 [At the time of the study, Mr. Brian Will worked at a non-profit organization called](#)  
20  
21 121 [Queens Quiet Skies who are a grass-roots group aiming to address airport noise.](#)  
22  
23

24 122

### 25

### 26 123 **Data Availability**

### 27

28 124 [We used individual-level claims data that contain protected Patient Health Information](#)  
29  
30 125 [\(PHI\). Therefore, the data cannot be made unavailable publicly as required by the Health](#)  
31  
32 126 [Insurance Portability and Accountability Act \(HIPAA\).](#)  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

1  
2  
3 127 ~~When aircraft enter urban La Guardia's~~ airspace, ~~they traditionally approach originally~~  
4 ~~utilized and~~ departures over areas that ~~are were~~ less populated, such as waterways, parks, or  
5  
6 128  
7  
8 129 areas with warehouses or manufacturing.<sup>1</sup> However, as air traffic increaseds over time, the  
9  
10 130 airspace used for traditional routes of arrivals and departures ~~has become~~became crowded and  
11  
12 131 ~~conflicted with that of a nearby airport, John F. Kennedy.~~<sup>2</sup> ~~To As with La Guardia, other airports~~  
13  
14 132 ~~sometimes handle manage this~~ increases in traffic, ~~landings and departures must sometimes be~~  
15  
16 133 ~~altered to optimize by optimizing~~ flight patterns ~~with less regard for the populations on the~~  
17  
18 134 ~~ground.~~<sup>2</sup> Almost invariably, these new flight patterns require routing aircraft over populated  
19  
20  
21 135 areas that were not previously exposed to aircraft noise.

22  
23  
24 136 Noise, and aircraft noise in particular, is associated with a number of health problems,  
25  
26 137 particularly sleep disturbances, mental illness, and substance use.<sup>3-8</sup> The sleep disturbances and  
27  
28 138 psychological stress associated with aircraft noise are, in turn, thought to produce a cascade of  
29  
30 139 biological effects that result in premature aging via endocrinologic changes.<sup>9-14</sup>

31  
32  
33 140 Noise is thought to produce stress by activating the central nervous system and by  
34  
35 141 interfering with sleep.<sup>3,6,8,15,16</sup> This stress produces predictable changes in biochemical pathways  
36  
37 142 in human and animal studies that accelerate the rate of aging.<sup>14,17,18</sup> This accelerated aging  
38  
39 143 process has been linked to the premature onset of age-related diseases, including cardiovascular  
40  
41 144 disease.<sup>9,19,20</sup>

42  
43  
44 145 While the pathways linking poor sleep and psychological stress to premature aging and  
45  
46 146 chronic disease are understood, few studies have experimentally examined interventions that  
47  
48 147 alter noise exposure in human populations.<sup>21</sup> Most of our knowledge about the health impact of  
49  
50 148 aircraft noise in humans is based upon associational studies.<sup>7</sup> These studies suffer from a number  
51  
52 149 of limitations. On one hand, people who live near airports may self-select, such that those who  
53  
54  
55  
56  
57  
58  
59  
60

1  
2  
3 150 are less sensitive to noise can take advantage of lower home prices on purchases or rentals for  
4  
5 151 homes.<sup>13,19,20</sup> On the other hand, those who live near airports tend to have lower than average  
6  
7 152 income, a major risk factor for premature disease and death.<sup>19,22-24</sup> There is limited evidence  
8  
9 153 based of the impact of aircraft noise on premature aging and health based on experimental or  
10  
11 154 quasi-experimental analysis.<sup>12,13,23,25</sup>

12  
13  
14  
15 155 Flight pattern changes afford a unique opportunity for studying the health impact of  
16  
17 156 aircraft noise in humans. In the past decade, flight patterns have shifted, and these shifts have  
18  
19 157 increasingly been accompanied by resident complaints.<sup>26</sup> As they do so, it becomes possible to  
20  
21 158 identify areas that are impacted by new aircraft noise. In general, the point of maximum noise  
22  
23 159 from an aircraft happens immediately after take-off as the aircraft is on full power. This is the  
24  
25 160 case in our study, for the experimental group in our study.

26  
27  
28 161 We conducted a longitudinal case/control study of one well-documented flight pattern  
29  
30 162 change in New York City. LaGuardia Airport is one of 3 major airports in the greater New York  
31  
32 163 City area. One of its departure patterns utilizes Flushing Meadows Park, a route known as the  
33  
34 164 "Whitestone Climb."<sup>24</sup> Because it is over greenspace, the Whitestone Climb has little impact on  
35  
36 165 humans living in nearby dwellings. However, this park is also the location of the US Open  
37  
38 166 Tennis match. During games, a seldom-used departure route called the "Flushing Climb" (now  
39  
40 167 called TNNIS) was used so that the tennis games were not disturbed by aircraft noise. The  
41  
42 168 TNNIS climb routes aircraft over densely populated Flushing, Queens, greatly increasing the  
43  
44 169 exposure of residents to noise on the ground.<sup>24</sup>

45  
46  
47 170 A Freedom of Information Act (FOIA) request by a local group opposed to airplane noise  
48  
49 171 in Queens demonstrated that flight patterns using the TNNIS climb have increased to year-round  
50  
51 172 use since 2012. Before that time, the use of the TNNIS climb was rare outside of the US Open.<sup>27</sup>

1  
2  
3 173 Previous work found that the year-round use of the TNNIS climb was costly, both in  
4  
5 174 terms of money and lives.<sup>24</sup> However, this economic analysis was primarily based on  
6  
7  
8 175 associational data. Using data on flight patterns over Flushing obtained using the FOIA as well  
9  
10 176 as Medicaid utilization data, we conducted a quasi-experimental analysis of the health impacts of  
11  
12 177 the airplane noise associated with this new route. [In the United States, Medicaid is a safety-net](#)  
13  
14 178 [health insurance program for the low-income population. In New York State, over five million](#)  
15  
16  
17 179 [low-income individuals enrolled in the Medicaid program in 2012.](#)

## 180 **Methods**

### 181 **Data**

182 The data used in this study are New York City Medicaid claims prepared by the New  
183 York University Health Evaluation and Analytics Lab. The data include Medicaid member  
184 demographic information, address history, eligibility, medical services, and diagnostic  
185 information. The database consists of Medicaid fee for service claims and managed care  
186 encounters; both are comparable in quality.<sup>28</sup>

### 187 *A priori* specifications and hypotheses

188 We hypothesized that exposure to airplane noise would increase health care utilization,  
189 insomnia, mood disorder, anxiety, depression, and cardiovascular disease depending upon the  
190 age group.<sup>3,6,8,9,12,13</sup> Specifically, exposure to airplane noise would produce sleep disorders across  
191 all age groups,<sup>29</sup> would lead to emotional or behavioral disturbances including substance abuse,  
192 mood disorder, depression, and developmental disorders among young adults aged 18 to < 45  
193 years who tend to be more at risk of these stress-associated disorders,<sup>30</sup> and would produce or  
194 exacerbate cardiovascular disease among older adults aged 45 and over when heart disease  
195 begins to increase in prevalence.<sup>31</sup> Noise studies suggest wide-ranging



1  
2  
3 196 psychoneuroendocrinological effects (allostatic load) producing hypertension, hyperglycemia,  
4  
5 197 and hypercholesterolemia.<sup>3,6,8,9,12,13,30,31</sup> These biological changes are linked to cardiovascular  
6  
7 198 disease, a correlate of exposure to airplane noise as well as other forms of nighttime  
8  
9  
10 199 noise.<sup>7,10,11,32</sup>

## 12 200 Study Design

14  
15 201 We used individual-level data at the member-cohort level for the analysis. We selected  
16  
17 202 samples of Medicaid members residing in each of the two neighborhoods at two points in time.  
18  
19 203 The pre-cohort was defined as Medicaid recipients living in the study neighborhoods between  
20  
21 204 2009-2011 (pre cohort) and 2013-2016 (post cohort). 64% of the Flushing pre cohort and 63%  
22  
23  
24 205 of the Sunset Park pre cohort were also in the post cohort. We used the difference-in-difference  
25  
26 206 models to analyze the results.

## 28 207 Exposure

30  
31 208 To determine exposure, we used data extracted under a FOIA request for flight patterns  
32  
33 209 over Flushing, Queens, New York and from Part 150 Study Technical Advisory Committee  
34  
35 210 Meeting No. 8 documents.<sup>33</sup> These documents were derived from a 2014 study conducted and  
36  
37 211 funded by the Port Authority of NY & NJ (Port Authority) in partnership with the Federal  
38  
39 212 Aviation Administration (FAA). In these documents the Port Authority presents estimated noise  
40  
41 213 exposure in geographies surrounding La Guardia Airport. Exposure is quantified using the  
42  
43 214 Integrated Noise Model in DNL (day-night average sound level) units. We also visually  
44  
45 215 inspected changes in sound related to aircraft flight over sound monitors on the ground in  
46  
47  
48  
49 216 Flushing using Flight Aware, a publicly-available flight tracking website and visited the area.<sup>34</sup>  
50  
51 217 This was done to ensure that the estimates from the Port Authority had face validity.  
52  
53  
54  
55  
56  
57  
58  
59  
60

1  
2  
3 218 These geographic regions or corridors were stratified according to intensity of noise  
4  
5 219 exposure over a 24-hour period. We divided census tracts into > 60 DNL, 55-60 DNL, and <55  
6  
7  
8 220 DNL (Figure 1). We aggregated census tracts and for regions of Flushing, Queens with noise  
9  
10 221 exposure levels of 55 DNL or greater after 2012.<sup>19</sup> These tracts after 2012 are therefore identified  
11  
12 222 as the treatment condition in this quasi-experimental analysis.

13  
14 223 Flushing, Queens is a vibrant, predominantly immigrant neighborhood.<sup>24</sup> It is  
15  
16 224 increasingly populated by Asians immigrants, particularly those of Chinese descent. The English  
17  
18 225 proficiency in 2018 was 49%, and the population was 54% Asian and 26% white. While the  
19  
20 226 neighborhood ranked as one of the poorest, the rates of education are higher than average and the  
21  
22 227 rates of crime, obesity, and hypertension are much lower than New York City as a whole.<sup>24</sup>

23  
24 228 Sunset Park in Brooklyn, New York was identified as an appropriate control  
25  
26 229 neighborhood as the neighborhood (1) did not experience a change in exposure to aircraft noise  
27  
28 230 after 2012 when the TNNIS climb began frequent use, and (2) is similar to Flushing with respect  
29  
30 231 to the distribution of sociodemographic and economic characteristics.<sup>35,36</sup> Like Flushing, Sunset  
31  
32 232 Park is increasingly populated by those of Chinese descent with 32% of the population  
33  
34 233 identifying as Asian and 23% identifying as white. About 48% of the residents were born outside  
35  
36 234 of the United States and the English proficiency in 2018 was 51%.<sup>25</sup> Sunset Park also has high  
37  
38 235 poverty rates with relatively low rates of crime, obesity, and hypertension, and high levels of  
39  
40 236 education relative to New York City as a whole.<sup>24</sup> Census tracts in Sunset Park were matched to  
41  
42 237 those identified in Flushing based on race, foreign-born status, and age distribution.

#### 43 238 Key outcomes

44  
45 239 We used International Classification for Disease revision (ICD-9 and ICD-10) codes as  
46  
47 240 well as Clinical Classifications Software (CCS) codes for diagnostic groups to identify the

1  
2  
3 241 following conditions of interest: insomnia (ICD-9 = 3270, 78052 or ICD-10 = G470),  
4  
5 242 cardiovascular disease (CCS = 109 – 113), alcohol use disorder (CCS=660), substance use  
6  
7 243 disorder (CCS = 661), anxiety (CCS = 651), depression (ICD-9 = 311 or ICD-10 = F33), mood  
8  
9 244 disorder (CCS = 657), and disorders usually diagnosed in infancy, childhood adolescence (CCS  
10  
11 = 655), which includes autism, childhood emotional disorder, and separation anxiety.  
12  
13

14  
15 246 We linked census tracts of Flushing and Sunset Park to geocoded Medicaid addresses. If  
16  
17 247 a recipient had a Medicaid-registered address within a given census tract, they were assigned to  
18  
19 248 that census tract. Participants were excluded if they had invalid addresses, dual Medicare status,  
20  
21 249 did not have a valid date of birth, or were not officially enrolled in Medicaid during the study  
22  
23 250 period (Table 1). Participant samples were then defined as Medicaid recipients in the period  
24  
25 251 2009-2011 (pre-implementation period) and 2013-2015 (the TNNIS use period) and who resided  
26  
27 252 within census tracts in Flushing and Sunset Park.  
28  
29

30  
31 253 For these identified records, indicator variables were created to identify type of medical  
32  
33 254 claims inpatient, outpatient, and emergency department (ED) visits as well as prescription drugs,  
34  
35 255 both overall and for visits related to substance use and mental health disorders (650-663, 670).  
36  
37 256 We additionally obtained information on the age of the subscriber associated with each record.  
38  
39 257 Because we did not have access to Medicare records, and did not include dual eligible  
40  
41 258 participants due to the high likelihood of pre-existing medical conditions and smaller sample  
42  
43 259 size, our sample does not include adults aged 65 or older. Age in years was defined as the  
44  
45 260 calculated age on January 1, 2009 and January 1, 2013, and stratified into three age cohorts, 5-  
46  
47 261 17, 18-44, 45-64 years.  
48  
49

50  
51 262 Statistical analyses  
52  
53  
54  
55  
56  
57  
58  
59

263 Our focus is on the rate of diagnoses for the hypothesized conditions. We first assess  
 264 whether there were significant changes in utilization overall between the baseline and TNNIS  
 265 use periods and whether the observed changes differed by neighborhood (i.e., exposure) after  
 266 considering other changes over time between these neighborhoods. We use Poisson regression  
 267 (see equation 1) to model the number of overall and substance use and mental health related  
 268 inpatient, emergency department and outpatient visits for those months in which participants  
 269 were enrolled in Medicaid.

270 For our primary analyses, we use logistic regression (see equation 2) to examine the odds  
 271 of receiving a diagnosis for the hypothesized conditions. Before implementing these regression  
 272 analyses, we examined trends in socio-demographic characteristics as well as trends in Medicaid  
 273 enrollment to ensure that no divergent patterns were noted around 2012. Because racial  
 274 composition varied somewhat between the two neighborhoods (Table 1), we controlled for race  
 275 in our analyses to ensure that compositional changes by race did not influence the analysis. We  
 276 also stratified by age so that we could better test our *a priori* hypotheses by condition. For  
 277 chronic diseases, i.e. cardiovascular disease, we adopted a longer follow-up period 2008-  
 278 2011(pre-implementation) and 2013-2016 (TNNIS implementation) to allow for lag time in  
 279 disease manifestation.

$$280 \log(E(Y | \mathbf{x})) = \alpha + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_1 x_2 + \beta_4 x_3, \quad (1)$$

281 where  $Y =$  number of Medicaid claims for condition of interest

282 offset = number of Medicaid enrollment months

283

$$284 \log\left(\frac{p}{1-p}\right) = \alpha + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_1 x_2 + \beta_4 x_3, \quad (2)$$

1  
2  
3 where  $p$

4 285 =  $\Pr(Y = 1)$  is the probability of  
5 having Medicaid claim for condition of interest

6  
7 286 Here,  $x_1$ , was the indicator for neighborhood exposure condition (Sunset Park=0 vs  
8 Flushing=1);  $x_2$ , indicated implementation period (pre-implementation=0 vs TNNIS  
9 implementation=1); and  $x_3$ , race/ethnicity group membership (Asian=1, Black=2, Hispanic=3,  
10 287  
11 implementation=1); and  $x_3$ , race/ethnicity group membership (Asian=1, Black=2, Hispanic=3,  
12 288  
13 White=4 [reference], Other=5, Unknown=6).  
14 289

15  
16  
17 290 Patient and Public Involvement

18  
19 291 The research question was inspired by the work of a non-profit community organization  
20 called Queens Quiet Skies that works to mitigate airplane noise. One of the coauthors of the  
21 292  
22 paper was a member of this organization and obtained the Freedom of Information Act requests  
23 293  
24 for Federal Aviation Administration documents. These documents were used to identify the  
25 294  
26 treatment census tracts and measuring the level of airplane noise exposure.  
27 295  
28

## 29 296 **Results**

30  
31  
32  
33 297 Participants were generally similar across both groups over the two points in time (Table  
34 298  
35 1), but health care utilization varied over time by age group and treatment status.

36  
37 299 The increased use of the TNNIS climb occurred in 2012.<sup>27</sup> Prior to that date the climb  
38 was only used for the US Open or unexpected weather/runway repairs.<sup>27</sup> We were only able to  
39 300  
40 obtain data on TNNIS departures after the New York Port Authority's Fiscal Year 2013 because  
41 301  
42 the Port Authority indicated that the earlier data had been lost. There were roughly 1,278 TNNIS  
43 302  
44 departures/year on average during US Open events in the 2013-2019 period, providing a point of  
45 303  
46 reference. Since 2013, the total annual number of TNNIS climbs ranged from between 9,349 and  
47 304  
48 29,676, with an average of 18,653/year. The DNL figures (Figure 1) reflect the average noise  
49 305  
50 exposure by census tract across the 2013-2019 period, and may not reflect the actual change in  
51 306  
52 aircraft noise in Flushing, NY in the pre-2012 and post-2012 periods.  
53  
54  
55  
56  
57  
58  
59  
60

## 308 Overall medical utilization

309 Table 2 provides results from regression models assessing period-related changes in  
310 medical utilization and diagnoses. The effects of the change in flight patterns on overall  
311 utilization were inconsistent across types of utilization and age. Overall, outpatient visits  
312 increased slightly in Flushing relative to Sunset Park for those aged 18-44 (rate ratio [RR] =  
313 1.04, 95% CI = 1.04, 1.05). Prescription drug claims also increased by a similar amount for this  
314 group (RR = 1.06, 95% CI = 1.06, 1.06). However, outpatient visits and prescription drug use for  
315 children in Flushing aged 5-17 (outpatient RR=0.86, 95% CI = 0.85, 0.87; prescription drug  
316 claims RR = 0.94, 95% CI = 0.94, 0.95) as well as for older adults 45 – 64 declined (outpatient  
317 RR=0.92, 95% CI = 0.92, 0.93; prescription drug claims RR = 0.93, 95% CI = 0.92, 0.93).

318 While the general pattern for outpatient visits indicates decreased medical utilization in  
319 Flushing compared to Sunset Park over time, emergency department visits in Flushing increased  
320 in the post TNNIS period among all age groups. For ages 5-17, the RR was 1.31 (95% CI= 1.24,  
321 1.37); for ages 18-44, the RR was 1.45 (95% CI = 1.41, 1.49); and for ages 45-64, the RR was  
322 1.16 (95% CI = 1.11, 1.21). Substance use and mental health-related emergency department  
323 visits also increased in Flushing in the post period relative to Sunset Park, with rate ratios  
324 ranging between 2.5 to 4.1. For ages 5-17 RR= 4.11 (95% CI= 3.28, 5.16); for ages 18-44 RR =  
325 2.46 (95% CI = 2.20, 2.76); and for ages 45-64, RR = 1.48 (95% CI = 1.31, 1.67).

326 Relative to Sunset Park, inpatient visits in Flushing also show statistically significant  
327 increases for overall visits for ages 18-44 (RR=1.05, 95% CI = 1.02, 1.08). However, statistically  
328 significant decreases were observed for ages 45-64 (RR=0.93, 95% CI = 0.88, 0.97).

## 329 Changes by diagnosis

1  
2  
3 330 Relative to Sunset Park, implementation of the TNNIS climb was associated with  
4  
5 331 increases in insomnia diagnoses, particularly for children. For example, the crude prevalence of  
6  
7 332 insomnia for children increased by 57% from 398 per 100,000 in Flushing, compared to a 6%  
8  
9 333 decrease from 477 per 100,000 in Sunset Park. For children in this age group, the odds ratio  
10  
11 334 (OR) for insomnia was 1.64 (95% CI =1.12, 2.39). For older ages, the effect sizes were  
12  
13 335 somewhat less striking (i.e., for the 18-44 age group, the OR was 1.17 [95% CI = 1.09, 1.26],  
14  
15 336 and for ages 45-64 the OR = 1.1 [95% CI = 1.09, 1.28]).

16  
17 337 Cardiovascular disease diagnoses increased significantly in Flushing relative to Sunset  
18  
19 338 Park in the post-2012 period. For 18-44-year-olds, the crude prevalence of cardiovascular disease  
20  
21 339 increased in both neighborhoods due to aging of the samples, by 83% from 1,955 per 100,000 in  
22  
23 340 Flushing and by 29% from 1,576 per 100,000 in Sunset Park. The OR for cardiovascular disease  
24  
25 341 diagnoses in Flushing relative to Sunset Park in this age group was 1.45 (95% CI = 1.30, 1.62).  
26  
27 342 For 45-64-year-olds, , the crude prevalence increased by 33% from 9,934 per 100,000 in  
28  
29 343 Flushing and 19% from 9,073 per 100,000 in Sunset Park. For this age group, the OR was 1.15  
30  
31 344 (95% CI = 1.07, 1.25). Substance use disorder only increased significantly for the 45-64 age  
32  
33 345 group in Flushing relative to Sunset Park (OR =1.24, 95% CI=1.07, 1.44).

34  
35 346 Figure 2 shows the monthly prevalence of insomnia and cardiovascular disease diagnoses  
36  
37 347 for the 45-64 age group. Age is measured at the beginning of each period, January 1, 2009 for  
38  
39 348 the pre-period and January 1, 2013 for the post period. The numerator is the number of unique  
40  
41 349 individuals with one or more diagnosis from inpatient, emergency room or outpatient claims and  
42  
43 350 the denominator is the number of Medicaid-enrolled patients. The trends of both conditions  
44  
45 351 increased throughout the study periods, because people are getting older, but Flushing showed  
46  
47 352 increases that were larger in magnitude in the post period relative to Sunset Park.  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

1  
2  
3 353 Results for other conditions were more mixed. Clinical depression diagnoses increased  
4  
5 354 for the two older age groups (ages 18-44 OR = 1.12, 95% CI = 1.02, 1.24; ages 45-64 OR = 1.20,  
6  
7 355 95% CI = 1.08, 1.33). Broader mood disorder diagnoses, however, only showed statistically  
8  
9  
10 356 significant increases for the 45-65 age group (OR = 1.10, 95% CI = 1.00, 1.20). For 5-17-year-  
11  
12 357 olds, developmental disorder diagnoses significantly decreased (OR=0.80, 95% CI = 0.66, 0.97)  
13  
14  
15 358 in Flushing relative to Sunset Park after the implementation of TNNIS.  
16  
17 359

## 19 360 Discussion

21 361 We find that increases in airplane noise at DNL levels greater than 55 were associated  
22  
23 362 with increases in insomnia, depression, substance abuse, and cardiovascular disease across most  
24  
25 363 age groups. These diagnoses are generally consistent with our *a priori* hypotheses regarding the  
26  
27 364 relationship between exposure to airplane noise and health.<sup>3,6,8,9,12,13,30,31</sup> Specifically, airplane  
28  
29 365 noise may produce disruptions in sleep and psychological stress, thereby producing  
30  
31 366 neuroendocrine disruptions that lead to mental health disorders and cardiovascular disease.  
32  
33

34  
35 367 ~~Our study was subject to a number of limitations. First, the health effects in a~~  
36  
37 368 ~~predominantly Chinese-American population may not be generalizable to other populations.~~  
38  
39 369 ~~Chinese-Americans in New York City are unusually healthy.<sup>37</sup> Medicaid data also present unique~~  
40  
41 370 ~~challenges. Participants can enter and exit the program, for example. If there are more~~  
42  
43 371 ~~participants exiting the program in one area relative to another, the observed outcomes will also~~  
44  
45 372 ~~change. We addressed this problem by adjusting for the months a participant was enrolled in~~  
46  
47 373 ~~Medicaid within a calendar year, but noise may nevertheless be introduced in the analysis.~~  
48  
49 374 ~~Finally, it is possible that the change in neighborhood composition over time differed before and~~  
50  
51 375 ~~after the implementation of year-round TNNIS departures in Flushing relative to Sunset Park.~~  
52  
53  
54  
55  
56  
57  
58  
59  
60



376 ~~However, we did not observe any trends in the available data that suggested this was the case,~~  
377 ~~and there were no major events in 2012 that clearly serve as an alternative causal factor for either~~  
378 ~~the primary or unexpected findings.~~

379 The biological pathways through which airplane noise impacts health have been  
380 elucidated.<sup>9-14</sup> Numerous associational studies suggest that airplane noise produces real-world  
381 health impacts, and experimental animal models show a wide range of health impacts associated  
382 with noise-induced stress as well.<sup>3-9,11-13,15-18,32</sup> Our study adds quasi-experimental evidence in  
383 humans to this substantial body of research showing that increasing airplane noise will have  
384 detrimental health impacts on communities surrounding airports. The magnitude of our findings  
385 is not strictly comparable to those in associational studies because lagged health effects (e.g., the  
386 time required for psychological stress to manifest as cardiovascular disease) tend to mute the  
387 measured impacts.

388 Nevertheless, the magnitude of the impact of airplane noise on the health outcomes we  
389 observe are generally in line with associational studies previous work. For instance, an earlier  
390 analysis of associational studies of the health impact of aircraft noise in Flushing, NY estimated  
391 that aircraft noise would produce a weighted increase in cardiovascular disease of 14% (RR =  
392 1.14, 95% CI = 1.08, 1.22) and a weighted increase in anxiety of 79% (RR = 1.79, 95% CI = 1.0-  
393 3.1).<sup>11,24</sup> We observe an odds ratio for cardiovascular disease among 18-64-year-olds in the range  
394 of 1.12 to 1.40. While the studies examine incident cardiovascular disease and we measure both  
395 incident and prevalent cardiovascular disease, it is reasonable to assume that the OR we estimate  
396 does not greatly overestimate the adjusted RR computed using associational studies.<sup>37</sup>

397 In the international literature, the self-reported annoyance, health, health-related quality  
398 of life, and cardiovascular disease rates for those who live close to airports is significantly lower

1  
2  
3 399 than for matched individuals living in quieter areas.<sup>38-40</sup> In this literature, these latter findings are  
4  
5 400 particularly true for noise-sensitive individuals.<sup>38,39</sup> This suggests that self-selection by noise  
6  
7 401 may mute previously observed effects in ecological studies, which control for socio-economic  
8  
9 402 status but not always noise sensitivity. One strength of our study is that the change in aircraft  
10  
11 403 noise was exogenous and moving out of a neighborhood requires time and effort.

12  
13  
14 404 Our study was subject to a number of limitations. First, the health effects in a  
15  
16 405 predominantly Chinese-American population may not be generalizable to other populations.  
17  
18 406 Chinese-Americans in New York City are unusually healthy.<sup>41</sup> Medicaid data also present unique  
19  
20 407 challenges. Participants can enter and exit the program, for example. If there are more  
21  
22 408 participants exiting the program in one area relative to another, the observed outcomes will also  
23  
24 409 change. We addressed this problem by adjusting for the months a participant was enrolled in  
25  
26 410 Medicaid within a calendar year.

27  
28  
29 411 Next, we use DNL as a measure. Frequency of noise exposure may be superior at  
30  
31 412 predicting health outcomes, but frequency data were not available. Finally, it is possible that the  
32  
33 413 change in neighborhood composition over time differed before and after the implementation of  
34  
35 414 year-round TNNIS departures in Flushing relative to Sunset Park. However, we did not observe  
36  
37 415 any trends in the available data that suggested this was the case, and there were no major events  
38  
39 416 in 2012 that clearly serve as an alternative causal factor for either the primary or unexpected  
40  
41 417 findings. Moreover, our findings apply only to the zip codes directly under the DNL zones  
42  
43 418 defined by our analysis.

44  
45  
46  
47  
48  
49 419 Cost-effectiveness analyses (based partly on earlier associational data) show that the  
50  
51 420 benefits of noise-mitigation strategies (reduced illness and discomfort) tend to outweigh the  
52  
53 421 costs.<sup>24,42</sup> Given that these earlier studies did not include the full range of health outcomes that  
54  
55  
56  
57  
58  
59  
60

422 we measure here, it is likely that these studies understate the already substantial benefits of  
423 aircraft noise mitigation strategies.

424 Much more comprehensive quasi-experimental and economic analyses are required to  
425 determine the extent to which policymakers may wish to act. The costliest options—building  
426 airports far from populated areas and providing high speed transit and freeways—can increase  
427 the cost of mitigation by billions of dollars.

### 429 **Research Ethics Approval**

430 This study is approved by the Institutional Review ~~Board~~Board at New York University  
431 Washington Square under IRB-FY2016-1101.

### 432 **Acknowledgements**

433 The authors thank NYU Health Evaluation and Analytics Lab and the New York State  
434 Department of Health for making the Medicaid claims data available and gratefully acknowledge  
435 the funding for this research from the Robert Wood Johnson Foundation's Policies for Action  
436 program.

437 Disclaimer: The views and opinions expressed in this article are those of the authors and  
438 do not necessarily reflect the official policy or position of the New York State Department of  
439 Health. Example of analysis performed within this article are only examples. They should not be  
440 utilized in real-world analytic products.

Table 1 – Demographics characteristics and outcome prevalence and rates for Flushing, New York and Sunset Park, New York before (earlier than 2012) and after (after 2013) airplane noise increased in Flushing, New York.

Baseline Characteristics	Pre-Period: 2009-2011						Post-Period: 2012-2015					
	Age 5 -17		Age 18-44		Age 45-64		Age 5-17		Age 18-44		Age 45-64	
	Flushing	Sunset Park	Flushing	Sunset Park	Flushing	Sunset Park	Flushing	Sunset Park	Flushing	Sunset Park	Flushing	Sunset Park
Demographics												
Total N	20,120	21,597	57,089	52,016	36,472	18,681	24,552	26,009	76,278	60,774	50,806	24,421
Age (Mean)	11.69	11.12	31.07	29.86	53.44	53.29	11.43	10.71	30.95	30.65	53.99	54.22
Age (STD)	3.94	3.92	8.19	7.54	5.59	5.5	3.94	3.87	7.84	7.5	5.44	5.57
Female (%)	48%	48%	58%	57%	54%	51%	48%	48%	56%	56%	54%	52%
Asian (%)	50%	46%	60%	62%	63%	60%	52%	47%	59%	59%	63%	62%
Black (%)	6%	2%	5%	1%	4%	2%	4%	1%	3%	1%	3%	1%
Hispanic (%)	17%	15%	11%	9%	11%	11%	14%	14%	7%	7%	7%	8%
White (%)	11%	24%	10%	15%	10%	14%	10%	24%	8%	14%	8%	12%
Other (%)	5%	3%	5%	4%	6%	7%	5%	3%	4%	3%	5%	6%
Unknown (%)	12%	11%	10%	8%	6%	5%	14%	12%	20%	16%	13%	11%
Average months on Medicaid per year	9	10	8	8	9	10	9	10	8	9	9	9
Total Medicaid Spending per Person per Year	\$1,911	\$1,904	\$3,818	\$3,954	\$6,754	\$6,076	\$1,783	\$1,972	\$3,398	\$3,114	\$6,520	\$6,115
Prevalence per 100,000												
Insomnia	398	477	4,208	6,096	8,036	9,143	623	450	4,755	5,573	11,034	10,843
Cardiovascular disease*	NA*	NA*	1,955	1,576	9,934	9,073	NA*	NA*	3,575	2,540	13,260	10,786

Downloaded from <http://bmjopen.bmj.com/> on 20 April 2024 by guest. Protected by copyright.

1	Alcohol Use Disorder	NA*	NA*	2,114	1,173	2,470	2,184	NA*	NA*	2,264	1,998	2,870	2,199
2	Substance Use Disorder	NA*	NA*	2,265	1,517	1,799	2,098	NA*	NA*	3,799	2,926	4,250	4,058
3	Anxiety	NA*	NA*	5,124	4,639	6,279	6,279	NA*	NA*	5,726	5,055	7,537	7,416
4	Depression	NA*	NA*	3,782	2,874	6,007	5,867	NA*	NA*	3,191	2,722	5,637	4,656
5	Mood Disorder	NA*	NA*	6,371	4,900	9,399	8,891	NA*	NA*	5,607	4,410	8,375	7,297
6	Disorders diagnosed	1,983	1,394	289	212	170	112	2,480	2,219	307	214	163	188
7	young												
8													
9													
10													
11													
12													
13													
14	Emergency Department	328	216	335	257	288	237	375	188	360	270	332	216
15	Emergency Department	13	20	26	21	31	39	20	7	32	19	45	36
16	(SM)												
17	Inpatient Stays	70	53	267	319	299	245	60	49	231	301	234	190
18	Inpatient Stays (SM)	14	7	43	24	45	32	11	5	37	20	37	21
19													
20													
21													
22													
23													
24	Total Outpatient	3.4	4.1	4.1	4.6	6.7	7.3	3.9	5.2	4.5	3.9	7.6	8.2
25	Outpatient (SM)	0.2	0.2	0.3	0.2	0.4	0.3	0.3	0.3	0.3	0.3	0.5	0.4
26													
27													

Visits per 1,000 per year

Outpatient visits per person per year

\* We adopted a longer follow-up period 2008-2011(pre-implementation) and 2013-2016 (TNNIS implementation) to allow for lag time in disease manifestation

0.1136/bmjopen.2023.057209 on 2 May 2022. Downloaded from http://bmjopen.bmj.com/ on April 18, 2024 by guest. Protected by copyright.

Table 2 – Model Results and 95% Confidence Intervals

	Rate Ratios from the Difference in Difference Poisson Model		
	Age 5 - 17	Age 18 - 44	Age 45 - 64
Inpatient Visits	0.92 (0.83, 1.03)	1.05 (1.02, 1.08)	0.93 (0.88, 0.97)
Emergency Department Visits	1.31 (1.24, 1.37)	1.45 (1.41, 1.49)	1.16 (1.11, 1.21)
Outpatient Visits	0.86 (0.85, 0.87)	1.04 (1.04, 1.05)	0.92 (0.92, 0.93)
Pharmacy Claims	0.94 (0.94, 0.95)	1.06 (1.06, 1.06)	0.93 (0.92, 0.93)
	Rate Ratios from the Difference in Difference Poisson Model Substance Use and Mental Health Related		
	Age 5 - 17	Age 18 - 44	Age 45 - 64
Inpatient Visits	NA*	1.11 (1.01, 1.22)	1.19 (1.04, 1.36)
Emergency Department Visits	4.11 (3.28, 5.16)	2.46 (2.20, 2.76)	1.48 (1.31, 1.67)
Outpatient Visits	1.12 (1.09, 1.16)	0.93 (0.92, 0.95)	0.87 (0.85, 0.89)
	Odds Ratios from the Difference in Difference Logistic Model		
	Age 5 - 17	Age 18 - 44	Age 45 - 64
Insomnia	1.64 (1.12, 2.39)	1.17 (1.09, 1.26)	1.18 (1.09, 1.28)
Cardiovascular Disease**	NA*	1.45 (1.30, 1.62)	1.15 (1.07, 1.25)
Alcohol Use Disorder	NA*	0.97 (0.86, 1.11)	1.16 (0.99, 1.35)
Substance Use Disorder	NA*	0.92 (0.83, 1.03)	1.24 (1.07, 1.44)
Depression	NA*	1.12 (1.02, 1.24)	1.20 (1.08, 1.33)
Anxiety	NA*	1.02 (0.95, 1.10)	1.01 (0.92, 1.11)
Mood Disorder	NA*	1.03 (0.95, 1.10)	1.10 (1.00, 1.20)
Disorders diagnosed young	0.80 (0.66, 0.97)	0.99 (0.72, 1.37)	0.56 (0.31, 1.04)

1  
2  
3  
4  
5 \*These diseases and conditions are rare or difficult to diagnose in children.  
6

7 \*\*We adopted a longer follow-up period 2008-2011(pre-implementation) and 2013-2016  
8

9 (TNNIS implementation) to allow for lag time in disease manifestation  
10  
11  
12  
13

14 Figure 1 – Intensity of noise exposure over a 24-hour period by census tract. The day night level  
15 (DNL) 55 corridor (outer line) is demarcated separately from the DNL 60 corridor (inner line).  
16  
17  
18

19  
20  
21 Figure 2 – Prevalence of insomnia and cardiovascular disease diagnoses per 100,000 among 45-  
22  
23  
24 64 age group  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

1. Nolan M. Fundamentals of air traffic control: Cengage learning; 2010.
2. Prevot T, Homola J, Mercer J, Mainini M, Cabrall C. Initial evaluation of NextGen air/ground operations with ground-based automated separation assurance. *ATM2009, Napa, California* 2009.
3. Zaharna M, Guilleminault C. Sleep, noise and health: review. *Noise and Health* 2010; **12**(47): 64.
4. Clark C, Stansfeld SA. The effect of transportation noise on health and cognitive development: A review of recent evidence. *Int J Comp Psychol* 2007; **20**(2).
5. Stansfeld S, Haines M, Burr M, Berry B, Lercher P. A review of environmental noise and mental health. *Noise and Health* 2000; **2**(8): 1.
6. Passchier-Vermeer W, Passchier WF. Noise exposure and public health. *Environ Health Perspect* 2000; **108**(Suppl 1): 123.
7. Morrell S, Taylor R, Lyle D. A review of health effects of aircraft noise. *Aust N Z J Public Health* 1997; **21**(2): 221-36.
8. Beutel ME, Jünger C, Klein EM, et al. Noise annoyance is associated with depression and anxiety in the general population-the contribution of aircraft noise. *PLoS One* 2016; **11**(5).
9. Münzel T, Schmidt FP, Steven S, Herzog J, Daiber A, Sørensen M. Environmental noise and the cardiovascular system. *J Am Coll Cardiol* 2018; **71**(6): 688-97.
10. Schmidt FP, Basner M, Kröger G, et al. Effect of nighttime aircraft noise exposure on endothelial function and stress hormone release in healthy adults. *Eur Heart J* 2013; **34**(45): 3508-14.
11. Babisch W. Cardiovascular effects of noise. *Noise and Health* 2011; **13**(52): 201.
12. Maschke C, Harder J, Ising H, Hecht K, Thierfelder W. Stress hormone changes in persons exposed to simulated night noise. *Noise and health* 2002; **5**(17): 35.
13. Melamed S, Bruhis S. The effects of chronic industrial noise exposure on urinary cortisol, fatigue, and irritability: a controlled field experiment. *J Occup Environ Med* 1996; **38**(3): 252-6.
14. McEwen BS. Protective and damaging effects of stress mediators. *N Engl J Med* 1998; **338**(3): 171-9.
15. Basner M, Babisch W, Davis A, et al. Auditory and non-auditory effects of noise on health. *The lancet* 2014; **383**(9925): 1325-32.
16. Perron S, Tétreault L-F, King N, Plante C, Smargiassi A. Review of the effect of aircraft noise on sleep disturbance in adults. *Noise and health* 2012; **14**(57): 58.
17. Xue L, Zhang D, Wang T, Shou X. Effects of high frequency noise on female rat's multi-organ histology. *Noise and Health* 2014; **16**(71): 213.
18. Ising H, Babisch W, Kruppa B. Noise-induced endocrine effects and cardiovascular risk. *Noise and health* 1999; **1**(4): 37.
19. Cohen JP, Coughlin CC. Changing noise levels and housing prices near the Atlanta airport. *Growth and Change* 2009; **40**(2): 287-313.
20. Cohen JP, Coughlin CC. Spatial hedonic models of airport noise, proximity, and housing prices. *Journal of Regional Science* 2008; **48**(5): 859-78.
21. Kawachi I, Adler NE, Dow WH. Money, schooling, and health: Mechanisms and causal evidence. *Ann N Y Acad Sci* 2010; **1186**: 56-68.
22. Muennig P, Franks P, Jia H, Lubetkin E, Gold MR. The income-associated burden of disease in the United States. *Soc Sci Med* 2005; **61**(9): 2018-26.



- 1  
2  
3 23. Boes S, Nüesch S, Stillman S. Aircraft Noise, Health, And Residential Sorting: Evidence  
4 From Two Quasi-Experiments. *Health Econ* 2013; **22**(9): 1037-51.
- 5 24. Zafari Z, Jiao B, Will B, Li S, Muennig PA. The trade-off between optimizing flight  
6 patterns and human health: a case study of aircraft noise in Queens, NY, USA. *Int J Environ Res*  
7 *Public Health* 2018; **15**(8).
- 8 25. Nüesch S. Aircraft noise, health, and residential sorting: evidence from two quasi-  
9 experiments. *Standardization news: SN* 2012; (6744).
- 10 26. Eagan ME, Hanrahan R, Miller R. Implementing performance based navigation  
11 procedures at US airport: Improving community noise exposure. INTER-NOISE and NOISE-CON  
12 Congress and Conference Proceedings; 2013: Institute of Noise Control Engineering; 2013. p.  
13 1577-86.
- 14 27. Buckley C. A rumble in the sky and grumbles below. Accessed 11/17/2020. Available  
15 online at: [https://www.nytimes.com/2013/08/26/nyregion/planes-roar-from-above-creates-a-](https://www.nytimes.com/2013/08/26/nyregion/planes-roar-from-above-creates-a-rumble-on-the-ground.html)  
16 [rumble-on-the-ground.html](https://www.nytimes.com/2013/08/26/nyregion/planes-roar-from-above-creates-a-rumble-on-the-ground.html).
- 17 28. Mathematica. (2013). Medicaid Managed Care and Integrated Delivery Systems:  
18 Technical Assistance to States and Strengthening Federal Oversight. Washington, DC:  
19 Mathematica Policy Research.
- 20 29. Bhaskar S, Hemavathy D, Prasad S. Prevalence of chronic insomnia in adult patients and  
21 its correlation with medical comorbidities. *J Family Med Prim Care*. 2016;5(4):780-784.  
22 doi:10.4103/2249-4863.201153.
- 23 30. Bernstein GA, Borchardt CM. Anxiety disorders of childhood and adolescence: A critical  
24 review. *J Am Acad Child Adolesc Psychiatry* 1991; **30**(4): 519-32.
- 25 31. Mensah GA, Brown DW. An overview of cardiovascular disease burden in the United  
26 States. *Health Aff (Millwood)* 2007; **26**(1): 38-48.
- 27 32. Halonen JI, Hansell AL, Gulliver J, et al. Road traffic noise is associated with increased  
28 cardiovascular morbidity and mortality and all-cause mortality in London. *Eur Heart J* 2015;  
29 **36**(39): 2653-61.
- 30 33. Technical Advisory Committee (TAC) meeting 8. Available online at:  
31 [http://www.panynjpart150.com/AdminPages/GetProjectFile.asp?a=LGA&f=LGA%20TAC%20Me-](http://www.panynjpart150.com/AdminPages/GetProjectFile.asp?a=LGA&f=LGA%20TAC%20Meeting%20No.%208%20Summary,%20August%2016,%202016.pdf)  
32 [eting%20No.%208%20Summary,%20August%2016,%202016.pdf](http://www.panynjpart150.com/AdminPages/GetProjectFile.asp?a=LGA&f=LGA%20TAC%20Meeting%20No.%208%20Summary,%20August%2016,%202016.pdf) Accessed 6/17/2020.
- 33 34. Flight Aware. Live flight tracking. Available online at: <https://flightaware.com>. Accessed  
34 6/20/2020.
- 35 35. NYC Health. Community Health Profile: Sunset Park. Available online at:  
36 <https://www1.nyc.gov/assets/doh/downloads/pdf/data/2018chp-bk7.pdf> Accessed 3/2/2020.
- 37 36. NYC Health. Community Health Profile: Flushing and Whitestone. Available online at:  
38 <https://www1.nyc.gov/assets/doh/downloads/pdf/data/2018chp-qn7.pdf> Accessed 3/2/2020.
- 39 37. Knol MJ, Le Cessie S, Algra A, Vandenbroucke JP, Groenwold RH. Overestimation of risk  
40 ratios by odds ratios in trials and cohort studies: alternatives to logistic regression. *CMAJ*.  
41 2012;184(8):895-899. doi:10.1503/cmaj.101715.
- 42 38. Welch D, Shepherd D, McBride D. Health-related quality of life is impacted by proximity  
43 to an airport in noise sensitive people. INTER-NOISE and NOISE-CON Congress and Conference  
44 Proceedings; 2016: Institute of Noise Control Engineering; 2016. p. 5003-10.
- 45 39. Shepherd D, McBride D, Dirks KN, Welch D. Annoyance and health-related quality of life:  
46 a cross-sectional study involving two noise sources. *J Environ Prot (Irvine, Calif)* 2014; **2014**.
- 47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

- 1  
2  
3 40. Bronzaft AL, Dee Ahern K, McGinn R, O'Connor J, Savino B. Aircraft noise: A potential  
4 health hazard. *Environ Behav* 1998; **30**(1): 101-13.  
5  
6 41. Muennig P, Wang Y, Jacobowski A. The health of immigrants to New York City from  
7 Mainland China: Evidence from the New York Health Examination and Nutrition Survey. *Journal*  
8 *of Immigrant and Refugee Studies* 2012; **10**: 1-7.  
9  
10 42. Jiao B, Zafari Z, Will B, Ruggeri K, Li S, Muennig P. The Cost-Effectiveness of Lowering  
11 Permissible Noise Levels Around US Airports. *Int J Environ Res Public Health* 2017; **14**(12): 1497.  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

For peer review only

STROBE Statement—Checklist of items that should be included in reports of *cohort studies*

	Item No	Recommendation	Page No
<b>Title and abstract</b>	1	(a) Indicate the study's design with a commonly used term in the title or the abstract (b) Provide in the abstract an informative and balanced summary of what was done and what was found	1
<b>Introduction</b>			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	2-3
Objectives	3	State specific objectives, including any prespecified hypotheses	4
<b>Methods</b>			
Study design	4	Present key elements of study design early in the paper	4-6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4-6
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up (b) For matched studies, give matching criteria and number of exposed and unexposed	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4
Bias	9	Describe any efforts to address potential sources of bias	7, 11
Study size	10	Explain how the study size was arrived at	8, 14- 15
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5-7
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding (b) Describe any methods used to examine subgroups and interactions (c) Explain how missing data were addressed (d) If applicable, explain how loss to follow-up was addressed (e) Describe any sensitivity analyses	7-8
<b>Results</b>			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed (b) Give reasons for non-participation at each stage (c) Consider use of a flow diagram	8, 14- 15
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders (b) Indicate number of participants with missing data for each variable of interest (c) Summarise follow-up time (eg, average and total amount)	8,14- 15
Outcome data	15*	Report numbers of outcome events or summary measures over time	8-11, 14

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

For peer review only

1	Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	8-11, 14-19
2			(b) Report category boundaries when continuous variables were categorized	
3			(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
4				
5				
6				
7				
8				
9	Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9
10				
11	<b>Discussion</b>			
12				
13	Key results	18	Summarise key results with reference to study objectives	11
14	Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	11-12
15				
16	Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12-13
17				
18				
19				
20	Generalisability	21	Discuss the generalisability (external validity) of the study results	11
21				
22	<b>Other information</b>			
23	Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Supplemental material, acknowledgements
24				
25				
26				

\*Give information separately for exposed and unexposed groups.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at <http://www.strobe-statement.org>.

# BMJ Open

## The impact of airplane noise on mental and physical health. A quasi-experimental analysis.

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2021-057209.R2
Article Type:	Original research
Date Submitted by the Author:	16-Feb-2022
Complete List of Authors:	Wang, Scarlett; New York University, Wagner School of Public Service Glied, Sherry; New York University, Wagner School of Public Service Williams, Sharifa; Nathan S Kline Institute for Psychiatric Research, Center for Research on Cultural and Structural Equity in Behavioral Health Will, Brian; Queens Quiet Skies Muennig, Peter; Columbia University Mailman School of Public Health, Global Research Analytics for Population Health
<b>Primary Subject Heading</b>:	Public health
Secondary Subject Heading:	Epidemiology
Keywords:	MENTAL HEALTH, EPIDEMIOLOGY, Cardiac Epidemiology < CARDIOLOGY, PUBLIC HEALTH

SCHOLARONE™  
Manuscripts



I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our [licence](#).

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which [Creative Commons](#) licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

- 1  
2  
3 1 Title Page  
4  
5 2 The impact of airplane noise on mental and physical health. A quasi-experimental analysis.  
6  
7

8 3  
9  
10 4 Scarlett Sijia Wang, MPH. MS  
11 5 Corresponding author.  
12 6 Associate Research Scientist  
13 7 Robert F. Wagner Graduate School of Public Service  
14 8 Email: [scarlett@nyu.edu](mailto:scarlett@nyu.edu)  
15 9 New York University  
16 10 295 Lafayette St.  
17 11 Second Floor  
18 12 New York, NY 10012

19 13  
20 14 Sherry Glied, PHD  
21 15 Dean  
22 16 Robert F. Wagner Graduate School of Public Service  
23 17 New York University  
24 18 295 Lafayette St.  
25 19 Second Floor  
26 20 New York, NY 10012

27 21  
28 22 Sharifa Z. Williams, DrPH, MS  
29 23 Research Scientist  
30 24 Nathan S. Kline Institute for Psychiatric Research  
31 25 Center for Research on Cultural and Structural Equity in Behavioral Health  
32 26 Division of Social Solutions and Services Research  
33 27 140 Old Orangeburg Road, Bldg. 35,  
34 28 Orangeburg, NY 10962-1159

35 29  
36 30 Brian Will  
37 31 (Mr. Will passed away prior to the submission of the manuscript.)  
38 32

39 33 Peter Muennig, MD, MPH  
40 34 Professor  
41 35 Mailman School of Public Health  
42 36 Columbia University  
43 37 722 West 168th St.  
44 38 ARB 4th Floor  
45 39 New York, NY 10032  
46 40

47  
48  
49  
50  
51  
52  
53  
54 41  
55  
56  
57  
58  
59  
60



43 The impact of airplane noise on mental and physical health: a quasi-experimental analysis.

44 **Abstract**

45 **Objectives.** Historically, departures at New York City's La Guardia airport (LGA) flew over a  
46 large sports complex within a park. During the US Open tennis games, flights were diverted to  
47 fly over a heavily populated foreign-born neighborhood for roughly two weeks out of the year so  
48 that the tennis match was not disturbed (the "TNNIS" departure). In 2012, the use of the TNNIS  
49 departure became year-round to better optimize flight patterns around the metropolitan area.

50 **Methods.** We exploited exogenously-induced spatial and temporal variation in flight patterns to  
51 examine difference-in-difference effects of this new exposure to aircraft noise on the health of  
52 individual residents in the community relative to individuals residing within a demographically  
53 similar community that was not impacted. We used individual-level Medicaid records, focusing  
54 on conditions associated with noise: sleep disturbance, psychological stress, mental illness,  
55 substance use, and cardiovascular disease.

56 **Results.** We found that increased exposure to airplane noise was associated with a significant  
57 increase in insomnia across all age groups, but particularly in children ages 5-17 (OR = 1.64).  
58 Cardiovascular disease increased significantly both among 18-44-year-old (OR = 1.45) and 45-  
59 64-year-old Medicaid recipients (OR = 1.15). Substance use and mental health-related  
60 emergency department visits also increased. For ages 5-17 RR= 4.11 (95% CI= 3.28, 5.16); for  
61 ages 18-44 RR = 2.46 (95% CI = 2.20, 2.76); and for ages 45-64, RR = 1.48 (95% CI = 1.31,  
62 1.67).

63 **Conclusion.** We find that increased exposure to airplane noise was associated with an  
64 increase in diagnosis of cardiovascular disease, substance use/mental health emergencies, and  
65 insomnia among local residents.

## 67 **Strengths and limitations**

- 68 1. We used a quasi-experimental design to study before and after impacts of a flight pattern  
69 change in two matched zip code clusters within New York City (a difference-in-  
70 difference design).
- 71 2. We used a large health insurance claims database that allowed us to capture diagnoses for  
72 most residents in both impacted and unimpacted zip code clusters.
- 73 3. Despite the difference-in-difference design, it is possible that participants self-segregated  
74 after the increase in aircraft noise or that other unmeasured factors influenced the  
75 observed outcomes.
- 76 4. We were unable to compute a dose-response relationship due to the use of aggregated  
77 noise data.
- 78 5. We find that a sudden and dramatic change in aircraft noise was associated with  
79 increased diagnoses of insomnia, cardiovascular disease, substance abuse, and mental  
80 illness.

1  
2  
3 84 La Guardia's airspace originally utilized departures over areas that were less populated,  
4  
5 85 such as waterways, parks, or areas with warehouses or manufacturing.<sup>1</sup> However, as air traffic  
6  
7 86 increased over time, the airspace used for traditional routes of arrivals and departures became  
8  
9  
10 87 crowded and conflicted with that of a nearby airport, John F. Kennedy.<sup>2</sup> As with La Guardia,  
11  
12 88 other airports sometimes manage increases in traffic by optimizing flight patterns with less  
13  
14 89 regard for the populations on the ground.<sup>2</sup> Almost invariably, these new flight patterns require  
15  
16 90 routing aircraft over populated areas that were not previously exposed to aircraft noise.

17  
18  
19 91 Noise, and aircraft noise in particular, is associated with a number of health problems,  
20  
21 92 particularly sleep disturbances, mental illness, and substance use.<sup>3-8</sup> The sleep disturbances and  
22  
23 93 psychological stress associated with aircraft noise are, in turn, thought to produce a cascade of  
24  
25 94 biological effects that result in premature aging via endocrinologic changes.<sup>9-14</sup>

26  
27  
28 95 Noise is thought to produce stress by activating the central nervous system and by  
29  
30 96 interfering with sleep.<sup>3,6,8,15,16</sup> This stress produces predictable changes in biochemical pathways  
31  
32 97 in human and animal studies that accelerate the rate of aging.<sup>14,17,18</sup> This accelerated aging  
33  
34 98 process has been linked to the premature onset of age-related diseases, including cardiovascular  
35  
36 99 disease.<sup>9,19,20</sup>

37  
38  
39  
40 100 While the pathways linking poor sleep and psychological stress to premature aging and  
41  
42 101 chronic disease are understood, few studies have experimentally examined interventions that  
43  
44 102 alter noise exposure in human populations.<sup>21</sup> Most of our knowledge about the health impact of  
45  
46 103 aircraft noise in humans is based upon associational studies.<sup>7</sup> These studies suffer from a number  
47  
48 104 of limitations. On one hand, people who live near airports may self-select, such that those who  
49  
50 105 are less sensitive to noise can take advantage of lower home prices on purchases or rentals for  
51  
52 106 homes.<sup>13,19,20</sup> On the other hand, those who live near airports tend to have lower than average  
53  
54  
55  
56  
57  
58  
59  
60

1  
2  
3 107 income, a major risk factor for premature disease and death.<sup>19,22-24</sup> There is limited evidence  
4  
5 108 based of the impact of aircraft noise on premature aging and health based on experimental or  
6  
7  
8 109 quasi-experimental analysis.<sup>12,13,23,25</sup>  
9

10 110 Flight pattern changes afford a unique opportunity for studying the health impact of  
11  
12 111 aircraft noise in humans. In the past decade, flight patterns have shifted, and these shifts have  
13  
14 112 increasingly been accompanied by resident complaints.<sup>26</sup> As they do so, it becomes possible to  
15  
16 113 identify areas that are impacted by new aircraft noise. In general, the point of maximum noise  
17  
18 114 from an aircraft happens immediately after take-off as the aircraft is on full power. This is the for  
19  
20 115 the experimental group in our study.  
21  
22

23  
24 116 We conducted a longitudinal case/control study of one well-documented flight pattern  
25  
26 117 change in New York City. LaGuardia Airport is one of 3 major airports in the greater New York  
27  
28 118 City area. One of its departure patterns utilizes Flushing Meadows Park, a route known as the  
29  
30 119 "Whitestone Climb."<sup>24</sup> Because it is over greenspace, the Whitestone Climb has little impact on  
31  
32 120 humans living in nearby dwellings. However, this park is also the location of the US Open  
33  
34 121 Tennis match. During games, a seldom-used departure route called the "Flushing Climb" (now  
35  
36 122 called TNNIS) was used so that the tennis games were not disturbed by aircraft noise. The  
37  
38 123 TNNIS climb routes aircraft over densely populated Flushing, Queens, greatly increasing the  
39  
40 124 exposure of residents to noise on the ground.<sup>24</sup>  
41  
42  
43

44 125 A Freedom of Information Act (FOIA) request by a local group opposed to airplane noise  
45  
46 126 in Queens demonstrated that flight patterns using the TNNIS climb have increased to year-round  
47  
48 127 use since 2012. Before that time, the use of the TNNIS climb was rare outside of the US Open.<sup>27</sup>  
49  
50

51 128 Previous work found that the year-round use of the TNNIS climb was costly, both in  
52  
53 129 terms of money and lives.<sup>24</sup> However, this economic analysis was primarily based on  
54  
55  
56  
57  
58  
59

1  
2  
3 130 associational data. Using data on flight patterns over Flushing obtained using the FOIA as well  
4  
5 131 as Medicaid utilization data, we conducted a quasi-experimental analysis of the health impacts of  
6  
7 132 the airplane noise associated with this new route. In the United States, Medicaid is a safety-net  
8  
9  
10 133 health insurance program for the low-income population. In New York State, over five million  
11  
12 134 low-income individuals enrolled in the Medicaid program in 2012.

## 135 **Methods**

### 136 Data

137 The data used in this study are New York City Medicaid claims prepared by the New  
138 York University Health Evaluation and Analytics Lab. The data include Medicaid member  
139 demographic information, address history, eligibility, medical services, and diagnostic  
140 information. The database consists of Medicaid fee for service claims and managed care  
141 encounters; both are comparable in quality.<sup>28</sup>

### 142 *A priori* specifications and hypotheses

143 We hypothesized that exposure to airplane noise would increase health care utilization,  
144 insomnia, mood disorder, anxiety, depression, and cardiovascular disease depending upon the  
145 age group.<sup>3,6,8,9,12,13</sup> Specifically, exposure to airplane noise would produce sleep disorders across  
146 all age groups,<sup>29</sup> would lead to emotional or behavioral disturbances including substance abuse,  
147 mood disorder, depression, and developmental disorders among young adults aged 18 to 45 years  
148 who tend to be more at risk of these stress-associated disorders,<sup>30</sup> and would produce or  
149 exacerbate cardiovascular disease among older adults aged 45 and over when heart disease  
150 begins to increase in prevalence.<sup>31</sup> Noise studies suggest wide-ranging  
151 psychoneuroendocrinological effects (allostatic load) producing hypertension, hyperglycemia,  
152 and hypercholesterolemia.<sup>3,6,8,9,12,13,30,31</sup> These biological changes are linked to cardiovascular

1  
2  
3 153 disease, a correlate of exposure to airplane noise as well as other forms of nighttime

4  
5 154 noise.<sup>7,10,11,32</sup>

## 6 7 8 155 Study Design

9  
10 156 We used individual-level data at the member-cohort level for the analysis. We selected  
11  
12 157 samples of Medicaid members residing in each of the two neighborhoods at two points in time.  
13  
14 158 The pre-cohort was defined as Medicaid recipients living in the study neighborhoods between  
15  
16 159 2009-2011 (pre cohort) and 2013-2016 (post cohort). 64% of the Flushing pre cohort and 63% of  
17  
18 160 the Sunset Park pre cohort were also in the post cohort. We used the difference-in-difference  
19  
20 161 models to analyze the results.

## 21 22 23 24 162 Exposure

25  
26 163 To determine exposure, we used data extracted under a FOIA request for flight patterns  
27  
28 164 over Flushing, Queens, New York and from Part 150 Study Technical Advisory Committee  
29  
30 165 Meeting No. 8 documents.<sup>33</sup> These documents were derived from a 2014 study conducted and  
31  
32 166 funded by the Port Authority of NY & NJ (Port Authority) in partnership with the Federal  
33  
34 167 Aviation Administration (FAA). In these documents the Port Authority presents estimated noise  
35  
36 168 exposure in geographies surrounding La Guardia Airport. Exposure is quantified using the  
37  
38 169 Integrated Noise Model in DNL (day-night average sound level) units. We also visually  
39  
40 170 inspected changes in sound related to aircraft flight over sound monitors on the ground in  
41  
42 171 Flushing using Flight Aware, a publicly-available flight tracking website and visited the area.<sup>34</sup>  
43  
44 172 This was done to ensure that the estimates from the Port Authority had face validity.

45  
46  
47 173 These geographic regions or corridors were stratified according to intensity of noise  
48  
49 174 exposure over a 24-hour period. We divided census tracts into > 60 DNL, 55-60 DNL, and <55  
50  
51 175 DNL (Figure 1). We aggregated census tracts and for regions of Flushing, Queens with noise  
52  
53  
54  
55  
56  
57  
58  
59  
60

176 exposure levels of 55 DNL or greater after 2012.<sup>19</sup> These tracts after 2012 are therefore identified  
177 as the treatment condition in this quasi-experimental analysis.

178  
179 Figure 1 – Intensity of noise exposure over a 24-hour period by census tract. The day night level  
180 (DNL) 55 corridor (outer line) is demarcated separately from the DNL 60 corridor (inner line).

181 [insert figure 1 here]

182 Flushing, Queens is a vibrant, predominantly immigrant neighborhood.<sup>24</sup> It is  
183 increasingly populated by Asians immigrants, particularly those of Chinese descent. The English  
184 proficiency in 2018 was 49%, and the population was 54% Asian and 26% white. While the  
185 neighborhood ranked as one of the poorest, the rates of education are higher than average and the  
186 rates of crime, obesity, and hypertension are much lower than New York City as a whole.<sup>24</sup>

187 Sunset Park in Brooklyn, New York was identified as an appropriate control  
188 neighborhood as the neighborhood (1) did not experience a change in exposure to aircraft noise  
189 after 2012 when the TNNIS climb began frequent use, and (2) is similar to Flushing with respect  
190 to the distribution of sociodemographic and economic characteristics.<sup>35,36</sup> Like Flushing, Sunset  
191 Park is increasingly populated by those of Chinese descent with 32% of the population  
192 identifying as Asian and 23% identifying as white. About 48% of the residents were born outside  
193 of the United States and the English proficiency in 2018 was 51%.<sup>25</sup> Sunset Park also has high  
194 poverty rates with relatively low rates of crime, obesity, and hypertension, and high levels of  
195 education relative to New York City as a whole.<sup>24</sup> Census tracts in Sunset Park were matched to  
196 those identified in Flushing based on race, foreign-born status, and age distribution.

197 Key outcomes

1  
2  
3 198 We used International Classification for Disease revision (ICD-9 and ICD-10) codes as  
4  
5 199 well as Clinical Classifications Software (CCS) codes for diagnostic groups to identify the  
6  
7  
8 200 following conditions of interest: insomnia (ICD-9 = 3270, 78052 or ICD-10 = G470),  
9  
10 201 cardiovascular disease (CCS = 109 – 113), alcohol use disorder (CCS=660), substance use  
11  
12 202 disorder (CCS = 661), anxiety (CCS = 651), depression (ICD-9 = 311 or ICD-10 = F33), mood  
13  
14 203 disorder (CCS = 657), and disorders usually diagnosed in infancy, childhood adolescence (CCS  
15  
16 = 655), which includes autism, childhood emotional disorder, and separation anxiety.  
17  
18

19 205 We linked census tracts of Flushing and Sunset Park to geocoded Medicaid addresses. If  
20  
21 206 a recipient had a Medicaid-registered address within a given census tract, they were assigned to  
22  
23 207 that census tract. Participants were excluded if they had invalid addresses, dual Medicare status,  
24  
25 208 did not have a valid date of birth, or were not officially enrolled in Medicaid during the study  
26  
27 209 period (Table 1). Participant samples were then defined as Medicaid recipients in the period  
28  
29 210 2009-2011 (pre-implementation period) and 2013-2015 (the TNNIS use period) and who resided  
30  
31 211 within census tracts in Flushing and Sunset Park.  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60



Table 1 – Demographics characteristics and outcome prevalence and rates for Flushing, New York and Sunset Park, New York before (earlier than 2012) and after (after 2013) airplane noise increased in Flushing, New York.

Baseline Characteristics	Pre-Period: 2009-2011						Post-Period: 2012-2015					
	Age 5 -17		Age 18-44		Age 45-64		Age 5-17		Age 18-44		Age 45-64	
	Flushing	Sunset Park	Flushing	Sunset Park	Flushing	Sunset Park	Flushing	Sunset Park	Flushing	Sunset Park	Flushing	Sunset Park
Demographics												
Total N	20,120	21,597	57,089	52,016	36,472	18,681	24,552	26,009	76,278	60,774	50,806	24,421
Age (Mean)	11.69	11.12	31.07	29.86	53.44	53.29	11.43	10.71	30.95	30.65	53.99	54.22
Age (STD)	3.94	3.92	8.19	7.54	5.59	5.5	3.94	3.87	7.84	7.5	5.44	5.57
Female (%)	48%	48%	58%	57%	54%	51%	48%	48%	56%	56%	54%	52%
Asian (%)	50%	46%	60%	62%	63%	60%	52%	47%	59%	59%	63%	62%
Black (%)	6%	2%	5%	1%	4%	2%	4%	1%	3%	1%	3%	1%
Hispanic (%)	17%	15%	11%	9%	11%	11%	14%	14%	7%	7%	7%	8%
White (%)	11%	24%	10%	15%	10%	14%	10%	24%	8%	14%	8%	12%
Other (%)	5%	3%	5%	4%	6%	7%	5%	3%	4%	3%	5%	6%
Unknown (%)	12%	11%	10%	8%	6%	5%	14%	12%	20%	16%	13%	11%
Average months on Medicaid per year	9	10	8	8	9	10	9	10	8	9	9	9
Total Medicaid Spending per Person per Year	\$1,911	\$1,904	\$3,818	\$3,954	\$6,754	\$6,076	\$1,783	\$1,972	\$3,398	\$3,114	\$6,520	\$6,115
Prevalence per 100,000												
Insomnia	398	477	4,208	6,096	8,036	9,143	623	450	4,755	5,573	11,034	10,843
Cardiovascular disease*	NA*	NA*	1,955	1,576	9,934	9,073	NA*	NA*	3,575	2,540	13,260	10,786

BMJ Open

1	Alcohol Use Disorder	NA*	NA*	2,114	1,173	2,470	2,184	NA*	NA*	2,264	1,508	2,870	2,199
2	Substance Use Disorder	NA*	NA*	2,265	1,517	1,799	2,098	NA*	NA*	3,799	2,526	4,250	4,058
3	Anxiety	NA*	NA*	5,124	4,639	6,279	6,279	NA*	NA*	5,726	5,055	7,537	7,416
4	Depression	NA*	NA*	3,782	2,874	6,007	5,867	NA*	NA*	3,191	2,722	5,637	4,656
5	Mood Disorder	NA*	NA*	6,371	4,900	9,399	8,891	NA*	NA*	5,607	4,400	8,375	7,297
6	Disorders diagnosed	1,983	1,394	289	212	170	112	2,480	2,219	307	214	163	188
7	young												
8													
9													
10													
11													
12													
13													
14	Emergency Department	328	216	335	257	288	237	375	188	360	247	332	216
15	Emergency Department	13	20	26	21	31	39	20	7	32	19	45	36
16	(SM)												
17	Inpatient Stays	70	53	267	319	299	245	60	49	231	309	234	190
18	Inpatient Stays (SM)	14	7	43	24	45	32	11	5	37	20	37	21
19													
20													
21													
22													
23													
24	Total Outpatient	3.4	4.1	4.1	4.6	6.7	7.3	3.9	5.2	4.5	5.0	7.6	8.2
25	Outpatient (SM)	0.2	0.2	0.3	0.2	0.4	0.3	0.3	0.3	0.3	0.3	0.5	0.4
26													
27													

Visits per 1,000 per year

Outpatient visits per person per year

\* We adopted a longer follow-up period 2008-2011(pre-implementation) and 2013-2016 (TNNIS implementation) to allow for lag time in disease manifestation

1  
2  
3 216 For these identified records, indicator variables were created to identify type of medical  
4  
5 217 claims inpatient, outpatient, and emergency department (ED) visits as well as prescription drugs,  
6  
7 218 both overall and for visits related to substance use and mental health disorders (650-663, 670).  
8  
9 219 We additionally obtained information on the age of the subscriber associated with each record.  
10  
11 220 Because we did not have access to Medicare records, and did not include dual eligible  
12  
13 221 participants due to the high likelihood of pre-existing medical conditions and smaller sample  
14  
15 222 size, our sample does not include adults aged 65 or older. Age in years was defined as the  
16  
17 223 calculated age on January 1, 2009 and January 1, 2013, and stratified into three age cohorts, 5-  
18  
19 224 17, 18-44, 45-64 years.

#### 23 24 225 Statistical analyses

25  
26 226 Our focus is on the rate of diagnoses for the hypothesized conditions. We first assess  
27  
28 227 whether there were significant changes in utilization overall between the baseline and TNNIS  
29  
30 228 use periods and whether the observed changes differed by neighborhood (i.e., exposure) after  
31  
32 229 considering other changes over time between these neighborhoods. We use Poisson regression  
33  
34 230 (see equation 1) to model the number of overall and substance use and mental health related  
35  
36 231 inpatient, emergency department and outpatient visits for those months in which participants  
37  
38 232 were enrolled in Medicaid.

39  
40  
41  
42 233 For our primary analyses, we use logistic regression (see equation 2) to examine the odds  
43  
44 234 of receiving a diagnosis for the hypothesized conditions. Before implementing these regression  
45  
46 235 analyses, we examined trends in socio-demographic characteristics as well as trends in Medicaid  
47  
48 236 enrollment to ensure that no divergent patterns were noted around 2012. Because racial  
49  
50 237 composition varied somewhat between the two neighborhoods (Table 1), we controlled for race  
51  
52 238 in our analyses to ensure that compositional changes by race did not influence the analysis. We  
53  
54  
55  
56  
57  
58  
59  
60

239 also stratified by age so that we could better test our *a priori* hypotheses by condition. For  
 240 chronic diseases, i.e. cardiovascular disease, we adopted a longer follow-up period 2008-  
 241 2011(pre-implementation) and 2013-2016 (TNNIS implementation) to allow for lag time in  
 242 disease manifestation.

$$243 \log(E(Y | \mathbf{x})) = \alpha + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_1 x_2 + \beta_4 x_3, \quad (1)$$

244 where  $Y =$  number of Medicaid claims for condition of interest

245 offset = number of Medicaid enrollment months

$$247 \log\left(\frac{p}{1-p}\right) = \alpha + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_1 x_2 + \beta_4 x_3, \quad (2)$$

248 where  $p = \Pr(Y = 1)$  is the probability of  
 having Medicaid claim for condition of interest

249 Here,  $x_1$ , was the indicator for neighborhood exposure condition (Sunset Park=0 vs  
 250 Flushing=1);  $x_2$ , indicated implementation period (pre-implementation=0 vs TNNIS  
 251 implementation=1); and  $x_3$ , race/ethnicity group membership (Asian=1, Black=2, Hispanic=3,  
 252 White=4 [reference], Other=5, Unknown=6).

### 253 Patient and Public Involvement

254 The research question was inspired by the work of a non-profit community organization  
 255 called Queens Quiet Skies that works to mitigate airplane noise. One of the coauthors of the  
 256 paper was a member of this organization and obtained the Freedom of Information Act requests  
 257 for Federal Aviation Administration documents. These documents were used to identify the  
 258 treatment census tracts and measuring the level of airplane noise exposure.

### 259 Results

1  
2  
3 260 Participants were generally similar across both groups over the two points in time (Table  
4  
5 261 1), but health care utilization varied over time by age group and treatment status.

6  
7 262 The increased use of the TNNIS climb occurred in 2012.<sup>27</sup> Prior to that date the climb  
8  
9 263 was only used for the US Open or unexpected weather/runway repairs.<sup>27</sup> We were only able to  
10  
11 264 obtain data on TNNIS departures after the New York Port Authority's Fiscal Year 2013 because  
12  
13 265 the Port Authority indicated that the earlier data had been lost. There were roughly 1,278 TNNIS  
14  
15 266 departures/year on average during US Open events in the 2013-2019 period, providing a point of  
16  
17 267 reference. Since 2013, the total annual number of TNNIS climbs ranged from between 9,349 and  
18  
19 268 29,676, with an average of 18,653/year. The DNL figures (Figure 1) reflect the average noise  
20  
21 269 exposure by census tract across the 2013-2019 period, and may not reflect the actual change in  
22  
23 270 aircraft noise in Flushing, NY in the pre-2012 and post-2012 periods.

24  
25 271 Overall medical utilization

26  
27 272 Table 2 provides results from regression models assessing period-related changes in  
28  
29 273 medical utilization and diagnoses. The effects of the change in flight patterns on overall  
30  
31 274 utilization were inconsistent across types of utilization and age. Overall, outpatient visits  
32  
33 275 increased slightly in Flushing relative to Sunset Park for those aged 18-44 (rate ratio [RR] =  
34  
35 276 1.04, 95% CI = 1.04, 1.05). Prescription drug claims also increased by a similar amount for this  
36  
37 277 group (RR = 1.06, 95% CI = 1.06, 1.06). However, outpatient visits and prescription drug use for  
38  
39 278 children in Flushing aged 5-17 (outpatient RR=0.86, 95% CI = 0.85, 0.87; prescription drug  
40  
41 279 claims RR = 0.94, 95% CI = 0.94, 0.95) as well as for older adults 45 – 64 declined (outpatient  
42  
43 280 RR=0.92, 95% CI = 0.92, 0.93; prescription drug claims RR = 0.93, 95% CI = 0.92, 0.93).

281 Table 2 – Model Results and 95% Confidence Intervals

	Rate Ratios from the Difference in Difference Poisson Model		
	Age 5 - 17	Age 18 - 44	Age 45 - 64
Inpatient Visits	0.92 (0.83, 1.03)	1.05 (1.02, 1.08)	0.93 (0.88, 0.97)
Emergency Department Visits	1.31 (1.24, 1.37)	1.45 (1.41, 1.49)	1.16 (1.11, 1.21)
Outpatient Visits	0.86 (0.85, 0.87)	1.04 (1.04, 1.05)	0.92 (0.92, 0.93)
Pharmacy Claims	0.94 (0.94, 0.95)	1.06 (1.06, 1.06)	0.93 (0.92, 0.93)
	Rate Ratios from the Difference in Difference Poisson Model Substance Use and Mental Health Related		
	Age 5 - 17	Age 18 - 44	Age 45 - 64
Inpatient Visits	NA*	1.11 (1.01, 1.22)	1.19 (1.04, 1.36)
Emergency Department Visits	4.11 (3.28, 5.16)	2.46 (2.20, 2.76)	1.48 (1.31, 1.67)
Outpatient Visits	1.12 (1.09, 1.16)	0.93 (0.92, 0.95)	0.87 (0.85, 0.89)
	Odds Ratios from the Difference in Difference Logistic Model		
	Age 5 - 17	Age 18 - 44	Age 45 - 64
Insomnia	1.64 (1.12, 2.39)	1.17 (1.09, 1.26)	1.18 (1.09, 1.28)
Cardiovascular Disease**	NA*	1.45 (1.30, 1.62)	1.15 (1.07, 1.25)
Alcohol Use Disorder	NA*	0.97 (0.86, 1.11)	1.16 (0.99, 1.35)
Substance Use Disorder	NA*	0.92 (0.83, 1.03)	1.24 (1.07, 1.44)
Depression	NA*	1.12 (1.02, 1.24)	1.20 (1.08, 1.33)
Anxiety	NA*	1.02 (0.95, 1.10)	1.01 (0.92, 1.11)
Mood Disorder	NA*	1.03 (0.95, 1.10)	1.10 (1.00, 1.20)
Disorders diagnosed young	0.80 (0.66, 0.97)	0.99 (0.72, 1.37)	0.56 (0.31, 1.04)

1  
2  
3 282  
4  
5 283 \*These diseases and conditions are rare or difficult to diagnose in children.  
6  
7  
8 284 \*\*We adopted a longer follow-up period 2008-2011(pre-implementation) and 2013-2016  
9  
10 285 (TNNIS implementation) to allow for lag time in disease manifestation  
11

12 286 While the general pattern for outpatient visits indicates decreased medical utilization in  
13  
14 287 Flushing compared to Sunset Park over time, emergency department visits in Flushing increased  
15  
16 288 in the post TNNIS period among all age groups. For ages 5-17, the RR was 1.31 (95% CI= 1.24,  
17  
18 289 1.37); for ages 18-44, the RR was 1.45 (95% CI = 1.41, 1.49); and for ages 45-64, the RR was  
19  
20 290 1.16 (95% CI = 1.11, 1.21). Substance use and mental health-related emergency department  
21  
22 291 visits also increased in Flushing in the post period relative to Sunset Park, with rate ratios  
23  
24 292 ranging between 2.5 to 4.1. For ages 5-17 RR= 4.11 (95% CI= 3.28, 5.16); for ages 18-44 RR =  
25  
26 293 2.46 (95% CI = 2.20, 2.76); and for ages 45-64, RR = 1.48 (95% CI = 1.31, 1.67).  
27  
28  
29

30  
31 294 Relative to Sunset Park, inpatient visits in Flushing also show statistically significant  
32  
33 295 increases for overall visits for ages 18-44 (RR=1.05, 95% CI = 1.02, 1.08). However, statistically  
34  
35 296 significant decreases were observed for ages 45-64 (RR=0.93, 95% CI = 0.88, 0.97).  
36

37  
38 297 Changes by diagnosis  
39

40 298 Relative to Sunset Park, implementation of the TNNIS climb was associated with  
41  
42 299 increases in insomnia diagnoses, particularly for children. For example, the crude prevalence of  
43  
44 300 insomnia for children increased by 57% from 398 per 100,000 in Flushing, compared to a 6%  
45  
46 301 decrease from 477 per 100,000 in Sunset Park. For children in this age group, the odds ratio  
47  
48 302 (OR) for insomnia was 1.64 (95% CI =1.12, 2.39). For older ages, the effect sizes were  
49  
50 303 somewhat less striking (i.e., for the 18-44 age group, the OR was 1.17 [95% CI = 1.09, 1.26],  
51  
52 304 and for ages 45-64 the OR = 1.1 [95% CI = 1.09, 1.28]).  
53  
54  
55  
56  
57  
58  
59

1  
2  
3 305 Cardiovascular disease diagnoses increased significantly in Flushing relative to Sunset  
4  
5 306 Park in the post-2012 period. For 18-44-year-olds, the crude prevalence of cardiovascular disease  
6  
7 307 increased in both neighborhoods due to aging of the samples, by 83% from 1,955 per 100,000 in  
8  
9  
10 308 Flushing and by 29% from 1,576 per 100,000 in Sunset Park. The OR for cardiovascular disease  
11  
12 309 diagnoses in Flushing relative to Sunset Park in this age group was 1.45 (95% CI = 1.30, 1.62).  
13  
14 310 For 45-64-year-olds, , the crude prevalence increased by 33% from 9,934 per 100,000 in  
15  
16 311 Flushing and 19% from 9,073 per 100,000 in Sunset Park. For this age group, the OR was 1.15  
17  
18 312 (95% CI = 1.07, 1.25). Substance use disorder only increased significantly for the 45-64 age  
19  
20 313 group in Flushing relative to Sunset Park (OR =1.24, 95% CI=1.07, 1.44).  
21  
22  
23

24 314 Figure 2 shows the monthly prevalence of insomnia and cardiovascular disease diagnoses  
25  
26 315 for the 45-64 age group. Age is measured at the beginning of each period, January 1, 2009 for  
27  
28 316 the pre-period and January 1, 2013 for the post period. The numerator is the number of unique  
29  
30 317 individuals with one or more diagnosis from inpatient, emergency room or outpatient claims and  
31  
32 318 the denominator is the number of Medicaid-enrolled patients. The trends of both conditions  
33  
34 319 increased throughout the study periods, because people are getting older, but Flushing showed  
35  
36 320 increases that were larger in magnitude in the post period relative to Sunset Park.  
37  
38  
39

40 321  
41  
42 322 Figure 2 – Prevalence of insomnia and cardiovascular disease diagnoses per 100,000 among 45-  
43  
44 323 64 age group  
45  
46

47 324 [insert figure 2 here]  
48

49 325 Results for other conditions were more mixed. Clinical depression diagnoses increased  
50  
51 326 for the two older age groups (ages 18-44 OR = 1.12, 95% CI = 1.02, 1.24; ages 45-64 OR = 1.20,  
52  
53 327 95% CI = 1.08, 1.33). Broader mood disorder diagnoses, however, only showed statistically  
54  
55  
56  
57  
58  
59



1  
2  
3 328 significant increases for the 45-65 age group (OR = 1.10, 95% CI = 1.00, 1.20). For 5-17-year-  
4  
5 329 olds, developmental disorder diagnoses significantly decreased (OR=0.80, 95% CI = 0.66, 0.97)  
6  
7  
8 330 in Flushing relative to Sunset Park after the implementation of TNNIS.  
9

## 10 331 **Discussion**

11  
12 332 We find that increases in airplane noise at DNL levels greater than 55 were associated  
13  
14 333 with increases in insomnia, depression, substance abuse, and cardiovascular disease across most  
15  
16 334 age groups. These diagnoses are generally consistent with our *a priori* hypotheses regarding the  
17  
18 335 relationship between exposure to airplane noise and health.<sup>3,6,8,9,12,13,30,31</sup> Specifically, airplane  
19  
20 336 noise may produce disruptions in sleep and psychological stress, thereby producing  
21  
22 337 neuroendocrine disruptions that lead to mental health disorders and cardiovascular disease.  
23  
24

25  
26 338 The biological pathways through which airplane noise impacts health have been  
27  
28 339 elucidated.<sup>9-14</sup> Numerous associational studies suggest that airplane noise produces real-world  
29  
30 340 health impacts, and experimental animal models show a wide range of health impacts associated  
31  
32 341 with noise-induced stress as well.<sup>3-9,11-13,15-18,32</sup> Our study adds quasi-experimental evidence in  
33  
34 342 humans to this substantial body of research showing that increasing airplane noise will have  
35  
36 343 detrimental health impacts on communities surrounding airports. The magnitude of our findings  
37  
38 344 is not strictly comparable to those in associational studies because lagged health effects (e.g., the  
39  
40 345 time required for psychological stress to manifest as cardiovascular disease) tend to mute the  
41  
42 346 measured impacts.  
43  
44

45  
46  
47 347 Nevertheless, the magnitude of the impact of airplane noise on the health outcomes we  
48  
49 348 observe are generally in line with previous work. For instance, an earlier analysis of associational  
50  
51 349 studies of the health impact of aircraft noise in Flushing, NY estimated that aircraft noise would  
52  
53 350 produce a weighted increase in cardiovascular disease of 14% (RR = 1.14, 95% CI = 1.08, 1.22)  
54  
55  
56  
57  
58  
59

1  
2  
3 351 and a weighted increase in anxiety of 79% (RR = 1.79, 95% CI = 1.0-3.1).<sup>11,24</sup> We observe an  
4  
5 352 odds ratio for cardiovascular disease among 18-64-year-olds in the range of 1.12 to 1.40. While  
6  
7 353 the studies examine incident cardiovascular disease and we measure both incident and prevalent  
8  
9 354 cardiovascular disease, it is reasonable to assume that the OR we estimate does not greatly  
10  
11  
12 355 overestimate the adjusted RR computed using associational studies.<sup>37</sup>  
13

14  
15 356 In the international literature, the self-reported annoyance, health, health-related quality  
16  
17 357 of life, and cardiovascular disease rates for those who live close to airports is significantly lower  
18  
19 358 than for matched individuals living in quieter areas.<sup>38-40</sup> In this literature, these latter findings are  
20  
21 359 particularly true for noise-sensitive individuals.<sup>38,39</sup> This suggests that self-selection by noise  
22  
23 360 may mute previously observed effects in ecological studies, which control for socio-economic  
24  
25 361 status but not always noise sensitivity. One strength of our study is that the change in aircraft  
26  
27 362 noise was exogenous and moving out of a neighborhood requires time and effort.  
28  
29

30  
31 363 Our study was subject to a number of limitations. First, the health effects in a  
32  
33 364 predominantly Chinese-American population may not be generalizable to other populations.  
34  
35 365 Chinese-Americans in New York City are unusually healthy.<sup>41</sup> Medicaid data also present unique  
36  
37 366 challenges. Participants can enter and exit the program, for example. If there are more  
38  
39 367 participants exiting the program in one area relative to another, the observed outcomes will also  
40  
41 368 change. We addressed this problem by adjusting for the months a participant was enrolled in  
42  
43 369 Medicaid within a calendar year.  
44  
45

46  
47 370 Next, we use DNL as a measure. Frequency of noise exposure may be superior at  
48  
49 371 predicting health outcomes, but frequency data were not available. Finally, it is possible that the  
50  
51 372 change in neighborhood composition over time differed before and after the implementation of  
52  
53 373 year-round TNNIS departures in Flushing relative to Sunset Park. However, we did not observe  
54  
55  
56  
57  
58  
59  
60

1  
2  
3 374 any trends in the available data that suggested this was the case, and there were no major events  
4  
5 375 in 2012 that clearly serve as an alternative causal factor for either the primary or unexpected  
6  
7 376 findings. Moreover, our findings apply only to the zip codes directly under the DNL zones  
8  
9  
10 377 defined by our analysis.

11  
12 378 Cost-effectiveness analyses (based partly on earlier associational data) show that the  
13  
14 379 benefits of noise-mitigation strategies (reduced illness and discomfort) tend to outweigh the  
15  
16 380 costs.<sup>24,42</sup> Given that these earlier studies did not include the full range of health outcomes that  
17  
18 381 we measure here, it is likely that these studies understate the already substantial benefits of  
19  
20 382 aircraft noise mitigation strategies.

21  
22  
23 383 Much more comprehensive quasi-experimental and economic analyses are required to  
24  
25 384 determine the extent to which policymakers may wish to act. The costliest options—building  
26  
27 385 airports far from populated areas and providing high speed transit and freeways—can increase  
28  
29 386 the cost of mitigation by billions of dollars.

30  
31  
32  
33 387

### 34 35 388 **Research Ethics Approval**

36  
37 389 This study is approved by the Institutional Review Board at New York University  
38  
39 390 Washington Square under IRB-FY2016-1101.

### 40 41 391 **Acknowledgements**

42  
43 392 The authors thank NYU Health Evaluation and Analytics Lab and the New York State  
44  
45 393 Department of Health for making the Medicaid claims data available and gratefully acknowledge  
46  
47 394 the funding for this research from the Robert Wood Johnson Foundation's Policies for Action  
48  
49 395 program.

1  
2  
3 396 Disclaimer: The views and opinions expressed in this article are those of the authors and  
4  
5 397 do not necessarily reflect the official policy or position of the New York State Department of  
6  
7 398 Health. Example of analysis performed within this article are only examples. They should not be  
8  
9  
10 399 utilized in real-world analytic products.

#### 11 12 400 **Contributorship Statement**

13  
14 401 Ms. Scarlett Sijia Wang, Dr. Sherry Glied, Dr. Sharifa Z. Williams and Dr. Peter  
15  
16 402 Muennig approved the final draft and agreed to be accountable for all aspects of the work. Ms.  
17  
18 403 Scarlett Sijia Wang contributed to study design, data linkage, analysis, interpretation of the data,  
19  
20 404 drafting the methods and results sections. Dr. Sherry Glied contributed to the acquisition of data,  
21  
22 405 study design, analysis, and interpretation of data. Dr. Sharifa Z. Williams contributed to data  
23  
24 406 analysis and interpretation of data. Dr. Peter Muennig contributed to study conception, study  
25  
26 407 design, analysis, interpretation of data and drafting the introduction and discussion sections.  
27  
28 408 Though Mr. Brian Will passed away prior to the submission of the manuscript, he had significant  
29  
30 409 contributions in the study conception, the acquisition of data and sample identification.

31  
32 410 Wang, Scarlett (proxy) (contact); Glied, Sherry; Williams, Sharifa; Will, Brian; Muennig, Peter  
33  
34 411

#### 35 36 37 38 412 **Competing interests**

39  
40 413 At the time of the study, Mr. Brian Will worked at a non-profit organization called  
41  
42 414 Queens Quiet Skies who are a grass-roots group aiming to address airport noise.

#### 43 44 415 **Funding**

45  
46 416 Robert Wood Johnson Foundation (75822)

#### 47 48 417 **Data Sharing**

1  
2  
3 418 We used individual-level claims data that contain protected Patient Health Information  
4  
5 419 (PHI). Therefore, the data cannot be made available publicly as required by the Health Insurance  
6  
7  
8 420 Portability and Accountability Act (HIPPA).  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

For peer review only

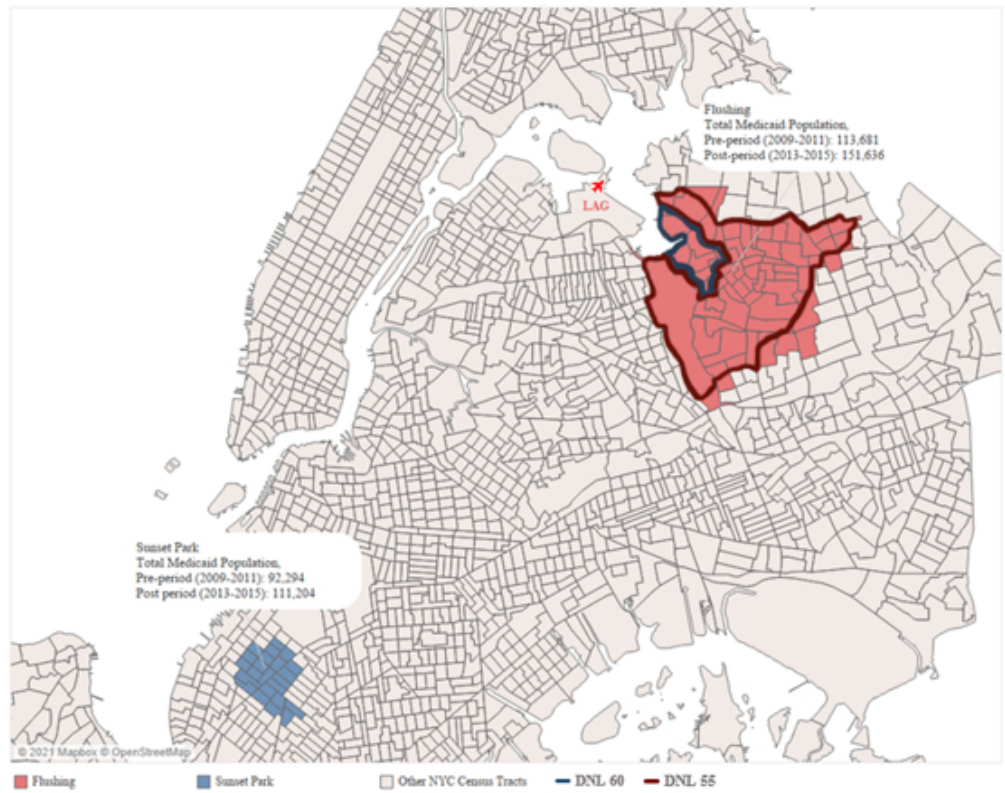
1. Nolan M. Fundamentals of air traffic control: Cengage learning; 2010.
2. Prevot T, Homola J, Mercer J, Mainini M, Cabrall C. Initial evaluation of NextGen air/ground operations with ground-based automated separation assurance. *ATM2009, Napa, California* 2009.
3. Zaharna M, Guilleminault C. Sleep, noise and health: review. *Noise and Health* 2010; **12**(47): 64.
4. Clark C, Stansfeld SA. The effect of transportation noise on health and cognitive development: A review of recent evidence. *Int J Comp Psychol* 2007; **20**(2).
5. Stansfeld S, Haines M, Burr M, Berry B, Lercher P. A review of environmental noise and mental health. *Noise and Health* 2000; **2**(8): 1.
6. Passchier-Vermeer W, Passchier WF. Noise exposure and public health. *Environ Health Perspect* 2000; **108**(Suppl 1): 123.
7. Morrell S, Taylor R, Lyle D. A review of health effects of aircraft noise. *Aust N Z J Public Health* 1997; **21**(2): 221-36.
8. Beutel ME, Jünger C, Klein EM, et al. Noise annoyance is associated with depression and anxiety in the general population-the contribution of aircraft noise. *PLoS One* 2016; **11**(5).
9. Münzel T, Schmidt FP, Steven S, Herzog J, Daiber A, Sørensen M. Environmental noise and the cardiovascular system. *J Am Coll Cardiol* 2018; **71**(6): 688-97.
10. Schmidt FP, Basner M, Kröger G, et al. Effect of nighttime aircraft noise exposure on endothelial function and stress hormone release in healthy adults. *Eur Heart J* 2013; **34**(45): 3508-14.
11. Babisch W. Cardiovascular effects of noise. *Noise and Health* 2011; **13**(52): 201.
12. Maschke C, Harder J, Ising H, Hecht K, Thierfelder W. Stress hormone changes in persons exposed to simulated night noise. *Noise and health* 2002; **5**(17): 35.
13. Melamed S, Bruhis S. The effects of chronic industrial noise exposure on urinary cortisol, fatigue, and irritability: a controlled field experiment. *J Occup Environ Med* 1996; **38**(3): 252-6.
14. McEwen BS. Protective and damaging effects of stress mediators. *N Engl J Med* 1998; **338**(3): 171-9.
15. Basner M, Babisch W, Davis A, et al. Auditory and non-auditory effects of noise on health. *The lancet* 2014; **383**(9925): 1325-32.
16. Perron S, Tétréault L-F, King N, Plante C, Smargiassi A. Review of the effect of aircraft noise on sleep disturbance in adults. *Noise and health* 2012; **14**(57): 58.
17. Xue L, Zhang D, Wang T, Shou X. Effects of high frequency noise on female rat's multi-organ histology. *Noise and Health* 2014; **16**(71): 213.
18. Ising H, Babisch W, Kruppa B. Noise-induced endocrine effects and cardiovascular risk. *Noise and health* 1999; **1**(4): 37.
19. Cohen JP, Coughlin CC. Changing noise levels and housing prices near the Atlanta airport. *Growth and Change* 2009; **40**(2): 287-313.
20. Cohen JP, Coughlin CC. Spatial hedonic models of airport noise, proximity, and housing prices. *Journal of Regional Science* 2008; **48**(5): 859-78.
21. Kawachi I, Adler NE, Dow WH. Money, schooling, and health: Mechanisms and causal evidence. *Ann N Y Acad Sci* 2010; **1186**: 56-68.

- 1  
2  
3 22. Muennig P, Franks P, Jia H, Lubetkin E, Gold MR. The income-associated burden of  
4 disease in the United States. *Soc Sci Med* 2005; **61**(9): 2018-26.  
5  
6 23. Boes S, Nüesch S, Stillman S. Aircraft Noise, Health, And Residential Sorting: Evidence  
7 From Two Quasi-Experiments. *Health Econ* 2013; **22**(9): 1037-51.  
8  
9 24. Zafari Z, Jiao B, Will B, Li S, Muennig PA. The trade-off between optimizing flight  
10 patterns and human health: a case study of aircraft noise in Queens, NY, USA. *Int J Environ Res*  
11 *Public Health* 2018; **15**(8).  
12  
13 25. Nüesch S. Aircraft noise, health, and residential sorting: evidence from two quasi-  
14 experiments. *Standardization news: SN* 2012; (6744).  
15  
16 26. Eagan ME, Hanrahan R, Miller R. Implementing performance based navigation  
17 procedures at US airport: Improving community noise exposure. INTER-NOISE and NOISE-CON  
18 Congress and Conference Proceedings; 2013: Institute of Noise Control Engineering; 2013. p.  
19 1577-86.  
20  
21 27. Buckley C. A rumble in the sky and grumbles below. Accessed 11/17/2020. Available  
22 online at: <https://www.nytimes.com/2013/08/26/nyregion/planes-roar-from-above-creates-a-rumble-on-the-ground.html>.  
23  
24 28. Mathematica. (2013). Medicaid Managed Care and Integrated Delivery Systems:  
25 Technical Assistance to States and Strengthening Federal Oversight. Washington, DC:  
26 Mathematica Policy Research.  
27  
28 29. Bhaskar S, Hemavathy D, Prasad S. Prevalence of chronic insomnia in adult patients and  
29 its correlation with medical comorbidities. *J Family Med Prim Care*. 2016;5(4):780-784.  
30 doi:10.4103/2249-4863.201153.  
31  
32 30. Bernstein GA, Borchardt CM. Anxiety disorders of childhood and adolescence: A critical  
33 review. *J Am Acad Child Adolesc Psychiatry* 1991; **30**(4): 519-32.  
34  
35 31. Mensah GA, Brown DW. An overview of cardiovascular disease burden in the United  
36 States. *Health Aff (Millwood)* 2007; **26**(1): 38-48.  
37  
38 32. Halonen JI, Hansell AL, Gulliver J, et al. Road traffic noise is associated with increased  
39 cardiovascular morbidity and mortality and all-cause mortality in London. *Eur Heart J* 2015;  
40 **36**(39): 2653-61.  
41  
42 33. Technical Advisory Committee (TAC) meeting 8. Available online at:  
43 <http://www.panynjpart150.com/AdminPages/GetProjectFile.asp?a=LGA&f=LGA%20TAC%20Meeting%20No.%208%20Summary,%20August%2016,%202016.pdf> Accessed 6/17/2020.  
44  
45 34. Flight Aware. Live flight tracking. Available online at: <https://flightaware.com>. Accessed  
46 6/20/2020.  
47  
48 35. NYC Health. Community Health Profile: Sunset Park. Available online at:  
49 <https://www1.nyc.gov/assets/doh/downloads/pdf/data/2018chp-bk7.pdf> Accessed 3/2/2020.  
50  
51 36. NYC Health. Community Health Profile: Flushing and Whitestone. Available online at:  
52 <https://www1.nyc.gov/assets/doh/downloads/pdf/data/2018chp-qn7.pdf> Accessed 3/2/2020.  
53  
54 37. Knol MJ, Le Cessie S, Algra A, Vandembroucke JP, Groenwold RH. Overestimation of risk  
55 ratios by odds ratios in trials and cohort studies: alternatives to logistic regression. *CMAJ*.  
56 2012;184(8):895-899. doi:10.1503/cmaj.101715.  
57  
58  
59  
60

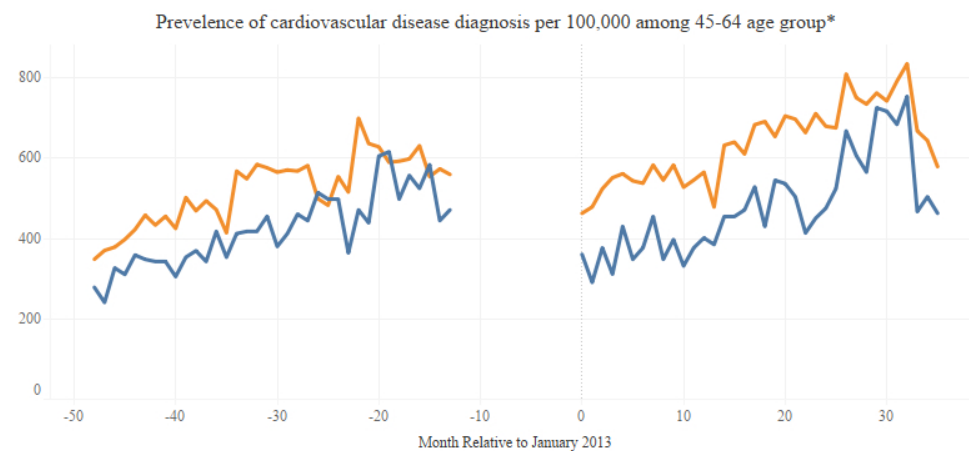
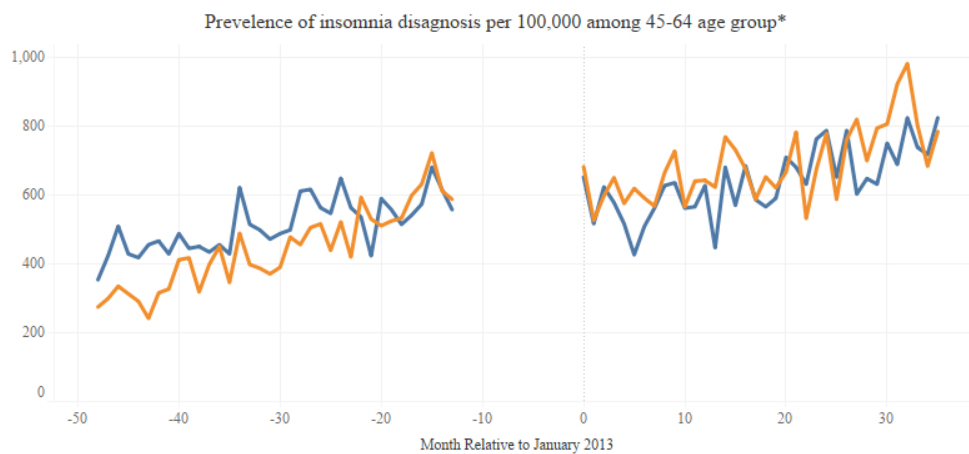
- 1  
2  
3 38. Welch D, Shepherd D, McBride D. Health-related quality of life is impacted by proximity  
4 to an airport in noise sensitive people. INTER-NOISE and NOISE-CON Congress and Conference  
5 Proceedings; 2016: Institute of Noise Control Engineering; 2016. p. 5003-10.  
6  
7 39. Shepherd D, McBride D, Dirks KN, Welch D. Annoyance and health-related quality of life:  
8 a cross-sectional study involving two noise sources. *J Environ Prot (Irvine, Calif)* 2014; **2014**.  
9  
10 40. Bronzaft AL, Dee Ahern K, McGinn R, O'Connor J, Savino B. Aircraft noise: A potential  
11 health hazard. *Environ Behav* 1998; **30**(1): 101-13.  
12  
13 41. Muennig P, Wang Y, Jacobowski A. The health of immigrants to New York City from  
14 Mainland China: Evidence from the New York Health Examination and Nutrition Survey. *Journal*  
15 *of Immigrant and Refugee Studies* 2012; **10**: 1-7.  
16  
17 42. Jiao B, Zafari Z, Will B, Ruggeri K, Li S, Muennig P. The Cost-Effectiveness of Lowering  
18 Permissible Noise Levels Around US Airports. *Int J Environ Res Public Health* 2017; **14**(12): 1497.  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60



1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60



117x93mm (120 x 120 DPI)



Exposed: Flushing Control: Sunset Park

\*Age is measured at the beginning of each period, January 1, 2009 for the pre-period and January 1, 2013 for the post-period

211x211mm (96 x 96 DPI)

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

STROBE Statement—Checklist of items that should be included in reports of *cohort studies*

	Item No	Recommendation	Page No
<b>Title and abstract</b>	1	(a) Indicate the study's design with a commonly used term in the title or the abstract (b) Provide in the abstract an informative and balanced summary of what was done and what was found	1
<b>Introduction</b>			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	2-3
Objectives	3	State specific objectives, including any prespecified hypotheses	4
<b>Methods</b>			
Study design	4	Present key elements of study design early in the paper	4-6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4-6
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up (b) For matched studies, give matching criteria and number of exposed and unexposed	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4
Bias	9	Describe any efforts to address potential sources of bias	7, 11
Study size	10	Explain how the study size was arrived at	8, 14- 15
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5-7
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding (b) Describe any methods used to examine subgroups and interactions (c) Explain how missing data were addressed (d) If applicable, explain how loss to follow-up was addressed (e) Describe any sensitivity analyses	7-8
<b>Results</b>			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed (b) Give reasons for non-participation at each stage (c) Consider use of a flow diagram	8, 14- 15
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders (b) Indicate number of participants with missing data for each variable of interest (c) Summarise follow-up time (eg, average and total amount)	8,14- 15
Outcome data	15*	Report numbers of outcome events or summary measures over time	8-11, 14

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

For peer review only

1	Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	8-11, 14-19
2			(b) Report category boundaries when continuous variables were categorized	
3			(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
4				
5				
6				
7				
8				
9	Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9
10				
11	<b>Discussion</b>			
12				
13	Key results	18	Summarise key results with reference to study objectives	11
14	Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	11-12
15				
16	Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12-13
17				
18				
19				
20	Generalisability	21	Discuss the generalisability (external validity) of the study results	11
21				
22	<b>Other information</b>			
23	Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Supplemental material, acknowledgements
24				
25				
26				

\*Give information separately for exposed and unexposed groups.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at <http://www.strobe-statement.org>.