Original article

The Impact of Physical Distancing Policies During the COVID-19 Pandemic on Health and Well-Being Among Australian Adolescents

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ABSTRACT

Purpose: Physical distancing policies in the state of New South Wales (Australia) were implemented on March 23, 2020, because of the COVID-19 pandemic. This study investigated changes in physical activity, dietary behaviors, and well-being during the early period of this policy.
Methods: A cohort of young people aged 13—19 years from Sydney (N = 582) were prospectively followed for 22 weeks (November 18, 2019, to April 19, 2020). Daily, weekly, and monthly trajectories of diet, physical activity, sedentary behavior, well-being, and psychological distress were collected via smartphone, using a series of ecological momentary assessments and smartphone sensors. Differences in health and well-being outcomes were compared pre- and post-implementation of physical distancing guidelines.
Results: After the implementation of physical distancing measures in NSW, there were significant decreases in physical activity (odds ratio [OR] = .53, 95% confidence interval [CI] = .34—.83), increases in social media and Internet use (OR = 1.86, 95% CI = 1.15—3.00), and increased screen time based on participants' smartphone screen state. Physical distancing measures were also associated with being alone in the previous hour (OR = 2.09, 95% CI: 1.33—3.28), decreases in happiness (OR = .38, 95% CI = .18—.82), and fast food consumption (OR = .46, 95% CI = .29—.73).
Conclusions: Physical distancing and social restrictions had a contemporaneous impact on health and well-being outcomes associated with chronic disease among young people. As the pandemic evolves, it will be important to consider how to mitigate against any longer term health impacts of physical distancing restrictions.
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IMPLICATIONS AND CONTRIBUTION

This study investigates the early impacts of physical distancing policies and school closures on health behavior and well-being among adolescents in Australia. There are potential ongoing impacts of physical distancing policies on physical and mental health outcomes and known risk factors for chronic disease.

The COVID-19 pandemic and subsequent policy responses in the Australian context resulted in substantial impact on community functioning and potentially will have ongoing psychosocial impacts postpandemic. One of the key strategies to reduce the rate of infection has been physical distancing and, for school-

aged children, a move to the online delivery of schooling. Authorities requested that people remain in their homes wherever possible and limit their travel to obtaining essential goods and services. This public health strategy was absolutely necessary and appears to be yielding the desired result in terms of "flattening the curve" in the Australian context [1].

There are potential impacts of physical distancing and social isolation, particularly among younger people, where social connection is a key part of psychosocial development. The necessary policy responses to COVID-19 may impact the determinants of poor mental health outcomes, including suicidal behavior [2]. Previous studies have shown psychological and physical health impacts of social isolation during quarantine [3], and more generally, social isolation has been shown to be associated with poor mental and physical health outcomes [4]. In addition, adolescents are likely to have reduced physical activity, particularly incidental physical activity, and increased screen time as a consequence of the physical distancing measures. Previous studies have shown the impacts of sedentary behavior on health outcomes in young people [5,6] and interrelated factors of diet, overweight and obesity, and well-being [5,7,8].

The impact of the public health interventions in response to COVID-19 to the daily routine of young people in Australia on key health and well-being measures known to be associated with chronic disease has not previously been investigated. Accordingly, this study investigates whether the physical distancing policies and school closures in the state of New South Wales (Australia) were associated with changes in physical activity, dietary behaviors, and well-being during the early period of this policy.

Methods

Participants

Participants were recruited as part of a broader prospective cohort study of adolescents investigating determinants of health and well-being over time. Young people were recruited via social media (Instagram and Facebook) from the general population aged 13–19 years of a Sydney population catchment. Promotional and recruitment materials were developed and modified by members of a Youth Advisory Group, and the social media strategy targeted those residing in Western Sydney; however, participants from areas outside of this catchment were not excluded if they enrolled in the study. The Western Sydney population catchment is a socioeconomically and ethnically diverse population of approximately one million people. Participants were followed prospectively over a period of 22 weeks, from November 8, 2019, to April 19, 2020, after a social media campaign that ran from November 8, 2019, to January 8, 2020. Institutional ethics approval for the study was obtained from the Western Sydney University Human Research Ethics Committee (HREC Approval Number: H13302).

The total reach of the social media recruitment campaign was 164,640 adolescents in the Western Sydney area, of which 61% were female (n = 100,640) and 39% were male (n = 62,944). The total number of impressions (i.e., the number of times advertisements were displayed in news feeds) was 1,389,957, and this was higher among females (n = 955,418, 69%) than males (n = 425,222, 31%). The total number of click-throughs to the study webpage was 11,048, with a higher level of interest among females (n = 8,295, 75%) than males (n = 2,680, 25%). Of 11,048

individuals who clicked through to the study website, a total of 1,298 participants enrolled in the study and completed the baseline questionnaire, from which 582 participants were selected who provided one or more responses to follow-up ecological momentary assessment (EMA). Participants were predominantly female and aged 16–18 years (Table 1), reflecting the higher engagement in Instagram and Facebook among females than males more generally [9,10].

The Ethica Data smartphone app (https://ethicadata.com/product) was used to collect data from questionnaires, EMAs, and smartphone sensors. Mobile sensor data were collected automatically through the Ethica app only from those participants who provided consent and included geolocation information (via GPS, Wi-Fi, and Bluetooth), pedometer, motion-based activity recognition (MBAR) data, and screen state (whether the screen of the smartphone is "on" or "off"). A baseline questionnaire and a 16-week schedule of follow-up EMAs were triggered when participants enrolled in the study, with questions sent directly to each participant's smartphone. There were nine EMAs relating to psychological distress, well-being, positive emotion, social networks, relationships, diet, physical activity, sleep, and academic behavior. Each EMA, except psychological distress and well-being, was administered weekly, but on different days. EMAs relating to psychological distress or well-being were administered monthly. Thus, participants received daily EMAs but received a different EMA on each day. EMAs were sent to participants at random times between 8 A.M. and 10 A.M. or between 3 P.M. and 8 P.M. to avoid notifications during school hours and periods when participants may have been sleeping. The 16-week schedule of EMAs resulted in weekly or monthly measures for each domain spanning the 22-week follow-up period.

Outcome variables

The primary outcome variables for this study included measures of physical activity, sedentary behavior, dietary behavior, and psychological well-being.

Physical activity and sedentary behavior

Self-reported physical activity at baseline was based on responses to the PACE + Adolescent Physical Activity Measures [11], and sedentary behavior was based on the Adolescent Sedentary Activities Questions [12] with the TV and computer items modified to also capture information on Internet streaming, mobile phone, tablet, or gaming console use. Self-reported physical activity and sedentary behavior relating to the previous 24-hour period were also collected each week for the 22-week follow-up period via an EMA. Questions included:

(i) *"In the past 24 hours, were you physically active for a total of 60 minutes or more? 'Physical activity' is any activity that increases your heart rate and makes you get out of breath some of the time"*;

(ii) *"In the past 24 hours, did you spend any time watching TV?"*; and

(iii) *"In the past 24 hours, did you spend any time on the internet, social media (like Instagram, Youtube, or Facebook), or playing computer games?"* For participants who answered "yes" to this question, a follow-up question was asked: *"If Yes, how long did you spend on the internet, social media, or playing computer games?"*

Table 1
Baseline characteristics of adolescents who contributed one or more ecological momentary assessments over the 22-week follow-up period, November 8, 2019, to April 8, 2020, Sydney (Australia)

Characteristics	Males (N = 102)	Females (N = 465)	Total (N = 582)
Age			
Median (IQR)	17 (16–18)	17 (16–18)	17 (16–18)
Body mass index			
Median (IQR)	21.36 (19.73–23.89)	22.23 (20.08–24.95)	22.17 (20.08–24.96)
Body mass index			
Underweight	4 (4)	30 (6.59)	34 (6.06)
Normal	72 (72)	298 (65.49)	372 (66.31)
Overweight	18 (18)	82 (18.02)	103 (18.36)
Obese	6 (6)	45 (9.89)	52 (9.27)
Year of school			
Year 7	1 (.98)	1 (.22)	2 (.34)
Year 8	2 (1.96)	9 (1.94)	11 (1.89)
Year 9	8 (7.84)	21 (4.52)	30 (5.15)
Year 10	14 (13.73)	62 (13.33)	78 (13.4)
Year 11	10 (9.8)	46 (9.89)	57 (9.79)
Year 12	23 (22.55)	103 (22.15)	131 (22.51)
Not at school	5 (4.9)	19 (4.09)	25 (4.3)
Finished school	39 (38.24)	204 (43.87)	248 (42.61)
Trade certificate			
No	36 (81.82)	187 (83.86)	229 (83.88)
Yes	8 (18.18)	36 (16.14)	44 (16.12)
Work at a job			
No	54 (53.47)	185 (39.96)	246 (42.49)
Yes	47 (46.53)	278 (60.04)	333 (57.51)
Looking for a job			
No	29 (53.7)	73 (39.46)	105 (42.68)
Yes	25 (46.3)	112 (60.54)	141 (57.32)
Work for salary			
No	5 (10.64)	24 (8.63)	31 (9.31)
Yes	42 (89.36)	254 (91.37)	302 (90.69)
Weekly work hours			
Median (IQR)	10 (7–20)	11 (6–20)	10 (6–20)
Language at home			
English	88 (86.27)	403 (86.67)	503 (86.43)
Other	14 (13.73)	62 (13.33)	79 (13.57)

IQR = interquartile range.

Additional information on physical activity was collected passively via smartphone sensors, including pedometer, screen state (i.e., whether the phone was "on" or "off"), and MBAR. The daily number of steps for each participant was collected via the pedometer. Screen state was used as a proxy measure of sedentary behavior, with the assumption that during periods where the phone screen was active, participants were less likely to be engaging in physical activity.

MBAR is a composite indicator of activity provided by the Ethica Data app, which combines information from the phone sensors, including accelerometer, gyroscope, gravity, and magnetic field [13]. The MBAR indicator is a categorical variable that divides each moment into an activity type: "On foot," "Walking," "Running," "On bicycle," "In vehicle," "Unknown," "Still" (the device is not moving), and "Tilting" (the device angle relative to gravity has changed significantly). Each categorization is also ascribed a confidence level score between 0 and 100. In the present study, each participant's MBAR category was weighted by this score, such that categories with high confidence level scores were considered a more accurate assessment of the type of activity.

Diet

Self-reported dietary behavior at baseline was measured using questions validated for adolescents by the NSW Centre for Public Health Nutrition [14] to allow comparisons with Dietary Guidelines for Children and Adolescents in Australia [15]. Self-reported dietary behaviors relating to the previous 24-hour period were also collected each week for the 22-week follow-up period via an EMA. Questions included:

(i) *"In the past 24 hours, have you eaten any serves of fruit?"* If participants responded "yes," a follow-up question was asked: *"How many serves of fruit? (A serve = 1 medium piece or 2 small pieces of fruit or 1 cup of diced pieces)"*;

(ii) *"In the past 24 hours, have you eaten any serves of vegetables?"* If participants responded "yes," a follow-up question was asked: *"How many serves of vegetables? (A serve = 1/2 cup cooked vegetables or 1 cup of salad vegetables)"*; and

(iii) *"In the past 24 hours, have you had any meals or snacks such as burgers, pizza, chicken, or chips from places like McDonalds, Hungry Jacks, Pizza Hut, KFC, Red Rooster or local takeaway food places?"* If participants responded "yes," a follow-up question was asked: *"How many meals?"*

Psychological well-being

Self-reported psychological distress was based on the Kessler Psychological Distress 6-item scale (K6) [16]. Response options for each K6 item included "none of the time," "a little of the

Table 2
Number of responses to health and well-being EMAs before and after the implementation of physical distancing guidelines in New South Wales (Australia) among adolescents in Sydney[a]

Characteristic	Pre (N = 4,504)	Post (N = 301)	Total (N = 4,805)
Diet			
Fruit consumption			
Median (IQR)	2 (0–3)	2 (0–2)	2 (0–3)
≤2 serves	1,846 (73.52)	121 (76.1)	1,967 (73.67)
≥3 serves	665 (26.48)	38 (23.9)	703 (26.33)
Vegetable consumption			
Median (IQR)	2 (1–3)	2 (1–3)	2 (1–3)
≤3 serves	2,116 (84.4)	130 (81.76)	2,246 (84.25)
≥4 serves	391 (15.6)	29 (18.24)	420 (15.75)
Fast food consumption			
Median (IQR)	0 (0–1)	0 (0–0)	0 (0–1)
Did not consume	1,585 (63.22)	126 (79.25)	1,711 (64.18)
Consumed	922 (36.78)	33 (20.75)	955 (35.82)
Physical activity, relationships, and sedentary behavior			
Physical activity			
No	1,256 (51.39)	93 (56.36)	1,349 (51.71)
Yes	1,188 (48.61)	72 (43.64)	1,260 (48.29)
Spend time with			
Not alone	2,161 (83.37)	130 (74.71)	2,291 (82.83)
Alone	431 (16.63)	44 (25.29)	475 (17.17)
Hours spent to access Internet social media			
Median (IQR)	3 (2–5)	3 (2–5)	3 (2–5)
≤3 hours	1,430 (58.7)	92 (55.76)	1,522 (58.52)
≥4 hours	1,006 (41.3)	73 (44.24)	1,079 (41.48)
Hours spent watching TV			
Median (IQR)	1 (0–2)	1 (0–2)	1 (0–2)
Did not watch	1,090 (44.65)	79 (47.88)	1,169 (44.86)
Watched	1,351 (55.35)	86 (52.12)	1,437 (55.14)
Sleep hours			
Median (IQR)	8.08 (7–9.05)	8.83 (6.92–9.58)	8.08 (7–9.12)
<8 hours	383 (42.65)	19 (35.85)	402 (42.27)
≥8 hours	515 (57.35)	34 (64.15)	549 (57.73)
Psychological well-being			
Positive emotion			
Median (IQR)	2 (1–3)	2 (1–2)	2 (1–3)
0–2	1,534 (57.93)	136 (80.47)	1,670 (59.28)
3–4	1,114 (42.07)	33 (19.53)	1,147 (40.72)
K6 score			
Median (IQR)	15 (11–20)	15.5 (11–20)	15 (11–20)
6–18	663 (69.7)	89 (68.46)	752 (69.57)
19–30	288 (30.3)	41 (31.54)	329 (30.43)
Engagement			
Median (IQR)	2.75 (2.25–3.25)	3 (2.25–3.5)	2.75 (2.25–3.5)
1–2	285 (35.63)	48 (30)	333 (34.69)
3–5	515 (64.38)	112 (70)	627 (65.31)
Perseverance			
Median (IQR)	3 (2.5–3.75)	3 (2.25–3.75)	3 (2.5–3.75)
1–2	191 (23.9)	48 (30)	239 (24.9)
3–5	608 (76.1)	112 (70)	720 (75.1)
Optimism			
Median (IQR)	2.75 (2–3.5)	2.75 (2–3.75)	2.75 (2–3.5)
1–2	264 (33.12)	58 (36.25)	322 (33.65)
3–5	533 (66.88)	102 (63.75)	635 (66.35)
Connectedness			
Median (IQR)	4 (3.25–4.75)	4 (3–4.5)	4 (3.25–4.75)
1–2	75 (9.4)	19 (11.88)	94 (9.82)
3–5	722 (90.6)	141 (88.13)	863 (90.18)
Happiness			
Median (IQR)	3.25 (2.25–3.75)	3 (2.25–3.75)	3 (2.25–3.75)
1–2	205 (25.69)	52 (32.5)	257 (26.8)
3–5	593 (74.31)	108 (67.5)	701 (73.2)

IQR = interquartile range.

[a] 4,805 responses were received for at least one weekly administered EMAs from 582 participants; psychological distress and EPOCH component category totals are smaller compared with other EMAs as these were administered monthly.

time," "some of the time," "most of the time," and "all of the time" and were scored in the range of 1–5 respectively. A score ≥19 was used as indicative of probable mental disorder as recommended [16]; however, it is important to note that this standard cut point may overlook those with more moderate levels of psychological distress that may still be important [17].

Table 3
The impact of physical distancing policies on physical activity and sedentary behaviors, dietary behavior, and psychological well-being among adolescents aged 13—19 years (N = 582) in Sydney (all EMA responses relate to the previous 24 hours unless indicated)

Outcome variable	Unadjusted odds ratio	Adjusted odds ratios[a]
Diet		
Fruit consumption (n = 454)		
Preimplementation	1.00	1.00
Postimplementation	.64 (.39—1.04)	.6 (.36—1.01)
Vegetable consumption (n = 454)		
Preimplementation	1.00	1.00
Postimplementation	1.11 (.61—2.01)	1.03 (.55—1.93)
Fast food consumption (n = 454)		
Preimplementation	1.00	1.00
Postimplementation	.47 (.3—.73)	.46 (.29—.73)
Physical activity, relationships, and sedentary behavior		
Physically active for 60+ mins (n = 464)		
Preimplementation	1.00	1.00
Postimplementation	.53 (.35—.8)	.53 (.34—.83)
Alone in the last hour (n = 477)		
Preimplementation	1.00	1.00
Postimplementation	1.94 (1.26—2.98)	2.09 (1.33—3.28)
Social media and Internet use (n = 464)		
Preimplementation	1.00	1.00
Postimplementation	2.21 (1.41—3.46)	1.86 (1.15—3)
TV hours (n = 464)		
Preimplementation	1.00	1.00
Postimplementation	.87 (.56—1.35)	.9 (.56—1.42)
Sleep hours (n = 341)		
Preimplementation	1.00	1.00
Postimplementation	1.40 (.71—2.78)	1.19 (.57—2.51)
Psychological well-being		
Positive emotions (n = 490)		
Preimplementation	1.00	1.00
Postimplementation	.26 (.16—.43)	.23 (.14—.39)
K6 score[b] (n = 421)		
Preimplementation	1.00	1.00
Postimplementation	1.59 (.81—3.12)	1.48 (.74—2.95)
Engagement (n = 375)		
Preimplementation	1.00	1.00
Postimplementation	1.36 (.77—2.41)	1.55 (.85—2.83)
Perseverance (n = 375)		
Preimplementation	1.00	1.00
Postimplementation	.42 (.21—.82)	.52 (.25—1.09)
Optimism (n = 375)		
Preimplementation	1.00	1.00
Postimplementation	1.17 (.61—2.24)	1.15 (.59—2.27)
Connectedness (n = 375)		
Preimplementation	1.00	1.00
Postimplementation	.58 (.23—1.47)	.61 (.24—1.52)
Happiness (n = 375)		
Preimplementation	1.00	1.00
Postimplementation	.41 (.2—.83)	.38 (.18—.82)

[a] Adjusted for sex, age, body mass index, employment status, and K6 score at baseline.
[b] Adjusted for sex, age, body mass index, and employment status.

The Engagement, Perseverance, Optimism, Connectedness, and Happiness (EPOCH) measure of well-being was also included in the study to capture information on positive psychological characteristics [18] using a 5-point scale from "almost never" to "almost always." The K6 and EPOCH questionnaires (Supplementary Materials) were completed by participants at baseline with follow-ups sent to each participant every 4 weeks and short EMAs relating to selected EPOCH items sent weekly [19].

In addition, social relationships were measured based on the question: *"In the past hour, who were you with?"* Participants could respond to one or more of the following options: "alone," "mother," "father," "sister(s)," "brother(s)," "other relatives," "classmates, peers," "strangers," "boyfriend or girlfriend," "friends," and "other, please specify." For participants who answered "friends," an additional question was asked: *"How many friends?"*

Finally, self-reported sleep duration in the previous 24 hours was also collected at baseline via a weekly EMA over the 22-week follow-up period.

Other study factors

A range of sociodemographic and other health factors were also collected at baseline. These factors included sex, age, language spoken at home, current year of school and educational achievement, employment status, income, and body mass index (based on self-reported height and weight; Table 1).

Data analysis

The change in measures of physical activity, dietary behavior, and well-being was compared pre- and post-implementation of the NSW guidelines for physical distancing to determine whether this policy resulted in significant changes in these key health behaviors. These guidelines officially came into effect on March 31, 2020 [20]; however, physical distancing began in the earlier period of March with the closure of pubs, clubs, gyms, cinemas, places of worship on March 23, 2020 [21] and evidence of parents keeping children at home from school. Accordingly, the period for when physical distancing began to be implemented was defined as March 23, 2020.

Analyses were restricted to those participants who completed at least one EMA over the follow-up period (N = 582; Table 1). Participants were predominantly female, with a median age of 17 years (interquartile range, 16—18). Most participants spoke English at home (86%), were either in their senior year of schooling (23%) or finished school (43%), and almost 60% worked in a job (mainly part time). These participants contributed 4,805 responses to EMAs over the 22-week follow-up period, including 301 responses in the period after implementation of physical distancing guidelines (Table 2). The mean number of EMAs per week for this group was 9.6 (standard deviation = 5.8), and the median number of EMAs per week was 10 (interquartile range = 3—16). Comparisons of participant characteristics between (1) those who completed baseline and follow-up, (2) those who completed EMAs pre- and post-implementation of the physical distancing policy, and (3) those who provided or did not provide sensor are provided in Supplementary Tables 1 and 2

Descriptive plots of trajectories of physical activity were examined over the 22-week follow period, based on daily pedometer data, MBAR, and weekly self-report EMAs. Trajectories of self-reported fruit, vegetable, and fast food consumption were also examined based on weekly EMAs, as were trajectories of psychological well-being based on distress, well-being, and sleep duration. Multivariate multilevel mixed effect logistic regression models were conducted to investigate associations between the implementation of NSW guidelines (specified as a binary pre-post variable on March 23, 2020) and subsequent changes in physical activity, dietary behavior, and well-being measures.
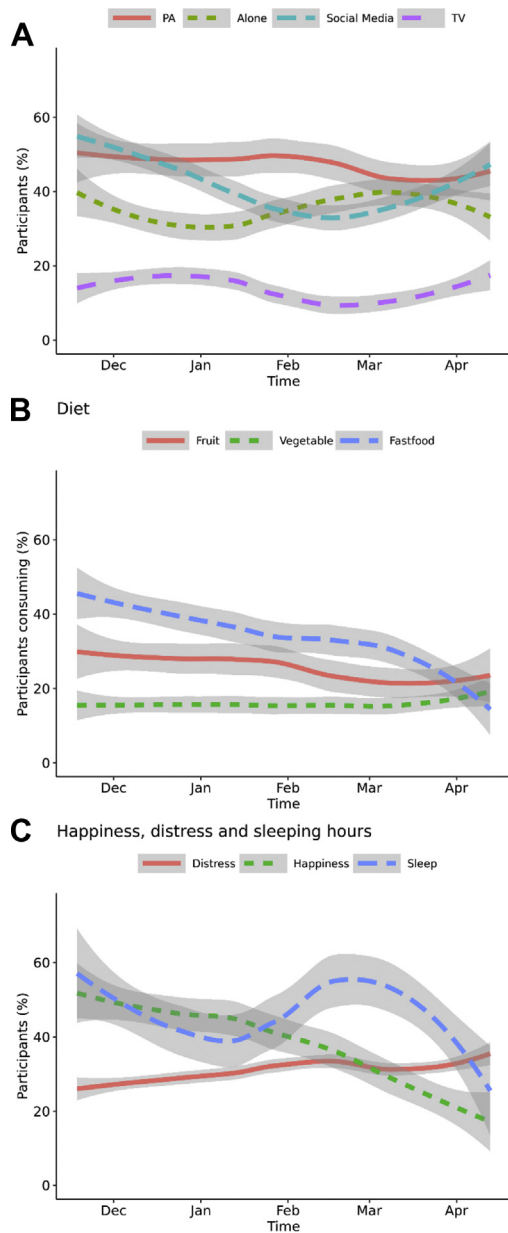
Figure 1. Trends in weekly ecological momentary assessments for (A) diet, (B) physical activity and sedentary behavior, and (C) psychological distress and happiness* among aged 13–19 years (n = 582) in Sydney, November 18, 2019, to April, 8, 2020. *Psychological distress based on K6 score ≥19 indicating "probable mental disorder"; Happiness based the question "At the moment how happy are you?" with percentage of participants responding "very much" or "quite a lot" presented. Sleep represents the percentage of participants referring less than 8 hours of sleep during the previous night.

Results

There were significant decreases in physical activity in the period after the implementation of physical distancing measures in NSW. Adolescents were significantly less likely to report ≥60 minutes of physical activity in the previous 24 hours in the period after physical distancing measures were implemented compared with the previous period (odds ratio [OR] = .53, 95% confidence interval [CI] = .34–.83; Table 3; Figure 1A). Declines

in physical activity were also evident based on the average number of steps per day and MBAR (Figure 2A,B). There was also a significant increase in sedentary activity postimplementation of physical distancing, with higher social media and Internet use (OR = 1.86, 95% CI = 1.15–3.0; Table 3, Figure 2A) and also evidence of increased screen time based on participants' smartphone screen state (Figure 2C).

The implementation of physical distancing measures was associated with lower levels of happiness (OR = .38, 95% CI = .18–.82) and positive emotions (OR = .23, 95% CI = .14–.39), respondents reporting being alone in the previous hour (OR = 2.09, 95% CI = 1.33–3.28), and slightly higher increases in psychological distress (OR = 1.48, 95% CI = .74–2.95; Table 3, Figure 2B). There were also declines in fast food consumption following implementation of physical distancing (OR = .46, 95% CI = .29–.73) but no substantial changes in fruit and vegetable consumption, TV watching, or sleep duration (Table 3; Figure 1C).

Discussion

This study investigated the impact of physical distancing guidelines implemented in New South Wales, Australia, on a range of health and well-being outcomes among a cohort of adolescents aged 13–19 years in Sydney. The implementation of physical distancing interventions was associated with decreases in physical activity and well-being, and increases in being alone and social media and Internet use in the 4 weeks after the policy was implemented. There was also a decrease in self-reported fast food consumption in the 4 weeks after the policy was implemented, but little change in fruit or vegetable consumption. These findings suggest that the substantial changes to the way in which communities are currently functioning, particularly for young people, has had a contemporaneous impact on health and well-being outcomes associated with chronic disease.

An important finding in the present study were the decreases in happiness reported after the implementation of the physical distancing guidelines and a higher likelihood of being alone during this period. Social isolation is an important risk factor for poorer psychological well-being among young people and, conversely, peer-, family- and school-connectedness play key roles as protective factors [22]. These protective connections may not have been as accessible to young people during the period of physical distancing resulting in lower levels of psychological well-being. It will be important to ensure that protective connections and other strategies to support the well-being of young people are maintained, to mitigate the potential psychological impact on young people. In Australia, COVID-19 cases remain low at the time of reporting; however, it is possible that physical distancing restrictions and online education may need to be reinstated if a second or third wave of infections eventuates.

The shift to online delivery of education in NSW and the requirement to defer any nonessential travel is reflected in the increase in social media and Internet use for the corresponding period in this study. There was also a decrease in physical activity likely related to the suspension of school and community sport and potentially mediated by a lack of access to green space in home environments. Recent reviews have suggested both positive and negative impacts of social media, determined by the type of involvement (e.g., passive use, high investment, or support seeking) as well as the amount of time spent on screen-based activity [7,23,24].
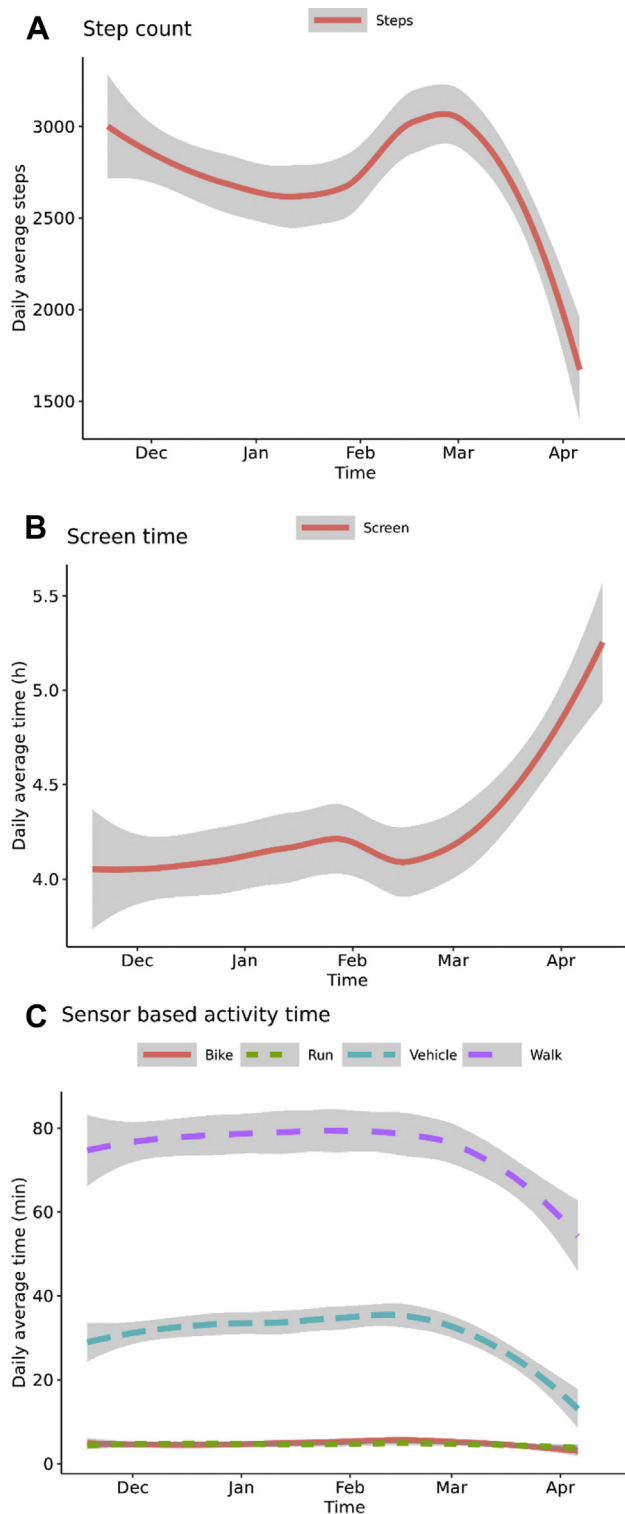
Figure 2. Declines in physical activity and increases in smartphone use in March and April 2020 among adolescents aged 13—19 years (n = 515) in Sydney, as measured by smartphone sensors.* Step counts (n = 429), screen time (n = 473), and sensor-based activity time (n = 490).

In addition, some studies have found that screen-based sedentary behavior supplants time spent sleeping or engaged in physical activity [7]. The present study did not directly examine the association between screen-based sedentary behavior and physical activity, but while the pattern of findings is consistent with the idea of displacement, this may only be relevant when time is constrained (such as during school term or nonholiday periods). The finding that sleep hours did not decline contemporaneously with increased screen time perhaps suggests study participants had more time to engage in sedentary behavior without disrupting sleep duration. It remains to be seen whether sedentary behavior observed during the period of physical distancing will revert back to levels observed before physical distancing measures. This will be an important focus for future research, given the evidence that sedentary habits in adulthood are typically established during adolescence [12].

An interesting finding was the decrease in fast food consumption in the context of limited changes to fruit and vegetable consumption. This likely reflects a decrease in opportunistic purchases of fast food during the day and traveling either to school or to work. Previous research has found increased consumption of this food type among adolescents and young people where there is a high density of fast food outlets located near schools and transport hubs [25,26]. Since the initial period of physical distancing, many fast food outlets have moved to take away and home delivery; however, the reduced consumption observed may indicate that fast food consumption was opportunistic and more associated with connecting socially with friends [26]. Future studies could consider the impact of these changes on food delivery on the consumption of fast food among younger people of different ages and with differing discretionary income and access to private transport.

The present study also found that consumption of fruit and vegetables did not increase, suggesting either that similar food types were substituted or there was a decrease in overall caloric intake. Consumption of calorie-dense foods can be positively associated with feelings of stress, and given the reduction in fast food consumption occurred in the context of increased social isolation and psychological distress, this might explain the lack of nutritional substitution implied in this finding. Despite reduced consumption of these food types via fast food outlets, there may have been an overreliance on processed supermarket food during this period—a limitation to this finding was that more specific questions relating to processed or junk food (i.e., not fast food purchases) were not explicitly measured. Australia experienced panic buying of processed foods resulting in supermarkets placing limits on a number of food items because of shortages. However, this was not observed for fresh fruit and vegetables. Alternatively, it may be that the development of new health-promoting behaviors takes time to develop, and the observation period of the present study was not long enough for this to emerge.

There are a number of methodological limitations to this study. First, although there was a positive response to the study through Instagram and Facebook, participants who were more likely to engage were overwhelmingly female and more likely to be older in age (16—18 years). The higher proportion of females may reflect greater engagement in social media among females than males, a phenomenon that has been noted in representative studies of social media use in Australia [9,10]. Despite the imbalance by sex, the distribution of responses by key dietary behaviors, physical activity, and well-being outcomes was not substantially dissimilar to other representative prevalence studies of adolescents [26,27]. The

higher proportion of older-age adolescents likely reflects that for those aged 13–15 years, parental or guardian consent was required before enrollment in the study. This involved additional steps in making contact with parents or guardians via email and to arrange for links to download the Ethica app, which likely discouraged some younger potential participants from enrolling in the study.

An additional limitation was the low EMA and follow-up survey completion rate. Despite the use of an incentive (AUD $30 GiftPay voucher), only 45% of baseline participants (N = 1,298) completed one or more subsequent EMA, and <1% completed all 96 EMAs over the follow-up period. The weekly schedule of EMAs may have been too burdensome for participants, and future research may need to consider different schedules or incorporation of personalized feedback to keep young people engaged.

There is also the risk of recall bias in this study, given the self-reported nature of the baseline and follow-up questionnaires. However, EMAs in (near) real time potentially reduce the likelihood or recall bias, in that questions relate to the immediate 24-hour period. Patterns of EMA responses relating to physical activity and screen time were also consistent with objective measures of physical activity based on available mobile phone sensor data, and the results were also generally comparable with previous adolescent health surveys for some of the measures [26,27].

Smartphone sensor data, collected passively from participants, were also used as proxy measures of physical activity and sedentary behavior. This was an innovative aspect of the study design and allowed comparison with EMA responses and investigation of trajectories of spatiotemporal movement among participants. However, a large proportion of participants either did not turn on some smartphone sensors (e.g., geolocation) or there were intermittent trajectories of movement, where sensor data were not collected. This resulted in complete sensor information being available on only 515 participants over the follow-up period, only 40% of baseline participants (N = 1,298). The reasons for participants choosing not to engage in this aspect of the study are unclear but may relate to concerns about individual privacy, among both participants and caregivers (who were required to give parental consent for young people aged <16 years).

There is also likely to be misclassification in smartphone sensor data, where periods between the initiation and cessation of a given state (e.g., "walking" in the MBAR sensor) were likely overestimated, as the smartphone did not register the cessation of the state but only the initiation of the subsequent state (e.g., "still" in the MBAR sensor). This means that the overall level of activity as measured by the smartphone sensor will be an overestimate; however, relative changes over time are likely to reflect actual declines or increases, and changes in EMAs appear to be consistent with changes in activities as measured by smartphone sensors.

The present study suggests the potential immediate impacts on health behaviors that are intermediary to chronic disease outcomes. However, it is not clear whether there will be long-term psychosocial and health impacts associated with the physical distancing policies. These policies will be slowly wound back over coming weeks, and education and employment experiences will return to a degree of normality. The wider economic impacts associated with physical distancing and other policies relating to the closure of businesses and entertainment precincts on health outcomes are also not known. It is unclear whether the changes in health and well-being documented in the present study will be transient or whether there may be ongoing impacts. Additional research needs to establish longer term trends in these outcomes to inform public health policy and intervention responses.

This study provided a unique opportunity to measure health behaviors and psychological well-being among Australian adolescents during the COVID-19 pandemic. Data collection occurred pre- and post-implementation of widespread physical distancing regulations in the community. These public health interventions have successfully "flattened the curve" on COVID-19 to date; however, there have also been important changes among young people on a range of health and well-being outcomes. Further research is needed to monitor the longer term trends in these outcomes. As the pandemic evolves, it will be important to consider how best to support psychological and physical well-being for young people to mitigate against potential longer term negative impacts.

Supplementary Data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jadohealth.2020.08.008.

Funding Sources

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