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Full Length Article

Promoting physical activity during the COVID-19 lockdown in Australia: The roles of psychological predictors and commercial physical activity apps

Jasmine M. Petersen, Eva Kemps, Lucy K. Lewis, Ivanka Prichard

ABSTRACT

Purpose: Physical activity confers many physical and mental health benefits. Thus, it is of great concern that the COVID-19 lockdown has adversely impacted engagement in physical activity. There is a need to understand the factors linked to physical activity during COVID-19 as this will be fundamental to the development of innovative approaches to support engagement in physical activity during a pandemic. This study aimed to ascertain the psychological and mental health predictors of physical activity during the COVID-19 lockdown. We also examined the value of harnessing commercial physical activity apps to facilitate physical activity during a pandemic.

Method: A nationwide online survey was completed by 408 Australian adults (Mage = 35.7 ± 13.9 years, 86.0% female) following the initial COVID-19 lockdown (April/May 2020). The survey incorporated measures that retrospectively assessed physical activity (and perceived changes in physical activity behaviour), psychological constructs (social support, self-efficacy, self-determined motivations), mental health, and engagement with commercial physical activity apps during the lockdown.

Results: Over half of participants (53.4%) reported a reduction in physical activity during the initial COVID-19 lockdown, with markedly fewer (23.8%) reporting an increase in physical activity. App use (β = 0.09, p = .027), social support (β = .10, p = .021), self-efficacy (β = .42, p < .001), and identified regulation (β = .25, p < .001) emerged as important predictors of physical activity engagement (min/week). Self-efficacy (OR = 4.2, p < .001) was also associated with a greater likelihood of perceived positive changes (increases) in physical activity. The relationship between app use and physical activity was mediated by self-efficacy (β = 0.10 [0.06, 0.15]) and identified regulation (β = 0.09 [0.04, 0.15]); self-efficacy (β = 0.15, [0.09, 0.21]) also mediated the relationship between app use and positive changes in physical activity.

Conclusions: It is imperative that interventions targeted at increasing social support, self-efficacy, and autonomous motivations are developed and utilised to support engagement in physical activity during a pandemic. Commercial physical activity apps demonstrate the potential to mitigate reductions in physical activity during a pandemic, and thus the use of these apps should be encouraged.

1. Introduction

Physical inactivity is a leading modifiable risk factor for morbidity and premature mortality globally (Australian Government Department of Health, 2017). There is robust evidence about the many physical and mental health benefits of physical activity, including a reduced risk of chronic disease, depression, and anxiety (Warburton, Nicol, & Bredin, 2006). Nevertheless, over half of the Australian adult population is insufficiently active (they do not meet current guidelines) (Australian Institute of Health and Welfare, 2020). Concerningly, COVID-19 and associated lockdown periods may have further reduced engagement in physical activity due to closure of indoor and outdoor sporting facilities, cancellation of sporting competitions, isolation, social distancing, and travel restrictions. Indeed, reductions in physical activity during COVID-19 lockdowns have already been reported in Australia (Stanton et al., 2020) and worldwide (López-Bueno et al., 2020; Mauger et al., 2020; Meyer et al., 2020). Therefore, it is imperative that innovative approaches are developed to support engagement in physical activity...
during a pandemic such as COVID-19. However, this first requires an understanding of the factors that are linked to physical activity during a pandemic.

A small body of research has begun to explore some psychological correlates of physical activity during COVID-19 including personality traits (e.g., extraversion), goal striving, strategic planning, exercise identity, perceived behavioural control, self-efficacy, and attitudes (Chirico et al., 2020; Kaushal, Keith, Aguina, & Hagger, 2020; Rhodes, Liu, Lithopoulos & Garcia-Barrera, 2020; Spence, Rhodes, McCurdy, Manga, Hopkins & Mummery, 2020; Terran-Escobar et al., 2021). Specifically, using a single item, Terran-Escobar et al., (2021) examined the role of self-efficacy, and found that it was not a significant predictor of physical activity during the COVID-19 lockdown. Another important psychological correlate is social support. Like self-efficacy, social support is among the strongest predictors of physical activity (during non-pandemic times) and is similarly underpinned by many behaviour change theories (Anderson-Bill, Winett, & Wojcik, 2011; Trost, Owen, Bauman, Sallis, & Brown, 2002). Motivation has also been consistently linked to physical activity (Teixeira, Carraca, Markland, Silva, & Ryan, 2012), and is commonly examined in relation to Self-determination Theory (SDT) (Deci & Ryan, 1985). This theory distinguishes autonomous forms of motivation, intrinsic motivation (enjoyment derived from physical activity) and identified regulation (personal value placed on the outcomes of physical activity), and controlling forms of motivation, introjected regulation (internal obligation to carry out activity, feelings of guilt or anxiety) and external regulation (seeking external reinforcements or avoiding punishments) (Deci & Ryan, 1985). Autonomous motivations are the strongest predictor of long-term engagement in physical activity (Teixeira et al., 2012); this is particularly important in the context of a pandemic which may lead to profound changes to opportunities for physical activity for a prolonged period. Recent research has demonstrated that autonomous motivations play an important role in predicting physical activity intentions (Chirico et al., 2020; Kaushal et al., 2020) and habits (Kaushal et al., 2020) during COVID-19. Therefore, the role of motivation in addition to those of self-efficacy and social support should be considered in determining the psychological constructs that are important in facilitating physical activity behaviour during a pandemic.

Mental health is another factor that has been linked to physical activity engagement (Mikkelsen, Stojanovska, Polenakovic, Bosevski, & Apostolopoulos, 2017), and is particularly pertinent in the context of a pandemic. Evidence exists to suggest a bi-directional relationship between physical activity and mental health, such that physical activity influences mental health, and reciprocally, mental health influences physical activity levels (Gucciardi, Law, Guerrero, & Jackson, 2020; Hiles, Lamers, Milaneschi, & Penninx, 2017). Research during COVID-19 has thus far focused on the former direction. For example, Stanton et al. (2020) reported that reductions in physical activity during COVID-19 were linked to more severe depression, anxiety, and stress symptoms in a sample of Australian adults. Similarly, Schuch et al. (2020) identified that physical activity (>30min/day moderate-vigorous PA or ≥15min day vigorous PA) was associated with a reduced likelihood of depression and anxiety among Brazilian adults. Because of the reciprocal relationship between mental health and physical activity observed during non-pandemic times (Gucciardi et al., 2020; Hiles et al., 2017), it is necessary to consider mental health as a factor that has the potential to affect physical activity behaviour during a pandemic. Therefore, the present study examined the role of mental health alongside the aforementioned psychological constructs in facilitating physical activity during the COVID-19 lockdown in Australia to gain a more comprehensive insight into the promotion of physical activity during a pandemic.

Harnessing digital technology provides a promising approach to promote engagement in physical activity during a pandemic. Technology such as commercial physical activity apps (e.g., Strava, Fitbit) can be used within the home, and are accessible and affordable. Commercial physical activity apps also hold great potential, given their acceptability by the general population, and ever-increasing availability (Grand View Research, 2017; Petersen, Kemps, Lewis, & Prichard, 2020a). In addition, many commercial physical activity apps incorporate social components that facilitate connections with other app users (app-specific communities) or existing social networking platforms (e.g., Facebook) (Bondaronek, Alkhaldi, Slea, Hamilton, & Murray, 2018; Mollee, Middelwoed, Kuvers, & Klein, 2017); these are particularly valuable during a pandemic when face-to-face social support is restricted. It is, therefore, perhaps not surprising that commercial physical activity apps were immensely popular during COVID-19, with reports that downloads of such apps increased by almost fifty percent during the first half of 2020 (Ang, 2020). Importantly, a study conducted in the U.S. showed that physical activity apps were beneficial in preventing declines in physical activity during the COVID-19 lockdown (Yang & Koenigstorfer, 2020). However, it is currently unclear how exactly these apps promote engagement in physical activity during a pandemic. Previous research (during non-pandemic times) has shown that the use of commercial physical activity apps is linked to higher physical activity engagement (Petersen et al., 2020a; Petersen, Kemps, Lewis, & Prichard, 2020b), due to their capacity to facilitate social support, and positively influence motivation and beliefs in one’s ability to perform physical activity (self-efficacy) (Petersen et al., 2020b). There is a clear need to further validate the value of engaging with commercial physical activity apps during the COVID-19 pandemic and resulting lockdowns. This includes examining the mechanisms underlying the purported relationship between app use and physical activity during a pandemic lockdown, with a specific focus on social support, self-efficacy, and self-determined motivations.

The present study aimed to provide insight into physical activity during the initial COVID-19 lockdown in Australia (April/May 2020). This included ascertaining the psychological (social support, self-efficacy, self-determined motivations) and mental health (depression, anxiety, stress) predictors of physical activity during the COVID-19 lockdown. We also investigated the role of commercial physical activity apps (and their social features) in facilitating physical activity during the COVID-19 lockdown. Finally, we sought to determine whether the relationship between commercial physical activity app use and physical activity during the lockdown was mediated by psychological constructs.

2. Method

2.1. Design and sample

The study used an observational design. Participants (n = 1106) from an existing database were contacted via email and invited to respond to an online survey about their physical activity behaviour during the initial COVID-19 lockdown in Australia (April/May 2020). A total of 471 Australian adults responded, of whom 412 provided complete data on the variables of interest. Data of four participants were excluded due to implausible physical activity values (>1000 min/week). This resulted in a final sample of 408. All participants provided informed consent electronically. Ethical approval was granted by the University’s Social and Behavioural Research Ethics Committee (protocol no. 8232).

2.2. Procedure

Data collection occurred from June to July 2020 using an online survey conducted through the Qualtrics platform. The survey incorporated measures that retrospectively assessed participants’ physical activity (behaviour and beliefs), mental health, and commercial physical activity app use during the COVID-19 lockdown in Australia (see details below). Participants were provided with the opportunity to enter a raffle to win one of five AUD25 gift vouchers in recognition of their time commitment.
2.3. Measures

2.3.1. Demographics
Participants reported their age, gender, postcode, height, and weight (to determine BMI (kg/m²)).

2.3.2. Physical activity
Participants retrospectively self-reported the physical activities they engaged in during the COVID-19 lockdown. Using an open-ended response format, they reported the specific type (e.g., running, walking), and frequency and duration (mins) per week of each activity. Total physical activity (min/week) was calculated by multiplying the frequency of each activity by its duration (Prichard & Tiggemann, 2008).

2.3.3. Perceived change in physical activity
Participants indicated whether they had changed their physical activity behaviours during the lockdown compared to prior to COVID-19. Specifically, following Stanton et al. (2020) participants selected from six possible categorical response options ranging from much more active than usual to ceased physical activity altogether, to indicate their change in physical activity. Responses were categorised as increased (much more or little more), no change (maintained), or decreased physical activity (little less, much less or ceased activity).

2.3.4. Social support
The Social Support for Exercise Behaviors Scale was used to assess perceived social support for physical activity (Sallis, Grossman, Pinski, Patterson, & Nader, 1987). Participants reported the perceived level of support received from family (13 items) and friends (13 items) during the COVID-19 lockdown on a 5-point Likert scale from 1 (never) to 5 (very often). An average score was generated from the 26 items Sallis et al. (1987). The internal reliability in the present sample was high (α = .90).

2.3.5. Physical activity self-efficacy
Perceived self-efficacy for physical activity was measured using The Physical Activity Self-efficacy Scale (Schwarzer & Renner, 2009). The scale comprises 5 items that determine how certain, from 1 (very uncertain) to 4 (very certain) an individual feels that they could exercise in the presence of barriers (e.g., tired, depressed) during the COVID-19 lockdown. A composite score was generated by averaging the 5 items. In the present study, the internal reliability was high (α = .95).

2.3.6. Behavioural regulation motives
Self-determined motivations for physical activity during the COVID-19 lockdown was assessed using the 19-item Behavioral Regulation in Exercise Questionnaire (BREQ-2) (Markland & Tobin, 2004). The BREQ-2 consists of 5 subscales that assess motivation types from Self-determination Theory (intrinsic motivation, identified regulation, introjected regulation, external regulation and amotivation). Items are rated on a 5-point Likert scale from 0 (not true for me) to 4 (very true for me), and a score for each self-determined motivation type is generated by averaging the representative items. The reliability of the subscales ranged from α = .83 for external regulation to α = .95 for intrinsic motivation.

2.3.7. Mental health
The Depression, Anxiety and Stress Scales (DASS-21) (Lovibond & Lovibond, 1995) were used to measure mental health during the COVID-19 lockdown. The measure consists of 21 items, comprising 3 subscales (each 7 items) assessing depression, anxiety, and stress. Items are rated on a 4-point Likert Scale from 0 (Did not apply to me) to 3 (Applied to me very much or most of the time). A score for each subscale was calculated by summing the representative items (scores ranging from 0 to 21) (Lovibond & Lovibond, 1995). The generated scores were interpreted according to the DASS sub-scale severity ratings (normal to extremely severe) suggested for Australia (Lovibond, 1995). The reliability for each subscale was high; depression (α = .93), anxiety (α = .86), and stress (α = .89).

2.3.8. Use of commercial physical activity apps
Engagement with commercial physical activity apps during the COVID-19 lockdown was assessed using items consistent with (Petersen et al., 2020a). Specifically, participants reported if they had used a physical activity app (app that has the capacity to track/monitor physical activity or provide guided training/workouts) during the COVID-19 lockdown. Those who reported using a physical activity app were asked to specify the name of the app (e.g., Fitbit) and level of engagement with the app (times/week).

2.3.9. Engagement with app-specific communities
Engagement with the app-specific community of the main physical activity app used during the COVID-19 lockdown was measured following (Petersen et al., 2020b). Using a 6-point Likert scale (from 0 (never) to 5 (very often)), participants indicated how often they engaged with various members of the app community (e.g., partner, family, close friends) by sharing physical activity posts, liking and/or providing positive comments on others’ posts, receiving likes and/or positive comments, comparing their physical activity performance to others, and engaging in competitions. A composite score was generated for the use of each feature of the app-specific community (e.g., sharing) across the various networks (e.g., family, friends) (Petersen et al., 2020a).

2.3.10. Engagement with social networking platforms
Participants reported their physical activity related use of existing social networking platforms during the COVID-19 lockdown using a series of Likert scales (Petersen et al., 2020a). Specifically, participants indicated how often (ranging from never (0) to very often (5)) they engaged with features (sharing physical activity posts, liking and/or providing positive comments on others’ posts, receiving likes and/or positive comments, and engaging in comparisons) of platforms such as Facebook, Instagram, and Twitter during the COVID-19 lockdown. A composite score was generated for the use of each feature (e.g., sharing) across the different social networking platforms (Petersen et al., 2020a).

2.4. Statistical analysis
All statistical analyses were performed with SPSS version 25 (IBM, Corp) and Mplus version 8. Normality of the data was assessed, and variables that were not normally distributed were log-transformed. Descriptive statistics were calculated for all variables. Preliminary analyses were then conducted to explore the relationships between physical activity (min/week and perceived change in physical activity), commercial physical activity app use, psychological constructs (social support, self-efficacy, and self-determined motivations), and mental health. The following analyses were conducted to further address the aims of this study.

First, to determine the predictors of physical activity and perceived changes in physical activity behaviour during the COVID-19 lockdown, a multiple linear regression and ordinal logistic regression were conducted, respectively. Both regression models incorporated psychological constructs (social support, self-efficacy, self-determined motivations), mental health and commercial physical activity app use, and controlled for demographic variables (age, gender, BMI, location). All variables were entered into the regression models simultaneously. Dummy variables were created for multilevel categorical variables (age, BMI, location). Assumptions for the linear regression analysis were checked, specifically, assumptions of independence of observations (Durbin-Watson statistic of 2.1), linearity and homoscedasticity (visual inspection of standardized residuals vs fitted values plot), normality (visual...
states and territories were represented in the sample. The mean body toria during the April/May COVID-19 lockdown; however, all Australian that excluded zero. Goodness-of-fit statistics are not reported as our aim tion was indicated by 95% confidence intervals for the indirect effects &

Second, path analyses were conducted in Mplus to assess statistical mediations among physical activity app use (independent variable; user vs non-user), psychological constructs (social support, self-efficacy, self- determined motivations), and physical activity (dependent variable; min/week) (Model 1) and perceived change in physical activity (dependent variable; increased, no change, decreased) (Model 2). Both models controlled for demographic variables (age, gender, BMI and location). They were estimated using maximum-likelihood estimation (ML) as is it robust to non-normality (untransformed values were used for ease of interpretation) and suitable for use with ordinal data. However, bootstrapping is currently unavailable with MLR, and thus, the models were re-estimated with the maximum likelihood estimation (ML); 5000 bootstrap samples were requested to calculate 95% bias corrected confidence intervals for testing mediation, the 95% bias corrected confidence intervals were examined for statistical significance. Mediation was indicated by 95% confidence intervals for the indirect effects that excluded zero. Goodness-of-fit statistics are not reported as our aim was to estimate specific effects (i.e., direct and mediation) of app use on physical activity rather than the fit of the whole model.

3. Results

3.1. Sample

The sample comprised of 408 participants. Table 1 presents the sample characteristics. Participants ranged in age from 18 to 74 years (M = 35.7 years, SD = 13.9) and were predominately female (86.0%). Almost half of the participants were located in South Australia or Victoria during the April/May COVID-19 lockdown; however, all Australian states and territories were represented in the sample. The mean body mass index (BMI) of the sample was 26.8 kg/m² (SD = 7.2) with almost half (47.5%) of participants reporting a BMI of 25 kg/m² or higher. On average, the sample engaged in 229 min of physical activity per week (SD = 210.2). A large proportion of participants (53.4%) reported a decrease in physical activity during the COVID-19 lockdown, while 23.8% reported an increase and 22.8% reported no change. The main types of physical activity participants reported engaging in during the COVID-19 lockdown were walking (43.5%), running (19.0%), home workouts (16.1%), yoga/Pilates (6.0%), cycling (5.6%), and strength training (3.1%). As shown in Table 1, physical activity (min/week) during the lockdown differed significantly according to age, BMI, and location.

Approximately half (51.2%, n = 209) of the sample used a commercial physical activity app during the COVID-19 lockdown. The most frequently used apps were Strava (23.0%), Fitbit (16.3%), and Garmin (10.0%). Participants largely reported using their apps seven times per week (35.0%), followed by 5 times (13.4%) and 3 times per week (13.0%). Among app users, 54.1% (n = 113) reported that the physical activity app they were currently using had an app-specific community, and of these 54.9% (n = 62) reported engaging with the community. Additionally, most app users (82.8%) engaged with existing social networking platforms in relation to physical activity.

3.2. Preliminary analyses

3.2.1. Associations between physical activity, psychological constructs, and mental health

Correlations between physical activity (min/week), perceived change in physical activity (increase, no change, decrease), psychological constructs and mental health are presented in Table 2. Social support, self-efficacy, and autonomous motivations (intrinsic motivation and identified regulation) were significantly positively associated with physical activity and perceived change in physical activity. Amotivation, depression, anxiety, and stress were significantly negatively associated with physical activity and perceived change in physical activity.

3.2.2. Physical activity and physical activity app use

Commercial physical activity app users (n = 209) reported engaging in significantly more physical activity (M = 297.6 min/week, SD = 208.2) than non-users (M = 156.6, SD = 187.1), t(406) = 8.4, p < .001, d = 0.71. In addition, perceived change in physical activity also significantly varied by app use, (X² (2) = 22.1, p < .001), such that a higher proportion of app users (31.6%) reported increased physical activity during the lockdown in comparison to non-users (15.6%). By contrast, a higher proportion of non-users (64.8%) reported a reduction in physical activity compared to app users (42.6%). Engagement with app-specific

| Table 1 | Sample characteristics (n = 408). |
| --- | --- |
| Characteristic | Overall, n (%) | Age (years) | Physical activity (min/week) | Gender | BMI (kg/m²) | Normal weight (BMI 18.5-24.9) | Underweight (BMI <18.5) | Overweight (BMI 25-29.9) | Obese (BMI >30) | State or territory | p-value | Perceived physical activity, n (%) | p-value | Perceived physical activity, n (%) | p-value |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Age (years) | Overall, n (%) | Physical activity (min/week) | p-value | Perceived physical activity, n (%) | p-value | Perceived physical activity, n (%) | p-value |
| 18-30 | 184 (45.1) | 194.7 (191.6) | .011 | 108 (58.7) | 31 (16.8) | 45 (24.5) | .087 |
| >30-50 | 150 (36.8) | 243.7 (215.2) | 70 (46.7) | 44 (29.3) | 36 (24.0) |
| <50 | 73 (17.9) | 284.8 (232.0) | 40 (54.8) | 17 (23.3) | 16 (21.9) |
| Gender | Female | 351 (86.0) | 232.6 (209.6) | .448 | 187 (53.3) | 79 (22.5) | 85 (24.2) | .688 |
| Male | 50 (12.2) | 213.7 (215.7) | 25 (50.0) | 14 (28.0) | 11 (22.0) |
| BMI (kg/m²) | Underweight (BMI <18.5) | 10 (2.5) | 118.2 (196.0) | <.001 | 6 (60.0) | 3 (30.0) | 1 (10.0) | .326 |
| Normal weight (BMI 18.5-24.9) | 185 (45.3) | 248.3 (201.0) | 95 (51.4) | 47 (25.4) | 43 (22.2) |
| Overweight (BMI 25-29.9) | 100 (24.5) | 274.6 (216.0) | 47 (47.0) | 25 (25.0) | 28 (28.0) |
| Obese (BMI >30) | 94 (23.0) | 147.6 (182.8) | 57 (60.0) | 14 (14.9) | 23 (24.5) |
| State or territory | SA | 124 (30.4) | 195.7 (208.3) | .034 | 75 (60.5) | 25 (20.2) | 24 (19.4) | .154 |
| VIC | 77 (18.9) | 288.8 (219.2) | 35 (45.5) | 20 (25.9) | 22 (28.6) |
| QLD | 62 (15.2) | 198.5 (173.0) | 32 (51.6) | 12 (19.4) | 18 (29.0) |
| NSW | 58 (14.2) | 251.3 (211.9) | 26 (44.8) | 21 (36.2) | 11 (19.0) |
| WA | 33 (8.1) | 252.8 (198.4) | 18 (54.5) | 8 (24.2) | 7 (21.2) |
| ACT | 24 (5.9) | 223.0 (249.8) | 17 (70.8) | 3 (12.5) | 4 (16.7) |
| TAS | 17 (4.2) | 174.1 (186.1) | 9 (53.0) | 3 (17.6) | 5 (29.4) |
| NT | 8 (2.0) | 336.8 (270.3) | 4 (50.0) | 0 (0.0) | 4 (50.0) |
Results of the multiple regression analysis are presented in Table 3. The regression model accounted for 58.8% of the variance in physical activity during the COVID-19 lockdown ($R^2 = 0.588$) and was significant, $F(24, 357) = 21.2, p < .001$. After controlling for age, gender, BMI, and location the following variables were significant positive predictors of physical activity: app use ($β = .09, p = .027$), social support ($β = .10, p = .021$), self-efficacy ($β = .42, p < .001$), and identified regulation ($β = .25, p < .001$). Amotivation was a significant negative predictor of physical activity ($β = -.13, p = .005$).

The ordinal logistic regression model accounted for 32.6% of the variance in perceived changes in physical activity behaviours during the COVID-19 lockdown (Nagelkerke $R^2$ of 0.326) and was significant, $χ^2 (24) = 125.7, p < .01$. Self-efficacy (OR = 4.2, $p < .001$) was associated with higher odds of increased physical activity during the COVID-19 lockdown after controlling for age, gender, BMI, and location (see Table 4).

### 3.4. Mediation analyses; exploring the relationships between commercial physical activity apps, psychological constructs and physical activity

**Model 1 (Physical activity (min/week)).** Overall, the model accounted for a significant ($p < .001$) amount of variance in physical activity (min/week) during the COVID-19 lockdown (40.0%). There were significant, direct positive paths from app use to social support ($β = 0.31 [0.23, 0.39]$), self-efficacy ($β = 0.27 [0.17, 0.36]$), intrinsic motivation ($β = 0.31 [0.23, 0.39]$), and social support ($β = 0.29 [0.22, 0.36]$), to physical activity during the COVID-19 lockdown (40.0%). There were significant, direct positive paths from app use to social support ($β = 0.31 [0.23, 0.39]$), self-efficacy ($β = 0.27 [0.17, 0.36]$), intrinsic motivation ($β = 0.31 [0.23, 0.39]$), and social support ($β = 0.29 [0.22, 0.36]$), to physical activity during the COVID-19 lockdown (40.0%).

**Model 2 (Perceived change in physical activity).** Overall, the model accounted for a significant ($p < .001$) amount of variance in perceived change in physical activity (min/week) during the COVID-19 lockdown (40.0%). There were significant, direct positive paths from app use to social support ($β = 0.31 [0.23, 0.39]$), self-efficacy ($β = 0.27 [0.17, 0.36]$), intrinsic motivation ($β = 0.31 [0.23, 0.39]$), and social support ($β = 0.29 [0.22, 0.36]$), to physical activity during the COVID-19 lockdown (40.0%). There were significant, direct positive paths from app use to social support ($β = 0.31 [0.23, 0.39]$), self-efficacy ($β = 0.27 [0.17, 0.36]$), intrinsic motivation ($β = 0.31 [0.23, 0.39]$), and social support ($β = 0.29 [0.22, 0.36]$), to physical activity during the COVID-19 lockdown (40.0%).
perceived change in physical activity during the COVID-19 lockdown (35.0%). Significant direct paths were identified from app use to social support (OR = 1.4 [1.2, 1.5]) and self-efficacy (OR = 1.3 [1.2, 1.4]), intrinsic motivation (OR = 1.4 [1.3, 1.5]), identified regulation (OR = 1.4 [1.3, 1.5]) and amotivation (OR = 0.79 [0.73, 0.87]). There was also a significant direct path from self-efficacy to perceived change in physical activity (OR = 1.7 [1.5, 1.9]). In addition, the indirect pathway from app use to perceived change in physical activity via self-efficacy was significant (β = 0.15, [0.09, 0.21]), and this showed complete mediation (Direct effect: β = 0.05 [-0.07, 0.16]). Thus, app users were more likely to report higher self-efficacy, and in turn, were more likely to perceive positive changes (increase) in physical activity during the COVID-19 lockdown.

4. Discussion

This study presents a comprehensive nation-wide examination of adults’ physical activity during the initial COVID-19 lockdown (April/May 2020) in Australia. It explored the psychological (social support, self-efficacy, self-determined motivations) and mental health predictors (depression, stress, anxiety) of physical activity during the COVID-19 lockdown. It also examined the role of commercial physical activity apps in facilitating physical activity during the COVID-19 lockdown.

Participants reported engaging on average in 229 min of physical activity per week. This is lower than the average physical activity level (294 min/week) among Australian adults during non-pandemic times (Australian Bureau of Statistics, 2019). Interestingly, despite the uniform regulations about physical activity across Australia during the initial COVID-19 lockdown (e.g., closure of indoor and outdoor sporting facilities), Victorians engaged in significantly more physical activity than South Australians. This fits with reports by the Australian Bureau of Statistics (during non-pandemic times) of a slightly higher proportion of adults meeting the Physical Activity Guidelines in Victoria (15.3%) than in South Australia (14.9%) (Australian Bureau of Statistics, 2019). We also found that older adults engaged in significantly more physical activity than younger adults. This finding conflicts with extant literature pertaining to age-related patterns of physical activity decline during non-pandemic times (Bennie et al., 2016). It does, however, fit with evidence that during COVID-19, younger adults (as compared to older adults) experienced higher levels of distress (Every-Palmer et al., 2020) and loneliness (Groarke et al., 2020), and reported poorer sleep quality (Cellini et al., 2021); all factors associated with lower levels of physical activity (Gucciardi et al., 2020; Kline, 2014; Peis & Kleinert, 2016). It had also been suggested that during COVID-19, older adults who are deemed a ‘vulnerable population’ may have developed greater concerns about health, which may have motivated them to increase their engagement in physical activity (Reynolds, 2020). Given the known links between physical activity and mental health (Mikkelsen et al., 2017), it is not surprising that the emerging COVID-19 literature (Huang & Zhao, 2020; Jia et al., 2020; Pieh, Budimir, & Probst, 2020) documents that older adults also have significantly better mental health outcomes than younger adults. This suggests that during a pandemic, physical activity interventions should be targeted at younger adults.

Most participants (77.2%) reported that their physical activity levels had changed during the initial COVID-19 lockdown. Specifically, over half of participants (53.4%) reported engaging in less physical activity than usual and markedly fewer (23.8%) reported an increase in physical activity. A study conducted by Stanton et al. (2020) on the links between changes in various health behaviours and mental health in Australian adults during COVID-19 similarly found that while almost half (48.9%) of their participants reported a reduction in physical activity since the onset of COVID-19, only 20.7% reported an increase. This is perhaps not surprising given the unique circumstances during the lockdown that may have impeded engagement in physical activity, including closure of indoor and outdoor physical activity facilities, shortages of exercise equipment to purchase, social distancing, and travel restrictions. Of particular concern is that the reported reductions in physical activity during the COVID-19 lockdown may have contributed to heightened levels of depression, anxiety, and stress compared to Australian adult population normative data (Crawford, Casley, Lovibond, Wilson, & Hartley, 2011). Therefore, it is imperative that interventions are designed to support engagement in physical activity during a pandemic to foster positive physical and mental health outcomes.

The present study examined both psychological and mental health predictors of physical activity during the COVID-19 lockdown. We found that the psychological constructs (i.e. social support, self-efficacy and autonomous motivations) were positively associated with physical activity and perceived change in physical activity during the COVID-19 lockdown whereas the mental health predictors (i.e., depression, anxiety, stress) were negatively associated with physical activity during the lockdown (min/week and perceived change). This is consistent with the psychological and mental health correlates of physical activity during non-pandemic times (Anderson-Bill et al., 2011; Mikkelsen et al., 2017; Teixeira et al., 2012; Trost et al., 2002). Interestingly, the regression analyses demonstrated that self-efficacy (an individual’s beliefs pertaining to their ability to perform physical activity) was the strongest positive predictor of both physical activity and positive perceived changes (increases) in physical activity during the COVID-19 lockdown. This shows that self-efficacy is fundamental to promoting engagement in physical activity during a pandemic, and therefore, is a psychological construct that should be targeted in subsequent physical activity interventions. Social support also emerged as a positive predictor of physical activity during the COVID-19 lockdown. Existing research has demonstrated that online social networking fosters the provision of social support (Petersen et al., 2020b), and thus could be leveraged to promote physical activity during a pandemic when face-to-face support is restricted. Finally, identified regulation (personal value placed on the outcomes of physical activity) was shown to positively predict physical activity during the COVID-19 lockdown. This is not surprising given that

### Table 4

Ordinal logistic regression analysis examining the predictors of perceived change in physical activity during the COVID-19 lockdown.

| Variable                  | Estimate | p    | Odds ratio | OR 95% CI |
|---------------------------|----------|------|------------|-----------|
| Age (years) (18-30 is ref) |          |      |            |           |
| >30-50                    | -1.5     | 0.577| 0.65       | [0.49, 1.47] |
| >50                       | -0.8     | 0.014| 0.41       | [0.20, 0.83] |
| Gender                    |          |      |            |           |
| Female (vs. Male)         | 0.05     | 0.893| 1.0        | [0.53, 2.08] |
| Location (SA is ref)      |          |      |            |           |
| NSW                       | 0.24     | 0.496| 1.27       | [0.63, 2.54] |
| ACT                       | -0.25    | 0.632| 0.78       | [0.28, 2.15] |
| VIC                       | 0.12     | 0.714| 1.12       | [0.60, 2.10] |
| QLD                       | 0.28     | 0.407| 1.33       | [0.67, 2.63] |
| TAS                       | 0.78     | 0.731| 2.19       | [0.71, 6.78] |
| NT                        | 0.63     | 0.389| 1.90       | [0.45, 7.87] |
| WA                        | 0.17     | 0.689| 1.19       | [0.51, 2.79] |
| BMI (kg/m²) (normal weight 18.5-24.9 is ref) |          |      |            |           |
| Underweight (<18.5)       | -0.28    | 0.732| 0.75       | [0.15, 3.75] |
| Overweight (25-29.9)      | -0.48    | 0.703| 1.62       | [0.95, 2.75] |
| Obese (>30)               | 0.38     | 0.224| 1.46       | [0.79, 2.72] |
| Psychological constructs  |          |      |            |           |
| Social support            | 0.09     | 0.669| 1.09       | [0.72, 1.68] |
| Self-efficacy             | 1.4      | <0.001| 4.24     | [2.94, 6.12] |
| Intrinsic motivation      | 0.30     | 0.052| 1.35       | [0.99, 1.83] |
| Identified regulation     | -0.34    | 0.093| 0.71       | [0.47, 1.05] |
| Introjected regulation    | 0.02     | 0.827| 1.02       | [0.82, 1.30] |
| External regulation       | 0.14     | 0.420| 1.15       | [0.82, 1.60] |
| Amotivation               | -0.12    | 0.534| 0.88       | [0.59, 1.31] |
| Mental Health             |          |      |            |           |
| Depression                | 0.01     | 0.745| 1.01       | [0.95, 1.07] |
| Anxiety                   | 0.006    | 0.491| 1.00       | [0.93, 1.09] |
| Stress                    | 0.04     | 0.236| 1.04       | [0.97, 1.12] |
| App Use                   |          |      |            |           |
| App user (vs. non-user)   | 0.23     | 0.349| 1.25       | [0.78, 2.03] |

For dependent variable, the reference group is increased.
identified regulation is an autonomous motivation that has consistently shown to be important in promoting physical activity behaviour during non-pandemic times (Teixeira et al., 2012), and has been shown to play a positive role in predicting physical activity intentions and habits during COVID-19 (Chirico et al., 2020; Kaushal et al., 2020). Mental health problems (anxiety, depression, stress) did not emerge as significant predictors of physical activity or perceived change in physical activity during the COVID-19 lockdown. We did, however, find a negative correlation between mental health (depression, anxiety and stress) and the psychological constructs (e.g., self-efficacy, autonomous motivations) linked to physical activity during the COVID-19 lockdown, suggesting that mental health may nevertheless play an important role in physical activity engagement during a pandemic. Recent research in Australia (Stanton et al., 2020) and more broadly (Schuch et al., 2020) has identified links between mental health and physical activity during COVID-19. The present study provides an important extension to the emerging body of research (Chirico et al., 2020; Kaushal et al., 2020; Rhodes et al., 2020; Spence et al., 2020) on correlates of physical activity during COVID-19 by ascertaining the roles of the psychological constructs social support, self-efficacy and self-determined motivations along with that of mental health. Together, the findings have identified the most important predictors of physical activity during the COVID-19 lockdown, which is imperative to the development of interventions that could effectively facilitate physical activity during a pandemic.

The present study also provides novel insights into the use of commercial physical activity apps during the COVID-19 lockdown. Over half of the sample (51.2%) reported using a commercial physical activity app during this time, comparable to rates of app use (51%-53%) reported during non-pandemic times (Petersen et al., 2020a; 2020b). Physical activity apps that primarily function to track or monitor behaviour were the most commonly used (e.g., Strava, Fitbit). This fits with participants reporting that they predominately engaged in running and walking during the lockdown. App users engaged in significantly more physical activity than non-users, which is consistent with extant literature during non-pandemic times (Petersen et al., 2020a; 2020b). They were also more likely to report an increase in physical activity during the lockdown in comparison to non-users who largely reported a reduction in physical activity. Engagement with app-specific communities and existing social networking platforms (in relation to physical activity) were not linked to physical activity. However, engagement with specific features of app-specific communities (receiving encouragement and engagement in competitions) and existing social networking platforms (sharing physical activity posts) were found to be valuable in facilitating physical activity, consistent with recent research conducted during non-pandemic times (Petersen et al., 2020b). Notably, physical activity app use was a significant predictor of physical activity (min/week) during the COVID-19 lockdown, highlighting its role in facilitating physical activity during a pandemic. In support, Yang and Koenigstorfer (2020) found that higher app use was associated with positive change in physical activity (pre vs during the COVID-19 lockdown), which suggests that app use may attenuate reductions in physical activity during a pandemic lockdown. Our findings also provide important insight into the capacity of physical activity apps to promote engagement in physical activity during COVID-19 by ascertaining that these apps facilitate self-efficacy and identified regulation, psychological constructs shown to be fundamental in promoting physical activity during a pandemic. Thus, it appears that commercial physical activity apps are tools that hold great potential to promote physical activity engagement during a pandemic lockdown. Future research could usefully examine app use (and physical activity) at different time points during a pandemic (post-lockdown, subsequent waves) to inform the development of app-based interventions to effectively facilitate physical activity throughout a pandemic.

Our findings have important implications for the promotion of physical activity during a pandemic. First, strategies should be implemented to facilitate engagement in physical activity during a pandemic, given that over half of participants reported a reduction in physical activity during the COVID-19 lockdown. Interventions should target young adults, all the more so as they are shown to experience greater mental health problems during the COVID-19 lockdown. Second, social support, self-efficacy and autonomous motivation are psychological constructs that were fundamental in predicting physical activity during the COVID-19 lockdown, and thus should be targeted in interventions designed to promote physical activity during a pandemic. Finally, commercial physical activity apps are a promising tool to promote engagement in physical activity during a pandemic, as they were linked to higher levels of physical activity during the COVID-19 lockdown, and were shown to facilitate self-efficacy and autonomous motivation.

As with all studies, there are some limitations that should be acknowledged. First, the sample was predominantly female and engaged in relatively high levels of physical activity which may limit the generalisability of the results. Second, the measure of physical activity was taken retrospectively and was self-report which may have been subject to recall bias or reporting inaccuracies (e.g. over-reporting). In addition, the assessment of physical activity did not measure the intensity of the activities (i.e. light, moderate, vigorous), but instead provided insight into the type of activities (e.g. running, walking). Future research should consider using accelerometer-derived measures of physical activity in conjunction with self-report measures that have the capacity to capture both intensity and type of activities. Third, because of the synchronic measurement of physical activity and perceived change in physical activity, it is not possible to ascertain the potential role of perceptions in driving physical activity behaviour. Perceptions of past behaviour (i.e., pre-lockdown behaviour) are another important consideration in this context (e.g., Kaushal et al., 2020). Finally, the cross-sectional nature of this study precludes conclusions of causality; for example, the associations between physical activity and mental health, and the relationships between psychological constructs and commercial physical activity app use may be bi-directional.

In conclusion, the present study has provided important insights into physical activity during the COVID-19 lockdown among Australian adults. The findings indicate that strategies targeted at increasing social support, self-efficacy, and autonomous motivations should be implemented to mitigate reductions and support the maintenance of physical activity during a pandemic. Commercial physical activity apps present an innovative approach to facilitating physical activity during a pandemic, and thus the use of these apps should be encouraged. Outcomes of this study have provided valuable knowledge pertaining to the promotion of physical activity during the COVID-19 lockdown that will be fundamental to facilitating positive physical and mental health outcomes in current and future pandemics.

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Authors’ contributions

All authors contributed equally to the drafting and finalization of the publication. All authors read and approved the final manuscript.

Declaration of competing interest

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Appendix A. Supplementary data

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