Child and parent physical activity, sleep and screen time during COVID-19 compared to pre-pandemic nationally representative data and associations with mental health

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Abstract

Objective: To investigate differences in movement behaviors (physical activity, sleep, screen time) in both parents and children during the early stages of COVID-19 pandemic in Australia, compared to pre-COVID-19 national data; and, estimate associations between these movement behaviors with parent and child mental health.

Methods: We used cross-sectional baseline data from the COVID-19 Pandemic Adjustment Study (CPAS; N=2,365). Participants were parents of children aged ≤ 18 years, residing in Australia. We drew on nationally representative pre-COVID data from the Longitudinal Study of Australian Children (LSAC; N=9,438). In both studies, parents provided the same self-report measures of physical activity, sleep quality, as well as measures of child physical activity and screen time. Parents reported on their own and their child's mental health.

Results: Compared to LSAC, children in CPAS had more sleep problems (17.4% vs 8.9%, $p < .001$) and more weekend screen time (3.98 hours vs 3.35 hours, $p < .001$), while more parents had poor sleep quality (56.7% vs 21.0%, $p < .001$) despite increased weekly physical activity (3.86 days vs 2.85 days, $p < .001$). Children's sleep problems were associated with increased depression, anxiety and irritability symptoms, after accounting for physical activity and screen time (all $p < .001$). Poorer parent sleep quality and lower levels of physical activity were associated with poorer mental health across all indicators (all $p \leq .001$).

Conclusion: Government funded mental health programs to implement evidence-based sleep interventions for children and their parents, along with targeted messaging around physical activity should be considered to promote mental health within the family context during lockdown restrictions.

Keywords: sleep, screen time, physical activity, mental health, COVID-19, depression, anxiety, children, adult, parent, family

Lay Summary: This study investigates how home confinement and social isolation restrictions occurring early in the COVID-19 pandemic are associated with physical activity, sleep and screen time in Australian parents and children compared to pre-pandemic rates. Compared to pre-pandemic nationally representative data, children in the current study had more sleep problems and more weekend screen time, while more parents had poor sleep quality despite greater weekly physical activity during the early stages of the pandemic. Children's sleep problems were associated with a range of mental health indicators including symptoms of depression, anxiety and irritability. Poorer parent sleep quality and lower levels of physical activity were associated with poorer mental health, including symptoms of depression, anxiety, stress, difficulties with emotion regulation and lower positive affect.

Introduction

COVID-19, a disease caused by the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-Cov-2), was classified as a pandemic by the World Health Organization on March 11, 2020.¹ In an attempt to stop the spread of COVID-19, strict quarantine and social distancing measures were implemented around the world, including in Australia, where Federal and State governments introduced Stage three lockdown² in April 2020 to reduce the rate of infection. Many of the behaviors that ultimately cause or prevent the spread of COVID-19 are likely to have an impact on a number of important health promoting movement behaviors, including physical activity, screen time and sleep.^{3,4} These include home confinement, school closures, restriction on the gathering of groups of people, and the shutdown of community services and facilities, such as organized sports, playgrounds, pools and gyms.

While there have been several commentaries published on the topic,^{5,6} there is limited evidence on how these COVID-19 related restrictions may be affecting people's physical activity, sleep quality and sedentary behavior, including recreational screen time. However, emerging literature points to a range of negative impacts of COVID-19 restrictions across these domains.⁷ For example, it is not difficult to see how the closure of parks, beaches and sports facilities, as well a lesser need for active transport as people are urged to stay home, and increases in screen use related to working and schooling from home, may reduce the time that children and parents spend in environments associated with physical activity. Similarly, increased time at home may disrupt normal routines, with increased access to screens, for example due to home schooling, and potential changes to bedtime routines, with a lack in structure that comes along with regular attendance at work, school and other extracurricular activities. In addition, pre-pandemic research has shown that, on unstructured and non-school days, which may be considered similar to those occurring during COVID-19-related home

confinement, there is a tendency for children to be less physically active and more sedentary,⁸ to engage in more recreational screen time⁹ and to have less regularity in their sleep patterns.¹⁰ To-date, there has been minimal evidence considering the impact of home confinement on physical activity, sleep and screen time for both children and parents within households, meaning that the overall family burden of changes in movement related behaviors is not well understood.

If COVID-19 changes around strict quarantine and social distancing have resulted in normative change across movement behaviors, such a change may pose a threat not only to physical health,^{11,12} but also their mental health. For example, poor sleep (e.g., increased sleep onset latency, waking overnight) has been linked with symptoms of depression and anxiety in children,¹³ as well as in adults.^{14,15} Similarly, lower levels of physical activity and greater amounts of time spent in sedentary activities have been linked to poorer mental health outcomes among children, including increased anxiety and depressive symptoms^{16,17} and irritability.¹⁸ A similar picture presents itself among adults, where reductions in physical activity are related to increases in mental health symptoms,^{19,20} and a greater likelihood of being diagnosed with a number of clinical disorders, including Major Depressive Disorder.^{21,22} Furthermore, any negative change to movement behaviors, brought about by COVID-19 restrictions, may be further compounded by the likely experience of a range of COVID-19 stressors, including environmental (e.g., loss of employment, housing) and biopsychosocial (e.g., COVID-19 diagnosis, loss of social support) stressors. Within families, these have the potential to directly impact child health through adverse impacts on parent health.

The aim of the current study was to investigate levels of physical activity, screen-time and sleep during the early stages of COVID-19 social restrictions in Australia compared to pre-COVID-19 national data and to estimate the association between these movement

behaviors and a range of mental health indicators among both parents and children. Specific aims were to:

- 1) Compare levels of child screen time and sleep (problems and regular bedtime routine) during the early stages of the COVID-19 social restrictions to Australian pre-pandemic national data.
- 2) Compare levels of parent sleep quality and physical activity during the early stages of the COVID-19 pandemic to Australian pre-pandemic national data.
- 3) Investigate the associations between child physical activity, sleep and screen time with child indicators of mental health, including depression symptoms (in children aged 2-18 years), anxiety symptoms (in children aged 2-18 years) and irritability (in children aged 0-18 years), and whether these associations were moderated by COVID related stressors.
- 4) Investigate the association between parent physical activity and sleep quality with parent depression, anxiety, stress, emotion regulation and positive affect, and whether these associations were moderated by COVID related stressors.

Method

The COVID-19 Pandemic Adjustment Survey (CPAS)

This study uses cross-sectional baseline data from the COVID-19 Pandemic Adjustment Survey (CPAS),²³ which aims to investigate the mental health impacts of the COVID-19 crisis in a sample of Australian parents via regular (longitudinal) online surveys. Participants were recruited via paid and unpaid social media advertisements using a range of methods (e.g., targeting demographic factors and postcodes) to increase the representativeness of the sample. Recruitment occurred over the period 8-28th April, 2020, which coincided with the Australian Federal and State governments introducing an

increasingly strict regime of social distancing and social isolation measures to slow the rate of infection early in the pandemic. Participants were 2,365 Australian parents. Parents were eligible to participate if they resided in Australia and were aged ≥ 18 years, English speaking and a current parent of a child aged 0-18 years. The current study was approved by the Deakin University Human Ethics Advisory Group (HEAG-H 52_2020).

The Longitudinal Study of Australian Children (LSAC)

We drew on national data from the Longitudinal Study of Australian Children (LSAC), a nationally-representative prospective cohort study of Australian children and their families.²⁴ Participating children were randomly selected in a two-stage cluster sampling design using Australian postcodes and the Medicare universal healthcare database.²⁵ We used biennial parent-report data (99% mothers) from three waves of the Baby cohort (N=5,107), covering child ages 0-1 (Wave 1, collected in 2004), 2-3, and 4-5 years; and from five waves of the Kindergarten cohort (4,656), covering child ages 6-7 (Wave 2, collected in 2006), 8-9, 10-11, 12-13, and 14-15 years.

Measures

Please see Table 1 for a summary of socio-demographic, parent, child and COVID-19 risk measures from CPAS and LSAC used in the current analysis.

Population weighting

Post-stratification weights in the CPAS dataset were derived to compensate for differences between the final sample and the national population of parents. Post-stratification weights for CPAS were produced through a raking approach,²⁶ using six demographic factors: (1) geographic location (major city, inner and outer regional areas, and

remote areas); (2) child age groups (0-4, 5-9, 10-12, 13-14, and 15-18 years); (3) parent gender (male, female); (4) family structure (single parent, couple family); (5) parent education (did not complete high school, high school completion; and (6) pre-pandemic parent employment status (employed, unemployed). The CPAS dataset was weighted to be equivalent to a subpopulation of Australian adults (i.e., parents of a child 0-18 years), with an estimated total population size of 8.4 million parents. LSAC population weights were also applied in weighted analyses.

Missing Data

Analyses were conducted in Stata version 16. Item level missing data in the CPAS study ranged from 0 to 8% on individual variables; and up to 29% in the LSAC study. Missing data were therefore replaced using multivariate multiple imputation by chained equations for each study separately. All variables from the final analytic models and weights were included in the multiple imputation model to create 50 imputed datasets. All reported results are from the multiply imputed datasets.

Statistical analysis

To address Aims 1 and 2, proportions and 95% confidence intervals were calculated for LSAC data using all available time-points for each measure. Two sets of CPAS estimates were calculated; firstly, for the full available sample; and secondly, for an age-matched subsample consistent with LSAC age ranges to allow comparison with the LSAC national data. LSAC estimates were averaged across available waves within each imputation model, and then combined across the Baby and Kindergarten cohorts using a meta-analysis process based on metaphor in R.^{27,28} For CPAS and LSAC, both unweighted and weighted data are presented to ensure reported outcomes are as close to population representation as possible.

However, given that our datasets varied from population statistics on a number of population indicators (see Table 2), we primarily focus on unweighted results. We conducted a series of independent samples t-tests to assess unweighted differences between samples/groups.

To address Aims 3 and 4, a series of unadjusted linear regression models, using unweighted CPAS data, were conducted to determine the association between movement behaviors and indicators of mental health in the CPAS sample. Next, adjusted models were conducted to assess the unique contribution of each movement behavior to each indicator of mental health, while accounting for the contribution of the other concomitant variables in the model. In regression models assessing adult data, adjustments were made for age, gender, deprivation, education, Aboriginal and Torres Strait Islander Peoples status and language other than English (LOTE) spoken at home, and for data related to child factors, adjustments were made for child age, child gender, parent age, parent gender, partner status, deprivation, and parent education. Final adjusted models were derived by including concomitant variables where there was evidence for an unadjusted association with the outcome ($p < 0.1$). Interaction terms were added to assess whether COVID related stressors moderated relationships between the movement behaviors and mental health indicators.

Results

Participant characteristics

Participant characteristics are presented in Table 2. CPAS parents had a mean age of 38 years ($SD=7.07$), were primarily female (81%), resided in a major city (70%) and had two children (46%) who were on average 9 years old ($SD=5.14$). Single parent households were a minority (11%), and half of the sample had a child at home while working (50%). Twelve percent of parents reported that their child had an Attention-Deficit/Hyperactivity Disorder

(ADHD) and/or Autism Spectrum Disorder (ASD) and more than half of parents indicated that they themselves had either a physical or mental health condition. In contrast, LSAC parents in both cohorts were almost all female, but there were similar proportions of LSAC parents born overseas or from single parent families, compared to CPAS parents. A greater proportion of LSAC parents spoke a language other than English and did not complete high school.

Physical activity, screen time and sleep during COVID-19 compared to national data

Table 3 presents parent and child physical activity, sleep, and screen time for CPAS compared to LSAC data.

Child

During the pandemic, approximately 1 in 6 parents reported that their child's sleep was a problem, in both the full CPAS sample (i.e., children 0-18 years) and the matched CPAS sample (children 0-13 years). This rate was close to double the rates reported by LSAC parents of children 0-13 years (17.4% vs 8.9%, $X^2(1, 11,621)=109.23, p<0.001$). Although 1 in 5 parents reported their child had no regular bedtime in the full CPAS sample, this was less frequent in the age-matched sample, where approximately 1 in 8 children did not have a regular bedtime. However, this rate was still much higher than the LSAC national data (13.1% vs 2.8%, $X^2(1, 11,621)=79.49, p<0.001$).

In the CPAS full sample, children spent on average just over three and four hours per day respectively engaged in weekday, and weekend day recreational screen time. These times were lower in the CPAS sample age-matched sample (i.e., aged 4-13 years), and there was evidence that CPAS parents reported their child spent less time engaged in recreational screen-time on weekdays ($t(11183)=4.31, p<.001, d=0.12$) but more time on weekend days ($t(11619)=-16.72, p<.001, d=-0.42$) compared to the LSAC national data.

Parents

On average, parents participated in at least 30 minutes of physical activity up to four days per week, in both the full and matched CPAS samples, which was higher than the average rates reported in the LSAC national data ($t(11620)=-24.96, p<.001, d=-0.63$). Over half of parents reported poor sleep quality in both the full and matched CPAS samples, which was more than double the average rates reported in LSAC national data (56.7% vs 21%, $\chi^2(1, 11,621)=1147.12$).

Sensitivity analysis

Given the high proportion of CPAS parents who reported having a child with ADHD and/or ASD, and the known links between the movement behaviors and mental health outcomes among these children and parents,^{29–31} a sensitivity analysis was run removing parents who reported having a child with these conditions to determine the effect on our findings (N=15%). No differences were found in our findings comparing CPAS age-matched sample with and without ADHD/ASD children compared to LSAC national data, indicating this over-representation did not change the interpretation of the findings reported.

Association between movement behaviors and mental health outcomes

Child

Unadjusted and adjusted models investigating the association between movement behaviors and mental health outcomes for children in the CPAS cohort are presented in Table 4. In unadjusted models, participating in at least 30mins of moderate or vigorous physical activity MVPA per day on fewer days ($B=-0.22, 95\% \text{ CI } [-0.32, -0.12], p<.001$), spending more hours per day engaged in weekday ($B=0.26, 95\% \text{ CI } [0.20, 0.32], p<.001$) and weekend day ($B=0.25, 95\% \text{ CI } [0.19, 0.31], p<.001$) recreational screen time, having no regular bedtime ($B=1.40, 95\% \text{ CI } [0.90, 1.90], p<.001$) and greater sleep problems ($B=2.68, 95\% \text{ CI }$

[2.18-3.18], $p < .001$) were associated with greater depressive symptoms. These associations remained significant in adjusted models for weekend screen time and sleep problems (both $p < .001$).

In unadjusted models, more problematic sleeping patterns in the CPAS cohort were associated with greater child anxiety symptoms ($B = 1.40$, 95% CI [1.11-1.68], $p < .001$) but no associations were found for having no bedtime routine, weekday or weekend screen time or physical activity (all $p > .05$). In adjusted models, the association remained for sleep problems ($B = 1.30$, 95% CI [1.01-1.60], $p < .001$) and having no regular bedtime became significantly associated with anxiety symptoms ($B = -0.30$, 95% CI [-0.59- -0.01], $p = .042$). Greater physical activity ($B = 0.04$, 95% CI [0.02-0.06], $p = .001$) and greater sleep problems ($B = 0.33$, 95% CI [0.20-0.45], $p < .001$) were both associated with child irritability in adjusted models. There was no significant moderating effect of COVID-19 environmental stressors or COVID-19 psychological stressors on the associations between movement behaviors and child mental health outcomes (all $p > .05$).

Sensitivity analysis. To account for our use of some measures in children of younger ages for which the measures have yet to be validated (e.g., our measure of depression and anxiety have been validated for children as young as 6 years, yet we investigated associations in children as young as 2 years in our full CPAS sample), we undertook a sensitivity analysis, including only children aged 6 years and above (see Supplementary Table 1). While for the most part our finding remained unchanged, when limiting the sample to 6 years and above, it was found that having an irregular bedtime was not associated with anxiety ($p = 0.181$) and that weekend screen time was not associated with depression ($p = 0.111$).

Parent

Unadjusted and adjusted models examining the association between movement behaviors and mental health outcomes for CPAS parents during the pandemic are summarized in Table 5. In adjusted models, lower levels of physical activity and poorer sleep quality were associated with greater parent depressive symptoms. Lower levels of physical activity and poorer sleep quality were also associated with parent anxiety and stress symptoms. Similarly, less physical activity and poorer sleep quality were associated with greater difficulties regulating emotions. More physical activity and greater sleep quality was associated with greater positive affect. COVID-19 environmental stressors moderated the association between sleep quality and depression ($B=0.31$, 95% CI [0.02-0.60], $p=.034$), and also moderated the association between sleep quality and difficulties with emotion regulation ($B=0.96$, 95% CI [0.09-1.84], $p=.031$), where parents reporting both high COVID-19 stressors and poor sleep quality reported the highest levels of emotion regulation difficulties and depression (see Figures 1 and 2). There was no significant moderating effect of COVID-19 psychological stressors on the associations between movement behaviors and parent mental health (all $p>.05$).

Discussion

This study aimed to understand associations between COVID-19 restrictions and movement behaviors in both children and parents, including whether movement behaviors are associated with poorer mental health in families. Given the growing body of research establishing the mental health impacts of COVID-19,³² identifying modifiable factors that can be targeted to improve mental health is a priority. Here we show that children and parents under lockdown restrictions report substantially higher rates of sleep problems compared to pre-pandemic rates, despite parents reporting increased physical activity. Children's sleep problems during COVID-19 were associated with elevated child depression, anxiety and irritability symptoms, after accounting for physical activity and screen time. Similarly, poorer parent sleep quality and lower levels of physical activity were associated with poorer parent mental health, increased emotion regulation difficulties, and reduced positive affect. Sleep and physical activity play an important role in our body's immune function,³³ thus promoting good sleep and regular physical activity is also likely to have benefits for physical and mental health during the COVID-19 pandemic.

A growing body of research has demonstrated an increase in sleep problems in the general population as a result of the COVID pandemic,³⁴⁻³⁷ however, these studies have not systematically compared rates of sleep problems to pre-pandemic levels and/or have not focused on parents and children specifically. The higher levels of child sleep problems and irregular bedtime reported by parents in the CPAS cohort, and the connection between child sleep problems and indicators of poorer mental health, suggest that sleep may be an important modifiable factor to improve children's functioning during the COVID-19 pandemic. Consistent with this notion, pre-pandemic studies have connected poorer sleep to increased mental health difficulties in children.³⁸ Even though it may be tempting to relax the rules around children's bedtime during lockdown restrictions, our data suggest that sleep problems

during the pandemic continue to be associated with worse mental health in children. Healthy sleep practices such as having a set bedtime and wake time, having a predictable bedtime routine, light exposure, reduced caffeine intake, and getting regular exercise, can all assist in regulating the circadian rhythm and improving sleep.³⁹ Children who have persisting sleep problems despite engaging in healthy sleep practices may benefit from more structured behavioral sleep strategies to improve sleep.³⁹ For example, this may involve working with parents to provide more consistency in implementing sleep routines and managing oppositional behavior at bedtime. Progressive muscle relaxation and cognitive behavioral strategies can also assist children to manage anxiety that may be interfering with sleep onset.⁴⁰

Parents in the current study also had substantially higher rates of sleep problems compared to national data, which is consistent with findings from a cross-sectional study of 1,005 adults in France.³⁷ It is notable that over half of parents rated their sleep quality as problematic. Moreover, sleep problems were associated with poorer parent mental health across multiple domains, even when accounting for physical activity levels. This is consistent with the findings of Stanton and colleagues (2020) in their general Australian sample of adults, however, we extend these findings by considering parents specifically, and simultaneously accounting for physical activity levels. Healthy sleep practices can be used to improve parent sleep difficulties, and again for more entrenched sleep problems, approaches such as cognitive behavior therapy for insomnia approaches may be beneficial.⁴¹

We found mixed evidence with regard to screen time. Children had lower levels of recreational screen use during weekdays but higher levels on weekends compared to pre-pandemic national data. It's important to note that parents reported on their child's screen-time related to 'non-educational purposes'. It may be that our findings are affected by variability in the context of schooling across participants. For example, a portion of children

are likely to have been on school holidays, which fell over a two week period between late March and late April (varying by State/Territory), and thus overlap with our data collection period (8th–28th April 2020). Further, about half the sample were juggling work from home while supervising children, and a portion of these children were engaged in remote learning ('home-schooling') at the time of data collection; which is likely to bear an increased screen-time load compared to on-campus school learning. It may be that parents restricted non-educational screen-time for children already spending much of their day on screens for educational purposes.

In unadjusted analyses, increased weekday and weekend screen time was associated with child depression symptoms but this association was attenuated for weekday sleep when accounting for sleep problems, physical activity, and other covariates. Similarly, associations between weekend screen time and child depression symptoms were attenuated when restricting analyses to those aged six years and above. Global movement behavior guidelines for children and adolescents⁴ recommend that young children aged 3-4 years engage in no more than 1 hour of sedentary screen time, and that older children and adolescents 5-17 years engage in no more than 2 hours of sedentary recreational screen time. On average, children in our study were engaging in 3 hours of screen time on week days and 4 hours on weekends, above recommended guidelines.

It is important to note that children may be using screens to maintain social connections and this likely has many positive benefits, particularly in context of limited opportunities for in-person interactions given COVID-19 restrictions. It is also difficult to tease apart the use of screens for educational and non-educational purposes. Overall the lack of association between screen time and poor child mental health is reassuring for parents. Further, it may not be realistic to reduce child screen time during COVID-19 social distancing restrictions. Instead, family media plans can be used to manage screen time at

home and parents should also consider the quality of the content that children are accessing during screen time.⁴² Fading (graduated extinction) approaches can also be considered to gradually reduce non-educational screen time to recommended levels. Overall, it will be important to monitor screen time in this cohort to see whether screen time naturally reduces once restrictions have lifted.

Australian movement behavior guidelines recommend that adults be active on most, and preferably all, days of the week, and that children should accumulate 60 minutes or more of moderate to vigorous physical activity per day, involving mainly aerobic activities.³ During the pandemic, children were engaging in five days of at least 30 minutes of moderate or vigorous physical activity, slightly below recommended levels. This finding is somewhat consistent with recent Canadian online survey showing that only 18% of children were adhering to physical activity recommendations.⁴³ Results are also consistent with Moore et al., who reported in their online survey that children experienced a significant decline in all physical activities compared to pre-pandemic rates, with the most dramatic decline seen in outdoor physical activity and sport.⁷

Although parents in the current sample appear to have high levels of physical activity compared to national data, it was lower than recommended guidelines. Even so, this increase compared to pre-pandemic national data is somewhat heartening, given lower levels of physical activity were associated with poorer mental health across all indicators, even when accounting for sleep quality. Prioritizing regular physical activity may be an important strategy for improving parent's mental health, and with COVID-19 related restrictions, it may be that parents are finding more time to engage in physical activity. Surprisingly, increased physical activity in children was associated with higher levels of irritability. It may be that parents of children with high irritability may be prioritizing exercise as an outlet to manage difficult child behavior.

Surprisingly, we found little evidence that COVID-19 related environmental or psychological stressors moderated associations between movement behaviors and mental health outcomes in children. However, for adults, COVID-19 environmental stressors moderated the association of sleep quality with both depression and emotion regulation. This is consistent with emerging research linking COVID-19 related risk factors to increased sleep difficulties.³⁴ This could mean that supporting parents to cope with COVID-19 environmental stressors could improve sleep and parent mental health, although this cross-sectional association needs to be examined using longitudinal designs.

Our study has a number of strengths. Our sample is relatively large, and we consider the connection between movement behaviors and mental health in both children and parents. Our study is comprehensive in that we examine multiple domains of mental health and movement behaviors. We also were able to compare movement behaviors to nationally representative pre-pandemic data. However, several limitations should be considered. First, our sample was recruited online and appears to be more vulnerable than the general population. One example is that the rates of ADHD and ASD are much higher than would be expected in the general population. To address this, we applied sample weighting and conducted a sensitivity analysis indicating that our results are robust, both with and without the higher-risk ADHD/ASD children. Second, we used some measures in children of younger ages for which the measures have yet to be validated and therefore may not be sensitive when used in younger children. However, most findings held when accounting for this in sensitivity analyses. Third, given that this is a cross-sectional study directionality cannot be inferred. For example, it may be that mental health difficulties are influencing movement behaviors, rather than the reverse. However, population-based longitudinal research has shown that sleep difficulties appear to precede internalizing difficulties in childhood, while there is more evidence of a bi-directional association between sleep and behavioral difficulties.³⁸

Longitudinal examination of this cohort will enable further understanding of the directionality between movement behaviors and mental health.

In summary, children in the current study had higher rates of sleep problems and increased weekend screen time compared to national pre-pandemic data. Parents had higher levels of sleep problems compared with pre-pandemic data, while physical activity appeared to also be higher. Improving child sleep problems may have flow on benefits to improving their mental health. Improving parent sleep and increasing parent physical activity may also be fruitful in improving parents' mental health. Monitoring this cohort over time will be important to examine whether changes in movement behavior are enduring or naturally improve with the easing of restrictions. Furthermore, recommendations about movement behaviors should be altered to reflect the challenges of the pandemic and incorporate some feasible approaches and tips to optimizing sleep and increasing physical activity during this pandemic.

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Table 1. Study measures

Construct	Measure (items)	CPAS	LSAC
Demographics	Parent age, gender, country of birth, Aboriginal and Torres Strait Islander status, whether a language other than English was spoken at home, highest level of education, relationship status, whether they were living with their partner, number of children in the household, geographic location and whether they had a mental health or physical health condition. Demographic information prior to COVID-19 included employment and study status, household income, source of income and shortage of money. Parents also reported on their child's age, gender and whether their child had a neurodevelopmental condition (Attention-Deficit/Hyperactivity Disorder, Autism Spectrum Disorder).	●	
COVID-19 psychological stressors	4 items adapted from the CoRonavIruS Health Impact Survey (CRISIS) V0.1. ⁴⁴ . Two items asked about participants feelings about the likelihood catching COVID-19, and COVID-19 being a serious health risk for the participant (both rated on a 7-point Likert scale ranging from 1=Strongly Disagree to 7=Strongly Agree) and two items asked about the extent to which they experience certain negative feelings (worry, fear) when thinking about their ability to deal with COVID-19 (both items rated on a 4-point scale from 'not at all' to 'a great deal'). These items were averaged to form a total score (range, 3-18), with higher scores reflecting greater COVID-19 related psychological stress ($\alpha=0.69$).	●	
COVID-19 environmental stressors	The following binary coded stressors (present/absence of stressor) were summed to form a count variable (range, 0-6). Housing insecurity, financial insecurity; job loss, new job, reduction or increases in work hours, or changes ('redeployment') in employment; food shortages; and COVID-19 illness (contracting the COVID-19 virus, hospitalization of themselves or a family member due to infection, and death of a family member due to the virus).	●	
Parent Measures			
Mental health	Depression Anxiety Stress Scale (DASS) - Symptoms of depression, anxiety and stress in the last week were assessed using the widely used and well-validated Depression Anxiety Stress Scale-21 (DASS-21, ^{45,46-47} . The scale comprises three 7-item subscales to measure depression ($\alpha=0.89$), anxiety ($\alpha=0.82$) and stress ($\alpha=0.87$), with items rated on a 4 point Likert scale (0=Did not apply to me at all to 3=Applied to me very much, or most of the time). Higher scores indicate greater symptom severity.	●	

Construct	Measure (items)	CPAS	LSAC
Emotion regulation	Difficulties in Emotion Regulation Scale-16 Item Version - Used to assess emotion regulation in parents ($\alpha=0.95$). Each item is rated on a 5-point Likert scale ranging from 1=Almost never to 5=Almost always (no time frame specified). Higher scores indicate greater emotion regulation difficulties.	●	
Positive affect	Positive and Negative Affect Schedule Short Form - A valid and reliable ⁴⁸ 5-item measure whereby participants rated on a 5-point Likert scale (1= Very Slightly or Not at All to 5=Extremely) whether each affective state applies to them in the present moment ($\alpha=0.80$). Higher scores indicate greater positive affect.	●	
Physical activity	Parent physical activity was assessed using the LSAC physical activity item, “About how many days each week do you do at least 30 minutes of moderate or vigorous physical activity (like walking briskly, riding a bike, gardening, tennis, swimming, running, etc.?)”, rated from 1 to 7 days.	●	●
Sleep	Parent sleep quality was assessed using the LSAC item, “During the past month, how would you rate your sleep quality overall?” Rated on a 4-point scale from ‘very good’ to ‘very bad. Item responses were then dichotomised, where response options 1-2 were coded 1 (very good/good) and 3-4 were coded 2 (very bad/bad).	●	●
Child measures			
Depression ^a	Short Mood and Feelings Questionnaire (SMFQ) – 13 item measure of child depression symptoms with items rated on a 3-point likert scale (1=Not true to 3=True) (overall $\alpha=0.87$; children 6 years and above, $\alpha=0.88$; children <6years, $\alpha=0.79$). Higher scores indicate greater depression symptoms.	●	
Anxiety ^a	Modified Brief Spence Children’s Anxiety Scale – 4-items assessing symptoms of anxiety ($\alpha=0.77$). Parents rated on a 4-point likert scale (‘never’ to ‘always’) how frequently their child had experienced symptoms in the last two weeks. Higher scores indicate greater anxiety symptoms.	●	
Irritability	1 item, adapted from the CoRonavIruS Health Impact Survey (CRISIS) ⁴⁴ , which asked, “During the past two weeks, how irritable or easily angered has your child been?” Parents rated this item on a 5-point Likert scale, ranging from ‘Not at all’ to ‘Extremely’, with higher scores indicating greater child irritability.	●	
Physical activity	Assessed via 1 item, adapted from LSAC, which asked parents, “About how many days each week did your child do at least 30 minutes of moderate or vigorous physical activity (like walking	●	●

Construct	Measure (items)	CPAS	LSAC
	briskly, riding a bike, gardening, tennis, swimming, running, etc.?)” Parents provided a rating ranging from 0 to 7 days.		
Sleep	Sleep pattern was assessed using the LSAC item, “How much is your child's sleeping pattern or habits a problem for you?” rated on a 4-point scale (‘not at all a problem’ to ‘a large problem’). Responses dichotomized, where response options 1-2 were coded 1 (not a problem/small problem) and response options 3-4 were coded 2 (moderate problem/large problem) as per previous research. ^{49,50} Child sleep regularity was assessed using the LSAC item, “Does the study child go to bed at regular times?” Parents rated this item on a 5-point scale, ranging from ‘never’ to ‘always’. Item responses were then dichotomized, where response options 1-3 (never/rarely/sometimes) were coded 1 and response options 4-5 (usually/always) were coded 2, with higher scores representing a more regular bedtime.	●	●
Screen time	Two items from LSAC, which asked how many hours on a typical (item 1) weekday and (item 2) weekend day did their child use media devices at home for non-educational purposes. Each item was rated on a sliding scale from 1 to 24 hours and provided a measure of weekday screen time and weekend day screen time (hours per day).	●	●

CPAS = LSAC = Longitudinal Study of Australian Children. ^a Measured only in children aged ≥ 2 years of age.

Table 2. Participant characteristics in the COVID-19 Pandemic Adjustment Survey ($N=2365$, child aged 0-18 years) and the Longitudinal Study of Australian Children Baby Cohort (Wave 1, $N=5,107$) and Kindergarten Cohort (Wave 3, $N=4,331$)

Participant characteristic ^a	CPAS (Time 1, 2020)	LSAC – B (Wave 1, 2004)	LSAC - K (Wave 3, 2008)
Parent age, m(sd)	38.30 (7.07)	31.0 (5.51)	39.1 (5.40)
Child age, m(sd)	8.66 (5.14)		8.26 (0.44)
Parent gender			
Cisgender men	19.2%	1.5%	4.3%
Cisgender women	80.7%	98.6%	95.8%
Transgender or nonbinary	<1.00%	NA	NA
Child gender			
Cisgender boy	50.9%	51.1%	51.1%
Cisgender girl	48.7%	48.9%	49.0%
Transgender or nonbinary	<1.0%	NA	NA
Aboriginal or Torres Strait Islander	2.1%	NA	NA
Language other than English	4.5%	14.4%	13.7%
Parent born overseas	17.9%	18.6%	20.4%
Low household income	14.0%	NA	NA
Receiving government benefit	5.8%	NA	NA
Did not complete high school	9.4%	33.3%	39.1%
Single parent household	10.9%	9.5%	29.3%
Geographic location			
Major Cities of Australia	69.8%	NA	NA
Inner Regional Australia	23.2%	NA	NA
Outer Regional Australia	6.1%	NA	NA
Remote Australia	1.0%	4.3%	3.7%
Number of children			
1 child	28.4%	39.5%	8.2%
2 children	46.1%	36.7%	44.2%
3 children	18.2%	16.1%	31.3%
4 or more children	5.3%	7.6%	16.4%
Parent mental or physical health condition	56.1%	NA	NA
Child neurodevelopmental condition			
Attention Deficit Hyperactivity Disorder	7.3%	NA	NA
Autism Spectrum Disorder	8.6%	NA	NA
COVID-19 related factors			
Deprivation index, m(sd)	0.38 (0.95)	NA	NA
Child home while working	49.64%	NA	NA

Notes: m(sd) = Mean (standard deviation), data are unweighted. NA = not applicable.

^a Data collected 8th-28th April 2020, data are multiply imputed and thus n cannot be presented for each characteristic.

^b \$52,000 or less per year

Table 3. Parent and child physical activity, sleep, and screen time compared to Australian normative data (LSAC)

	Unweighted						Weighted					
	CPAS			LSAC			CPAS			LSAC		
	%	LL	UL	%	LL	UL	%	LL	UL	%	LL	UL
Child sleep problem												
Full CPAS sample	17.7	15.9	19.4				16.4	13.6	19.2			
Matched: Children 0–13 years	17.4	15.5	19.3	8.9	8.6	9.3	16.9	13.6	20.2	9.6	9.1	10.0
Child no regular bed-time												
Full CPAS sample	20.1	18.3	21.8				21.5	18.2	24.9			
Matched: Children 0–13 years	13.1	11.4	14.8	2.8	2.5	3.0	15.0	11.3	18.7	3.1	2.7	3.4
Parent poor sleep quality												
Full sample	56.0	53.9	58.1				58.3	54.4	62.2			
Matched: Children 0–13 years	56.7	54.3	59.0	21.0	20.4	21.6	59.1	54.6	63.5	21.6	21.0	22.3
	M (SE)	LL	UL	M (SE)	LL	UL	M (SE)	LL	UL	M (SE)	LL	UL
Screen-time (weekday)												
Full CPAS sample	3.19 (0.07)	3.05	3.33				3.56 (0.13)	3.31	3.82			
Matched: Children 4–13 years	2.84 (0.07)	2.70	2.99	2.98 (0.01)	2.97	2.99	3.14 (0.13)	2.89	3.39	3.02 (0.01)	3.01	3.04
Screen-time (weekend)												
Full CPAS sample	4.33 (0.08)	4.18	4.48				4.84 (0.14)	4.56	5.11			
Matched: Children 4–13 years	3.98 (0.08)	3.82	4.13	3.35 (0.01)	3.34	3.37	4.45 (0.17)	4.12	4.79	3.36 (0.01)	3.34	3.38
Child physical activity												
CPAS: Children 1-18 years	4.93 (0.05)	4.84	5.02				4.91 (0.08)	4.75	5.07			
Parent physical activity												
Full CPAS sample	3.88 (0.04)	3.80	3.97				4.03 (0.09)	3.85	4.22			
Matched: Children 0–13 years	3.86 (0.05)	3.77	3.96	2.85 (0.01)	2.82	2.88	4.04 (0.11)	3.82	4.25	2.85 (0.02)	2.81	2.88

Notes: ‘Full CPAS sample’ refers to children aged 0-18 years. ‘Matched’ samples refer to CPAS participants that match the child age range available for LSAC normed data. LL/UL refer to the lower limit (LL) and upper limit (UL) estimates from 95% confidence intervals. SE = standard error.

Table 4. Associations between child movement behaviours (physical activity, screen time, sleep problems, and sleep routine) and mental health outcomes

	Unadjusted				Adjusted			
	<i>Coefficient</i>	LL	UL	<i>p</i>	<i>Coefficient</i>	LL	UL	<i>p</i>
Child Depression ^a								
Physical activity	-0.22	-0.32	-0.12	0.000	-0.05	-0.15	0.06	0.362
Screen time (weekday)	0.26	0.20	0.32	0.000	0.08	-0.02	0.18	0.123
Screen time (weekend)	0.25	0.19	0.31	0.000	0.13	0.03	0.23	0.009
Sleep problems	2.68	2.18	3.18	0.000	2.35	1.83	2.88	0.000
No regular bedtime	1.40	0.90	1.90	0.000	-0.08	-0.64	0.48	0.776
Child Anxiety ^b								
Physical activity	0.03	-0.03	0.09	0.298	0.05	-0.01	0.11	0.090
Screen time (weekday)	0.02	-0.02	0.05	0.382	-0.02	-0.07	0.03	0.455
Screen time (weekend)	0.02	-0.02	0.05	0.312	0.05	-0.01	0.10	0.078
Sleep problems	1.40	1.11	1.68	0.000	1.36	1.06	1.65	0.000
No regular bedtime	0.08	-0.18	0.34	0.562	-0.30	-0.59	-0.01	0.042
Child Irritability ^c								
Physical activity	0.03	0.01	0.05	0.010	0.04	0.02	0.06	0.001
Screen time (weekday)	0.01	-0.01	0.02	0.229	0.01	-0.02	0.03	0.654
Screen time (weekend)	0.01	-0.01	0.02	0.375	0.02	0.00	0.05	0.057
Sleep problems	0.34	0.22	0.46	0.000	0.33	0.20	0.45	0.000
No regular bedtime	0.01	-0.10	0.13	0.809	-0.01	-0.14	0.12	0.862

^a adjusted for child age, parent gender, no partner and other movement behaviours

^b adjusted for child age, parent gender, deprivation, no partner, education and other movement behaviours

^c adjusted for child age, parent age, parent gender and other movement behaviours.

Table 5. Associations between parent movement behaviours (physical activity and sleep quality) and mental health outcomes

	Unadjusted				Adjusted			
	<i>Coefficient</i>	LL	UL	p	<i>Coefficient</i>	LL	UL	p
Depressive symptoms ^a								
Physical activity	-0.40	-0.48	-0.31	0.000	-0.28	-0.36	-0.20	0.000
Poor sleep quality	2.63	2.29	2.98	0.000	2.16	1.82	2.51	0.000
Anxiety symptoms ^b								
Physical activity	-0.23	-0.30	-0.17	0.000	-0.13	-0.19	-0.07	0.000
Poor sleep quality	1.97	1.69	2.25	0.000	1.59	1.31	1.87	0.000
Stress ^c								
Physical activity	-0.29	-0.38	-0.21	0.000	-0.14	-0.22	-0.06	0.001
Poor sleep quality	3.56	3.21	3.91	0.000	3.18	2.83	3.53	0.000
Emotion Regulation ^d								
Physical activity	-0.89	-1.13	-0.65	0.000	-0.56	-0.80	-0.33	0.000
Poor sleep quality	6.60	5.57	7.62	0.000	5.44	4.42	6.46	0.000
Positive Affect ^e								
Physical activity	0.57	0.50	0.64	0.000	0.49	0.42	0.56	0.000
Poor sleep quality	-1.98	-2.29	-1.68	0.000	-1.59	-1.88	-1.29	0.000

^a adjusted for parent age, deprivation, parent education and other movement behaviours

^b adjusted for parent age, parent gender, deprivation, parent education, parent ATSI status and other movement behaviours

^c adjusted for parent age, parent gender, deprivation, language other than English spoken at home and other movement behaviours

^d adjusted for parent age, deprivation, parent education and other movement behaviours

^e adjusted for parent age, parent gender, parent Aboriginal and Torres Strait Islander Peoples status and other movement behaviours

Supplementary Table 1. Parent and child physical activity, sleep, and screen time compared to Australian normative data (LSAC): Sensitivity analysis excluding children diagnosed with ADHD and/or ASD

	Unweighted						Weighted					
	CPAS			LSAC			CPAS			LSAC		
	%	LL	UL	%	LL	UL	%	LL	UL	%	LL	UL
Child sleep problem												
Full CPAS sample	15.8	14.1	17.5				13.8	11.2	16.5			
Matched: Children 0–13 years	15.6	13.7	17.4	8.9	8.6	9.3	14.6	11.5	17.7	9.6	9.1	10.0
Child no regular bed-time												
Full CPAS sample	18.6	16.8	20.4				19.4	16.4	22.4			
Matched: Children 0–13 years	12.7	10.9	14.5	2.8	2.5	3.0	13.6	10.5	16.7	3.1	2.7	3.4
Parent poor sleep quality												
Full sample	56.3	54.1	58.6				58.3	54.3	62.2			
Matched: Children 0–13 years	57.1	54.6	59.6	21.0	20.4	21.6	59.2	54.9	63.5	21.6	21.0	22.3
	M (SE)	LL	UL	M (SE)	LL	UL	M (SE)	LL	UL	M (SE)	LL	UL
Screen-time (weekday)												
Full CPAS sample	3.04 (0.07)	2.90	3.17				3.30 (0.12)	3.07	3.53			
Matched: Children 4–13 years	2.73 (0.07)	2.58	2.87	2.98 (0.01)	2.97	2.99	2.88 (0.12)	2.64	3.12	3.02 (0.01)	3.01	3.04
Screen-time (weekend)												
Full CPAS sample	4.07 (0.08)	3.92	4.22				4.45 (0.13)	4.18	4.71			
Matched: Children 4–13 years	3.81 (0.09)	3.64	3.97	3.35 (0.01)	3.34	3.37	4.11 (0.15)	3.82	4.41	3.36 (0.01)	3.34	3.38
Child physical activity												
CPAS: Children 1-18 years	4.93 (0.05)	4.84	5.02				4.91 (0.08)	4.75	5.07			
Parent physical activity												
Full CPAS sample	3.94 (0.05)	3.84	4.03				4.06 (0.09)	3.89	4.23			
Matched: Children 0–13 years	3.91 (0.05)	3.80	4.01	2.85 (0.01)	2.82	2.88	4.07 (0.10)	3.88	4.26	2.85 (0.02)	2.81	2.88