Running Head: PHYSICAL ACTIVITY AND MENTAL HEALTH IN UK LOCKDOWN

Relationships Among Behavioural Regulations, Physical Activity, and Mental Health Pre- and During COVID–19 UK Lockdown

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Introduction

COVID–19 is a highly contagious disease related to the spread of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The outbreak of the disease was declared a Public Health Emergency on 30 January 2020, and subsequently categorised as a pandemic on 11 March 2020 (World Health Organization, 2020c). At the time of writing, there have been ~4.5 M lab-confirmed cases of COVID–19 and ~150,000 deaths in the UK (with COVID–19 on the death certificate). The UK Government enforced its inaugural state of lockdown on 23 March 2020 in order to reduce the spread of COVID–19, and to ensure that the National Health Service (NHS) was able to cope with the demands placed upon it.

The days that followed saw the closure of schools, restaurants, public houses, and exercise facilities. Residents were instructed to leave their homes for very limited purposes, such as shopping for food or seeking medical attention (UK Government, 2020). Stringent guidelines were introduced for high-risk segments of the UK population (i.e., the clinically vulnerable), which entailed “shielding” at home and avoiding face-to-face contact for a period of 12 weeks (Extance, 2020). In December 2020, a de facto lockdown (Tier 4 restrictions) was imposed in Wales as well as many other parts of the UK, albeit the present study is focused on the initial UK national lockdown in March to May 2020.

Lockdowns and Physical Activity

Exercise psychologists anticipated that the additional time spent in home isolation would be associated with a sharp decline in physical activity (PA; Chen et al., 2020; Hall et al., 2020; Jakobsson et al., 2020). This is particularly worrisome given that physical inactivity is a leading risk factor for non-communicable diseases and chronic conditions (Cunningham et al., 2020; Kohl et al., 2012). The financial implications of prolonged physical inactivity in the UK are substantial, estimated to cost the NHS £0.9 billion each year (Public Health England, 2019). According to Sallis et al. (2020, p. 4): “There is ample evidence to justify making PA promotion a global public health priority during the coronavirus pandemic.”

Early findings from other European countries pertaining to PA under lockdown appear to be inconclusive. For example, increased PA levels have been observed during lockdowns in Belgium and Italy (Constandt et al., 2020; Di Renzo et al., 2020). Increased levels of moderate PA were reported without corresponding increases in vigorous levels of PA in France and Switzerland (Cheval et al., 2020). Contrastingly, declines in PA were reported across all intensities (i.e., low, moderate, and vigorous) in a transcontinental study (Ammar et al., 2020).

Mixed findings have also been observed in the UK. For example, Robinson et al. (2021) found that 40% of adults reported a decrease in PA during lockdown, but 45% reported an increase. The researchers detailed that higher body mass index (BMI) was associated with lower engagement in PA during lockdown. Similarly, Spence et al. (2020) found that 57% of their sample either maintained or increased PA during the UK lockdown. Nonetheless, the percentage of adults who met the recommended quantity of PA per week was low (i.e., 31%). When examining such findings, it is helpful to consider the determinants of behaviour as indicated in relevant theories.

A theory that has been widely drawn upon in the investigation and measurement of PA is the Theory of Planned Behaviour (TPB; Fishbein & Ajzen, 2010). This holds that intention is the immediate antecedent of behaviour. Intention can be predicted from attitude, normative beliefs, and perceptions of behavioural control. Although researchers have assessed planned forms of PA (e.g., structured exercise) during the pandemic (e.g., Kaushal et al., 2020; Rhodes et al., 2020; Smith et al., 2020), in comparative terms, there is a dearth of research oriented towards unplanned PA. This is noteworthy given that PA encompasses any bodily movement produced by skeletal muscles that requires energy expenditure, including activities undertaken while working, playing, and carrying out household chores (World Health Organization, 2020b). Previous work is also largely predicated on self-report measures, which are subject to recall bias (van Berkel et al., 2019).

Accordingly, there is ample scope to investigate both planned and unplanned dimensions of PA, alongside objective measures that combine the two (e.g., daily step counts). Examining the possible explanatory variables for PA under conditions of lockdown would facilitate the formulation of targeted interventions (Sallis et al., 2020). Notably, objective measures that entail the self-monitoring of PA levels using electronic devices hold some propensity to introduce bias (Tison et al., 2020). This is because those who routinely measure their PA (e.g., using a smartwatch) are more likely to persist with it regardless of environmental conditions (Kirwan et al., 2012).

Explanatory Variables for Physical Activity

A large number of researchers have used Self-Determination Theory (SDT) as a guiding framework to examine motivation for PA (Edmunds et al., 2006; Hancox et al., 2018). A central tenet of SDT is that there are varying forms of motivation that pertain to the ways in which a behaviour can be regulated (Markland & Tobin, 2004). Deci and Ryan (1985) proposed a taxonomy of regulatory styles that was predicated on the extent to which individuals *internalise* specific behaviours, ranging from completely non-self-determined to completely self-determined regulations. Specifically, six forms of regulation were identified within the taxonomy: amotivation, external, introjected, identified, integrated, and intrinsic.

Amotivation concerns an absence of motivation or lack of intention to engage in a specific behaviour. *External regulation* occurs when behaviours are performed to obtain external rewards or the approval of others. *Introjected regulation* is when behaviours are performed because of self-imposed pressures (e.g., avoiding guilt, maintaining self-esteem). *Identified regulation* involves acceptance of a behaviour as being significant to achieve personally valued outcomes. *Integrated regulation* concerns engaging in a behaviour because it represents an individual's sense of self. *Intrinsic regulation* involves taking part in an activity for reasons of inherent enjoyment and interest (Ryan & Deci, 2017).

Autonomous forms of motivation (i.e., intrinsic motivation and identified regulation) have been shown to be positive predictors of PA behaviour pre- and during lockdown (Chirico et al., 2020; Standage et al., 2008). However, a limitation of the Chirico et al. (2020) study that was conducted during lockdown, was the application of the somewhat controversial Relative Autonomy Index, which has been subject to theoretical and statistical criticism (see e.g., Chemolli & Gagné, 2014). The degree to which the six forms of behavioural regulation explained planned and unplanned dimensions of PA pre- and during the initial UK COVID–19 lockdown is presently unknown. This is one of the key foci of the present study, which combines SDT with TPB – the former providing explanatory variables and the latter providing outcome variables.

Lockdowns and Mental Health

Lockdowns have the potential to profoundly influence people's mental health (World Health Organization, 2020a), which is of particular concern in light of the proliferation of mental health issues evident in European nations (Gutiérrez-Colosía et al., 2019). Holmes et al. (2020) theorised that a significant consequence of COVID–19 lockdowns is increased social isolation and loneliness, both of which are strongly associated with a range of mental health issues (e.g., anxiety, depression, and self-harm).

Early findings indicate that individuals subjected to lockdown have reported PTSD-like symptoms as well as moderate-to-severe stress (8.1%), anxiety (28.8%), and depression (16.5%; Wang et al., 2020). Similarly, Pearce et al. (2020) found an increase in mental distress using a British sample aged ≥ 16 years, when compared to the previous year. Nonetheless, an immediate research priority is to increase knowledge of the antecedents of mental health issues during lockdown, as a means by which to inform future interventions (Holmes et al., 2020).

Explanatory Variables for Mental Health

A vast corpus of research supports the notion that PA is positively associated with mental health. For example, Farren et al. (2018) conducted a three-step hierarchical regression analysis and reported that moderate and vigorous-intensity PA explained depression beyond sex and fitness attributes. As a counterpoint to theories of PA, researchers have exhibited a growing interest in sedentary behaviour over the last decade (Biddle, 2018). A number of conceptual frameworks have been put forth (e.g., Behavioural Epidemiology Framework; Biddle, 2015; Sallis et al., 2000) and arguably the most salient in the present context is the Ecological Model of Health Behaviour (Hadgraft et al., 2018). This places particular emphasis on policy and regulatory environments, which pertain directly to circumstances such as national lockdowns.

Sedentary behaviour (e.g., sitting and screen time; Gardner et al., 2016) has been associated with several mental health outcomes (e.g., anxiety, depression; Hallgren et al., 2020; Hamer & Stamatakis, 2014). Using a sample of UK adults, Hamer et al. (2014) found that self-reported and objective assessments of sedentary behaviour were associated with psychological distress. Lockdown-related findings indicate that sedentary behaviour has increased during the pandemic (Constandt et al., 2020; Pietrobelli et al., 2020; Stockwell et al., 2021). Ammar et al. (2020) reported that daily sitting time increased from 5 hr to 8 hr internationally. Intentions to engage in screen time rose following COVID–19 lockdowns, as evidenced by Google searches for “television show” (Ding et al., 2020). Nonetheless, the extent to which sedentary behaviour is associated with mental health during COVID–19 lockdowns remains largely unknown.

Aims and Hypotheses

The promotion of PA and mental health during periods of COVID–19 lockdown is a public health priority (Holmes et al., 2020; Sallis et al., 2020). Accordingly, a more thorough understanding of the antecedents of PA and mental health is desirable. Such understanding will facilitate health practitioners in developing interventions targeted towards the enhancement of PA behaviours and mental health during subsequent periods of lockdown. The aim of this study was to examine the extent to which exercise motives explained planned and unplanned dimensions of PA pre- and during lockdown. Moreover, we sought to investigate the degree to which planned and unplanned PA and sedentary behaviour explained mental health in the same timeframe. It is plausible that demographic and anthropometric variables (e.g., age, sex, and BMI) might function as potential confounds in the relationships among exercise motives, PA, sedentary behaviour, and mental health (Cheval et al., 2020; Pierce et al., 2020). Accordingly, we sought to account for such potential confounds through initial exploration and, where relevant, their inclusion in hierarchical multiple regression analyses or partial correlations (see Figure 1).

*** Insert Figure 1 about here ***

We hypothesised that greater variance would be explained in planned PA by exercise motives pre-, when compared to during lockdown, but the variance explained in unplanned PA would remain unchanged (H_1). This was because opportunities to engage in planned PA were hampered by the closure of exercise facilities during lockdown. Conversely, opportunities to engage in unplanned PA were relatively unaffected. We hypothesised that the percentage of variance explained in steps per day by exercise motives would remain stable from pre- to during- lockdown (H_2), given that UK residents could leave their homes once daily for exercise during the first lockdown. We hypothesised that planned and unplanned PA would explain a greater proportion of variance in mental health during, as opposed to pre-lockdown (H_3). This was because PA had a greater propensity to enhance people's mental health at a time when they were confined to their homes (Jacob et al., 2020). Using the same premise as for H_3, we predicted that there would be a small but significant correlation between steps per day and mental health during lockdown (H_4). Finally, we hypothesised that sedentary behaviour would be more strongly associated with mental health during, when compared with pre-lockdown (H_5), given the negative psychological consequences of confinement (Holmes et al., 2020).

Method

Participants

This study was approved by __________________ and participants provided written informed consent. Recruitment was conducted through word-of-mouth and facilitated by social media posts. Participants met three inclusion criteria: (a) able to respond to questions presented in English; (b) aged ≥ 18 years; and (c) currently residing in the UK. A total of 392 UK adults (18–85 years; $M_{\text{BMI}} = 25.48$; $SD_{\text{BMI}} = 5.05$; 314 women) completed the survey (summary demographic details are provided in Table 1 and the full complement can be found in Supplementary Table 1).

Measures

Initially, a range of demographic data was requested within the survey (e.g., age, ethnicity, education; see Table 1 and Supplementary Table 1).

Exercise Motives

Exercise-related motivation was assessed using the Behavioural Regulations in Exercise Questionnaire-3 (BREQ-3; Markland & Tobin, 2004; Wilson et al., 2007), which is comprised of 24 items attached to a 5-point Likert scale anchored by 0 (*Not true for me*) and 4 (*Very true for me*). Four items (e.g., "It's important to me to exercise regularly" [item 1]) tap each of the six forms of behavioural regulation identified in SDT (Deci & Ryan, 1985). We adopted a multidimensional approach to scoring and thus calculated the mean score for each subscale (i.e., six scores in the range 0–4). A unidimensional index of the degree of self-determination (i.e., the Relative Autonomy Index) was not calculated due to a range of theoretical and statistical concerns (see Chemolli & Gagné, 2014). The BREQ-3 has demonstrated both construct validity and internal consistency (Rodrigues et al., 2020).

Physical Activity

PA was assessed using the Brunel Lifestyle Physical Activity Questionnaire (BLPAQ; Karageorghis et al., 2005), which is comprised of nine items attached to 5-point continuous-closed numerical scales (e.g., 1 = *Not at all,* 5 = *Highly*). Items 1–6 measure planned PA (e.g., "In general, what is the duration of each session of pre-planned physical activity that you engage in?" [item 3]) and items 7–9 measure unplanned PA (e.g., "In general, how physically demanding are your job or your day-to-day activities?" [item 9]). Factor scores for planned and unplanned PA are derived by adding scores from items 1–6 (planned) and 7–9 (unplanned), then dividing them by six and three, respectively. Factor scores ranged from 1–5, with higher scores indicating higher PA engagement. The BLPAQ is a criterion- and cross-validated measure of PA that exhibits high test–retest reliability (Vencato, Karageorghis, Nevill, et al., 2017; Vencato, Karageorghis, Priest, et al., 2017). Participants were also asked to specify their average step count per day, but only if they used a mobile device (e.g., a smartwatch) for this purpose (n = 190; 18–85 years; M_{BMI} = 25.06; SD_{BMI} = 4.90; 148 women).

Mental Health

The General Health Questionnaire-12 (GHQ-12; Goldberg & Williams, 1988) was used to measure mental health. This inventory contains 12 items attached to 4-point Likert scales (e.g., 0 = *Better than usual,* 3 = *Much less than usual*). The items pertain to a variety of psychological constructs that include anxiety, depression, and social dysfunction (e.g., "Have you recently been feeling unhappy and depressed?" [item 9]). A mental health score is derived through adding the item scores. Hence, values range from 0–36, with higher scores indicating poor mental health. The GHQ-12 has demonstrated both convergent validity and internal consistency (Hardy et al., 1999).

Sedentary Behaviour

Each participant was asked to provide daily estimates in hours for sitting time and time spent viewing a screen (e.g., computer or television).

Procedure

A cross-sectional study design was employed and a survey administered via web-based software (Qualtrics; Provo, UT, USA). After recording demographic data, we assessed exercise-related behavioural regulations (i.e., amotivation, external, introjected, identified, integrated, and intrinsic). Thereafter, we measured PA levels, mental health, and sedentary behaviour pre- and during the UK lockdown. A retrospective frame was adopted for pre-lockdown measures through attaching batches of items to relevant anchors (e.g., "Before the COVID–19 lockdown …"). The one-off survey was launched on 30 April 2020 and closed on 31 May 2020 (i.e., during a period of strict lockdown). It took ~20 min to complete and volunteers were not offered any incentive for their participation.

Data Analysis

The Statistical Package for the Social Sciences (SPSS) v26.0.0.1 (Armonk, NY, USA) was used to conduct the analyses described herein. Data were screened for univariate outliers using standardised scores ($z > \pm 3.29$). We considered the potential confounds of age, sex, and BMI in the relationship between our explanatory and dependent variables. Accordingly, we explored the relationship between the potential confounds and the dependent variables by means of Pearson product-moment correlations (age and BMI) and independent-samples *t* tests (sex). Thereafter, multivariate outliers were screened for using the Mahalanobis distance test ($p < .001$; Tabachnick & Fidell, 2019).

The assumptions that underlie hierarchical multiple regression analysis were examined (e.g., absence of outliers, normality, multicollinearity), as were the assumptions that underlie partial correlation (e.g., linearity; see Weir & Vincent, 2020). Six hierarchical multiple regression analyses were used to explain PA (i.e., planned, unplanned, and number of steps per day) pre- and during lockdown from BREQ-3 factor scores, while controlling for the potential confound of BMI. Accordingly, BMI was entered at Step 1, followed by the BREQ-3 factors at Step 2. Two hierarchical multiple regressions were computed to explain mental health pre- and during lockdown from PA, while controlling for the potential confound of age. Hence, age was entered at Step 1, planned PA was entered at Step 2 and unplanned PA at Step 3, in accord with TPB (Fishbein & Ajzen, 2010).

Two partial correlations facilitated an exploration of the relationship between steps per day and mental health pre- and during lockdown, while controlling for the potential confound of BMI and age (Avila et al., 2015; Hemmingsson & Ekelund, 2007). Two hierarchical multiple regressions were used to examine the degree to which sedentary behaviour explained mental health pre- and during lockdown, while controlling for age. Therefore, age was entered at Step 1, sitting time was entered at Step 2 and screen time at Step 3. This was because sitting time has been described as a ubiquitous health threat (Stamatakis et al., 2019). Comparatively, there were greater opportunities to engage in screen time without being sedentary, such as participating in online PA classes, which grew in popularity during the pandemic (Parker et al., 2021).

Multiple comparisons were not Bonferroni adjusted due to the increased probability of the emergence of a Type II error (Rothman, 1990). Moreover, we used an ANOVA as an omnibus assessment of the significance of each regression model to prevent inflation of family-wise error (i.e., non-significant ANOVAs rendered significant independent variables in the model moot). To compare explanatory variables from pre- to during lockdown in all regression analyses, we standardised variables by computing *z*-scores (i.e., with $M = 0$, $SD = 1$). Thereafter, we calculated standardised regression coefficients and their associated 95% confidence intervals (Bring, 1996). Ropeladder plots were employed to facilitate pre- vs. during visual inspection of differences (Jann, 2014).

Results

Data Screening and Diagnostic Tests

Checks for univariate outliers revealed 207 cases that were modified to be one unit larger or smaller than the next most extreme score in the distribution, until the corresponding *z*-scores were within the range -3.29–3.29 (Tabachnick & Fidell, 2019). Checks for multivariate outliers revealed 18 cases that were duly screened out of the analysis with which they corresponded. Normality was assessed by inspecting the normal probability plots (P–P) of standardised residuals. The normality violations were sufficiently minor so as not to warrant data transformation (Tabachnick & Fidell, 2019). Multicollinearity was assessed through examination of correlation matrices, as well as variance inflation factor (VIF) and tolerance scores. Correlations among explanatory variables were not sufficiently strong to warrant any exclusions ($rs < .90$; Tabachnick & Fidell, 2019). Furthermore, VIF and tolerance values indicated an absence of multicollinearity (VIF < 5 and tolerance > .2; Hair et al., 2010). Each multiple regression equation is presented in Supplementary Table 2.

Exploratory Analyses

Exploratory analyses were conducted to identify potential confounds in the relationships between explanatory and dependent variables. These indicated that BMI should be used in the analyses pertaining to all PA variables (inc. steps per day) and that age should be used in the analyses pertaining to mental health (see Supplementary Table 3 and Supplementary Table 4).

Exercise Motives as Explanatory Variables for Planned and Unplanned PA

BMI was entered at Step 1 and explained 4.2% of the variance in planned PA pre-lockdown. Following entry of the BREQ-3 factors at Step 2, the total variance explained by the model was 41.5%, $F(7, 374) = 37.90$, $p < .001$. Identified regulation was the strongest explanatory variable ($\beta = .41$, $p < .001$, 95% CI [0.24, 0.57]), followed by integrated regulation (β = .16, p = .027, 95% CI [0.02, 0.30]; see Figure 2a). During lockdown, BMI accounted for 4.7% of the variance in planned PA. Following entry of the BREQ-3 factors at Step 2, the total variance explained by the model was 24.2%, $F(7, 374) = 17.05$, $p < .001$ (see Supplementary Table 5). Integrated regulation was the strongest explanatory variable for planned PA (β = .28, p = .001, 95% CI [0.11, 0.43]), followed by external regulation (β = -.10, p = .045, 95% CI [-0.20, 0.00]; see Figure 2a), which was negatively associated with planned PA. Ninety-five percent CIs indicated that a difference emerged from pre- to during lockdown in identified regulation (see Figure 2a).

BMI was entered at Step 1 and explained 1.4% of the variance in unplanned PA pre-lockdown. Following entry of the BREQ-3 factors at Step 2, the total variance explained by the model was 9.5%, $F(7, 374) = 5.58$, $p < .001$, and integrated regulation emerged as the only significant explanatory variable (β = .28, p = .002, 95% CI [0.11, 0.46]; see Figure 2b). During lockdown, BMI accounted for 1.2% of the variance in unplanned PA. Following entry of the BREQ-3 factors at Step 2, the total variance explained by the model was 8.2%, $F(7, 374) = 4.78$, $p < .001$. Neither BMI nor any of the BREQ factors made a statistically significant contribution towards the explanation of unplanned PA during lockdown (ps > .05; see Supplementary Table 5). Moreover, no differences emerged from pre- to during lockdown, as depicted by 95% CIs (see Figure 2b).

Exercise Motives as Explanatory Variables for Steps Per Day

BMI was entered at Step 1 and explained 0.6% of the variance in steps pre-lockdown. Following entry of the BREQ-3 factors at Step 2, the total variance explained by the model was 9.2%, $F(7, 177) = 2.57$, $p = .015$. Intrinsic regulation (β = .30, p = .030, 95% CI [0.03, 0.59]) and introjected regulation (β = .18, p = .034, 95% CI [0.01, 0.34]) were the only statistically significant explanatory variables for steps pre-lockdown (see Figure 2c). During lockdown, BMI explained 3.4% of the variance in steps. Following entry of the BREQ-3 factors at Step 2, the total variance explained by the model was 20%, $F(7, 175) = 6.25$, $p < .001$. Neither BMI nor any of the BREQ factors made a statistically significant contribution towards the explanation of steps per day during lockdown (*p*s > .05; see Supplementary Table 5 and Figure 2c).

*** Insert Figure 2 about here ***

Planned and Unplanned PA as Explanatory Variables for Mental Health

Age was entered at Step 1 and explained 2.3% of the variance in mental health pre-lockdown (see Supplementary Table 6). Planned PA was entered at Step 2 and the model accounted for 3.4% of the variance in mental health scores pre-lockdown. Upon entry of the unplanned PA scores at Step 3, the total variance explained by the model as a whole was 4.7%, $F(3, 388) = 6.36$, $p < .001$ (see Figure 3a). Age ($\beta = -.18$, $p = .001$, 95% CI [-0.27, -0.08]), planned PA ($\beta = -.13$, $p = .010$, 95% CI [-0.23, -0.03]), and unplanned PA ($\beta = .12$, $p = .022$, 95% CI [0.02, 0.22]) made significant contributions to the final model.

During lockdown, age explained 1.9% of the variance in mental health (see Supplementary Table 6). Planned PA was entered at Step 2 and the model accounted for 5.4% of the variance in mental health scores. Following entry of the unplanned PA scores at Step 3, the total variance explained by the model as a whole was 6.6%, $F(3, 387) = 9.19$, $p < .001$. Age ($\beta = -.12$, $p = .016$, 95% CI [-0.22, -0.02]), planned PA ($\beta = -.16$, $p = .001$, 95% CI [-0.26, -0.06]) and unplanned PA ($\beta = -.12$, $p = .023$, 95% CI [-0.22, -0.02]) made significant contributions to the final model. Unplanned PA differed significantly, as indicated by 95% CIs, from pre- (95% CI [0.02, 0.22]) to during lockdown (95% CI [-0.22, -0.02]; see Figure 3a).

Partial Correlations of Steps Per Day with Mental Health

With BMI and age partialled out, there was a nonsignificant partial correlation between steps per day and mental health both pre- and during lockdown, respectively (r = .10, r^2 = 0.01, n = 189, p = .093; r = -.08, r^2 = 0.01, n = 186, p = .144).

Sedentary Behaviour as an Explanatory Variable for Mental Health

Age was entered at Step 1 and explained 2.4% of the variance in mental health pre-lockdown (see Supplementary Table 6). Sitting time was entered at Step 2 and the model accounted for 2.6% of the variance in mental health scores pre-lockdown. After entry of the screen time scores at Step 3, the total variance explained by the model as a whole was 3.3%, $F(3, 381) = 4.29$, $p = .005$. Age made a significant contribution to the final model (β = -.13, p = .017, 95% CI [-0.23, -0.02]), but neither sitting nor screen time emerged as statistically significant explanatory variables for mental health pre-lockdown ($ps > .05$; see Supplementary Table 6 and Figure 3b).

During lockdown, age explained 2.3% of the variance in mental health (see Supplementary Table 6). Sitting time was entered at Step 2 and the model accounted for 5.1% of the variance in mental health scores. Following entry of the screen time scores at Step 3, the total variance explained by the model as a whole was 5.5%, $F(3, 382) = 7.35$, $p < .001$. Age, sitting time, and screen time did not significantly contribute to the final model ($ps > .05$; see Supplementary Table 6). Furthermore, there were no differences from pre- to during lockdown for sitting time or screen time (see Figure 3b).

*** Insert Figure 3 about here ***

Discussion

The main purpose of the present study was to examine the degree to which exercise-related behavioural regulations explained PA pre- and during UK lockdown. We also examined associations between PA and sedentary behaviour with mental health in the same timeframe. The hypothesis that a greater percentage of variance in planned PA would be explained pre- vs. during lockdown, while explanation of unplanned PA would remain unchanged (H_1), is supported by visual inspection of the present data (see Figure 2a and Figure 2b). The hypothesis that the percentage of variance explained in steps per day by exercise motives would not differ from pre- to during lockdown (H_2) is only partially supported (see Supplementary Table 5 and Figure 2c).

The hypothesis that planned and unplanned PA would explain a greater proportion of variance in mental health during vs. pre-lockdown (H_3) is also supported by visual inspection of the data (see Figure 3a). The expectation of a small but significant correlation between steps per day and mental health during lockdown (H_4) was not manifest in the data. Nonetheless, the hypothesis that sedentary behaviour would be more strongly associated with mental health during lockdown (H_5) is supported (see Supplementary Table 6 and Figure 3b).

Exercise Motives as Explanatory Variables for PA and Steps

A relatively large proportion of variance in planned PA was explained by exercise motives pre-lockdown (37.3%). However, as expected, this figure was considerably lower during lockdown (19.5%), albeit the difference between models was not subject to statistical analysis. The self-determined motives that were strongly associated with planned PA pre-lockdown, appear to have been tempered by the restrictions imposed by lockdown. It is notable that external regulation exhibited a negative association with planned PA during lockdown (see Figure 2a), which suggests that some participants may have carried a sense of coercion to exercise that served to limit their planned PA. Moreover, such participants perhaps felt that they lacked exercise-related social support and this was coupled with a low perception of behavioural control (Chirico et al., 2020).

The findings for unplanned PA were as expected, with little difference in explained variance from pre- (8.1%) to during (7.0%) lockdown, albeit that such a difference was not subject to statistical analysis (see Supplementary Table 5). There was one significant explanatory variable pre-lockdown, namely integrated regulation, but its explanatory power appears to have diminished during lockdown (see Figure 2b). This finding suggests that participants' values and needs may have shifted somewhat during lockdown, perhaps due to a realisation that by necessity, unplanned or spontaneous activity, particularly outside of the home (e.g., strolling around a department store), was severely restricted.

The findings for steps per day differed considerably to those of planned PA (see Supplementary Table 5) and there are several reasons for this, as well as for why the associated hypothesis was only partially accepted. The imposition of lockdown by the UK Government and the devolved governments of the home nations, meant that indoor and even some outdoor facilities that individuals would use routinely for exercise and physical activity were unavailable. This left people with two main choices for daily exercise, which essentially inhibited the contribution of self-determined motives. One was to engage in callisthenics, yoga, bodyweight-type exercises, and suchlike in their homes (unlimited); another was to walk, run, or cycle outdoors (≤ 1 hr per day). Accordingly, bipedal activity, such as stepping, was one of the few items available on the daily "menu" of PA, particularly for outdoor PA. This reduction in choice might have held partial responsibility for the increase in variance explained in steps from pre- to during lockdown. Another contributory factor could have been that people were engaged in physical tasks in their homes and gardens, leading to more unplanned PA that entailed taking steps (Rogers et al., 2020).

Dimensions of Physical Activity and Steps as Explanatory Variables for Mental Health

The findings illustrate how planned and unplanned PA are more strongly associated with mental health during lockdown (4.7%) when compared to pre-lockdown (2.4%; see Supplementary Table 6). In the absence of lockdown, people have multiple stimuli and social contacts to enable them to maintain mental health. Albeit PA is important for mental health in general terms (Farren et al., 2018), under conditions of lockdown, its importance is elevated given the lack of alternative stimuli/contacts (Holmes et al., 2020). The psychosocial benefits of exercise may have been inhibited for many, but the biological benefits (e.g., increase in serotonin release, physiological activation, and thermogenesis) would have played a salient role in moderating mental health (Mandolesi et al., 2018). It seems that unplanned PA made a small contribution (1%) to the regression model and hints at the potential benefits to mental health of activities that are unscheduled (Hamer et al., 2009).

Figure 3a illustrates the significant difference from pre- to during lockdown in how unplanned PA predicts mental health. Given that unplanned PA emerged as a negative explanatory variable during lockdown, this would suggest that with increases in unplanned PA, mental health is enhanced (a reminder that high GHQ-12 scores indicate compromised mental health). The present data suggest that *any* unplanned activity that people were able to experience under lockdown, had potentially positive ramifications for their mental health (Hamer et al., 2009). There is an alternative plausible explanation, which is that compromised mental health leads people to engage in less planned and unplanned PA (Da Silva et al., 2012).

Steps per day did not explain mental health either pre- or during lockdown, and the relationship between the two variables was weak (r^2s = .01). This might be attributed to steps being only part of an individual's complement of PA, and that only a subsection of the sample had the means by which to record their steps. These are likely individuals who have a strong interest in maintaining high daily step counts (Kirwan et al., 2012), whose efforts are thus not thwarted by conditions of lockdown. Accordingly, their perceived mental health is not associated with their step count.

Sedentary Behaviour as an Explanatory Variable for Mental Health

Sedentary behaviour explained a greater percentage of variance during vs. pre-lockdown (3.2% vs. 0.9%; see Supplementary Table 6), although this difference was not examined statistically. This, however, is a relatively small difference and almost entirely analogous with explanations of mental health during lockdown in other European countries (e.g., Cheval et al., 2020). Another point of interest is that, during lockdown, sitting time emerged as a significant explanatory variable for mental health scores at Step 2 of the hierarchical regression (i.e., as sitting time increased, mental health was compromised). However, it was not a significant explanatory variable at Step 3 when both sedentary behaviour variables were entered into the model (see Supplementary Table 6).

The implication of the differences between Step 2 and Step 3 of the hierarchical regression, is that screen time might be pleasurable for some, and thus promote better mental health (i.e., through facilitating communication with others, playing immersive video games, or watching TV; Johannes et al., 2020). This is likely given that Spence et al. (2020) found that almost two thirds of UK adults reported higher engagement with screen-based devices for leisure purposes during the first lockdown. Nonetheless, excessive periods of sitting during lockdown have the potential to compromise mental health in a small way (Qi et al., 2020).

Theoretical and Practical Implications

Among the most compelling findings in the present study is the degree to which behavioural regulations derived from SDT (Deci & Ryan, 1985) explained planned PA pre-lockdown (R^2 = .37), when compared to during lockdown (R^2 = .19). Accordingly, in the absence of lockdown, SDT exhibited high predictive efficacy, but when people's autonomy was thwarted by lockdown, the theory's explanatory power appeared to decline (see Supplementary Table 5). Interestingly, this relates somewhat to epistemological arguments posed by scholars in regard to the relevance of SDT in autocratic states where, by design, individual autonomy is undermined (Church et al., 2013). The findings provide insight as to how SDT predicts PA dimensions predicated on the Theory of Planned Behaviour (TPB; Fishbein & Ajzen, 2010). A tenet of TPB is that beliefs held about a likely outcome can be instrumental to the execution of a given behaviour, and so it is notable that identified regulation was so strongly associated with planned PA pre-lockdown (see Supplementary

Table 5). Identified regulation relates specifically to awarding a conscious value to a behaviour that might be important to an individual (Deci & Ryan, 2002).

Also of interest from a theoretical standpoint, is the possible link between sedentary behaviour and mental health, particularly with regard to screen time (see Figure 3b). From the perspective of the Ecological Model of Health Behaviour (Hadgraft et al., 2018), it is evident how the phenomenon of lockdown impacted all components of this model. For example, the policy and regulatory environment dictated that health and fitness facilities were closed and that people should stay at home for 23 hr per day. The physical environment may have presented severe restrictions for some with regard to sedentary behaviour, particularly if they did not have the luxury of a garden and/or lived in an apartment (Dogra & Stathokostas, 2014). Further, the interpersonal dimension of the model conjures the notion that, for many, friends and colleagues who would ordinarily promote and encourage PA, were inaccessible during lockdown (Holmes et al., 2020).

In terms of practical applications, it seems that even those who are highly self-determined to exercise are inhibited somewhat by lockdown (see Supplementary Table 5). This means that in terms of maintaining the physical health of the entire population, governments and public health agencies need to consider keeping fitness facilities (e.g., swimming pools) open and the provision of high-quality, technology-mediated exercise (e.g., daily yoga classes). An extension of this might be to apportion 30 min of each day to exercise so that people in their homes and those in workplaces have an opportunity to engage in PA synchronously. Linked to this, with the propensity of excessive hours of sitting leading to compromised mental health during lockdown, it is imperative that government messaging includes detail on the benefits of intermittent movement throughout waking hours (Bailey et al., 2020).

Strengths and Limitations

We were able to integrate a number of theories in the selection of explanatory and dependent variables (e.g., SDT and TPB). The multi-theory approach afforded a broad perspective on the issue of PA and mental health during the strictest period of UK lockdown. Also, the analytical strategy affords some originality in the pantheon of COVID–19 studies (Ammar et al., 2020; Di Renzo et al., 2020). The questionnaires employed had been subject to fulsome validation procedures (i.e., BREQ-3, BLPAQ, GHQ-12). Moreover, an extensive set of data-screening procedures characterised our analyses and help in giving credence the present findings.

Use of a cross-sectional design precludes any claim of causality, thus the findings need to be viewed within the frame of association. Allied to this, ideally, we would have implemented a time gap between explanatory and dependent variables. However, as the window of opportunity for seeking ethical clearance and collecting data for the study was limited, we were not able to include such a gap. This limitation pervades many similar studies conducted throughout the world during lockdown (Constandt et al., 2020; Di Renzo et al., 2020; Qi et al., 2020). Non-probability sampling was used and there is a participant self-selection bias that is common to surveys of this nature, meaning that lower socio-economic groups and ethnic minorities are underrepresented (Bethlehem, 2010; Spence et al., 2020). Conversely, other groups were overrepresented in the present study (e.g., women; see Supplementary Table 1).

The use of retrospective recall in the case of planned/unplanned PA, sedentary behaviour, and mental health pre-lockdown is duly acknowledged as a limitation. It is well documented that respondents provide less accurate information when asked about the past compared to the present (Coughlin, 1990). We sought to overcome this potential source of error through the use of suitable response sets in the survey (e.g., “Before the COVID–19 lockdown …"), in accord with recommendations for health-related COVID–19 research (Hipp et al., 2020).

Future Directions

Given the cross-sectional nature of the present study, it would be advantageous for future studies to take pre-, mid-, and end-of-lockdown measures (i.e., a longitudinal approach). This would provide exercise scientists and policy makers with a fuller understanding of the physical and mental health consequences of lockdown. Future studies might also examine eating and sleep behaviours (Holmes et al., 2020). Such an approach would elucidate the effects of lockdown on energy balance. Moreover, measures that tap the various components of sedentary behaviour (e.g., computer use, TV watching, reading) would be useful (Biddle, 2018).

From the demographic detail that we collected (see Supplementary Table 1), it is evident that there are some hard-to-reach subgroups in the UK population. Accordingly, future lockdown-based studies would need access to sufficient funds to incentivise representatives of such subgroups (e.g., BAME groups). In addition, 80.3% of respondents were women and so offline methods of data collection could run in parallel with online methods, with a view to eliciting more responses from men. One of the biggest concerns to emanate from the present findings is the degree to which those who were intrinsically motivated to exercise pre-lockdown were inhibited in so doing by the government-imposed lockdown. Finding ways to keep these people active, as well as their less motivated counterparts – who are a perennial concern for exercise scientists – is an imperative for future researchers.

Conclusions

The self-determined behavioural regulations that emerged as significant explanatory variables for planned PA pre-lockdown appear to have been tempered by lockdown-related restrictions (see Figure 2a). As expected, the amount of variance in unplanned PA explained by behavioural regulations remained similar from pre- to during lockdown (see Supplementary Table 5). Planned/unplanned PA and sedentary behaviour accounted for 4.7% and 3.2% of the variance in mental health during lockdown, respectively, which illustrates how our physical movement patterns bear some relationship with mental wellbeing (see Supplementary Table 6). The marked decline in the explanatory power of the BREQ-3 variable, identified regulation, during lockdown (see Figure 3a), suggests that interventions aimed at enhancing the degree to which people value planned PA, are likely to yield positive health outcomes (Standage et al., 2008).

Clearly, there would have been many instances of people either engaging in sedentary social activity or watching TV/playing video games during lockdown that may have been beneficial to their mental health (see e.g., Johannes et al., 2020). Where psychologists observe detriments in mental health, it seems warranted that they should assess individuals' PA behaviours to gauge whether any targeted advice or intervention might be of benefit (e.g., walk/run a mile a day). The present results suggest that *any* unplanned activity that people were able to engage in during lockdown had positive ramifications for their mental health (see Figure 3a). From a government and public health agency perspective, the potential salience of media-based interventions, and possibly targeting a 30-min slot in each day of national lockdown for the public to exercise, is worthy of serious consideration.

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Table 1

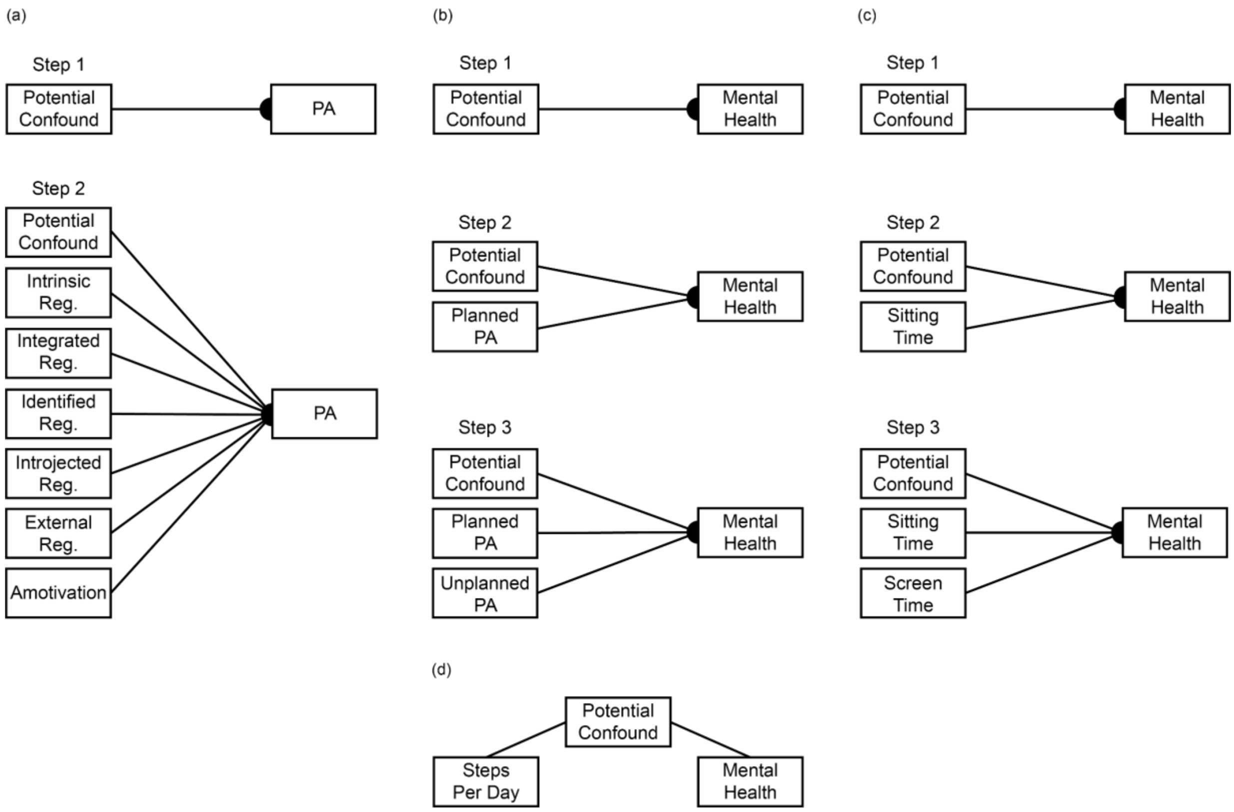
Demographic Characteristics of the Present Sample

	Total Sample (*N* = 392; 100%)		Age 18–30 years (*n* = 56; 14.3%)		Age 31–50 years (*n* = 130; 33.2%)		Age 51–70 years (*n* = 149; 38.0%)		Age > 70 years (*n* = 57; 14.5%)	
Variable	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Height (m)	1.67	0.09	1.70	0.09	1.69	0.09	1.66	0.09	1.62	0.10
Weight (kg)	70.86	14.00	69.93	13.38	71.80	13.67	69.95	14.01	72.00	15.38
Body mass index (BMI)	25.48	5.05	24.21	3.99	25.16	4.32	25.50	5.41	27.39	6.05
	n	%	*n*	%	*n*	%	*n*	%	*n*	%
Sex										
Female	314	80.3	42	75.0	95	73.1	128	85.9	49	87.5
Male	77	19.7	14	25.0	35	26.9	21	14.1	7	12.5
Setting										
Rural	128	32.7	12	21.4	37	28.5	59	39.6	20	35.1
Urban	264	67.3	44	78.6	93	71.5	90	60.4	37	64.9
Ethnicity										
White	358	91.8	45	80.4	116	89.9	142	95.9	55	96.5
BAME	32	8.2	11	19.6	13	10.1	6	4.1	2	3.5
Education										
No academic qualifications	2	0.5	–	–	–	–	1	0.7	1	1.8
GCSE/O-Level	42	10.9	1	1.8	1	0.8	22	15.1	18	32.7
National vocational qualification	8	2.1	–	–	2	1.6	5	3.4	1	1.8
Business and technology education council diploma	9	2.3	1	1.8	2	1.6	4	2.7	2	3.6
A-Level	40	10.4	7	12.7	6	4.7	21	14.4	6	10.9
Undergraduate degree	139	36.1	26	47.3	42	32.6	54	37.0	17	30.9
Postgraduate degree	106	27.5	16	29.1	51	39.5	32	21.9	7	12.7
Doctoral degree	39	10.1	4	7.3	25	19.4	7	4.8	3	5.5
Socio-economic status										
Large employers, higher managerial, professional	90	23.9	5	9.1	43	34.4	31	21.7	11	20.4
Lower managerial, administrative, professional	173	45.9	27	49.1	53	42.4	65	45.5	28	51.9
Intermediate occupations	65	17.2	10	18.2	14	11.2	29	20.3	12	22.2
Small employers, own-account workers	26	6.9	1	1.8	10	8.0	13	9.1	2	3.7
Lower supervisory, technical occupations	3	0.8	1	1.8	2	1.6	–	–	–	–
Semi-routine occupations	12	3.2	5	9.1	2	1.6	4	2.8	1	1.9
Routine occupations	3	0.8	1	1.8	1	0.8	1	0.7	–	–
Never worked, long-term unemployed	5	1.3	5	9.1	–	–	–	–	–	–

Note. BAME = Black, Asian, and minority ethnic. In the interests of brevity, participants who responded with “prefer not to say” to any of the items included in this table have been excluded.

Figure 1

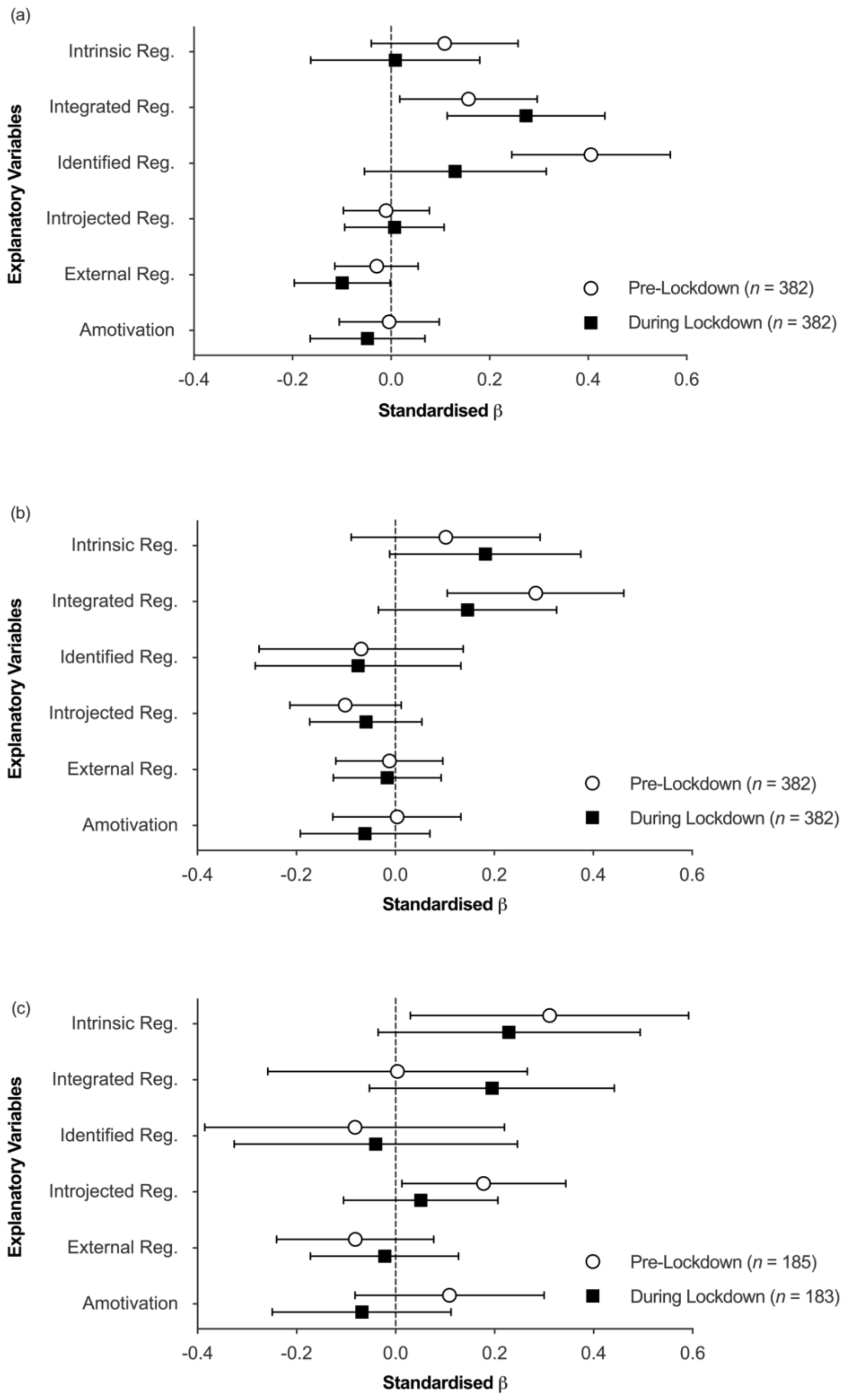
Associations Between (a) Exercise Motives and Physical Activity, (b) Planned/Unplanned Physical Activity and Mental Health, (c) Sedentary Behaviour and Mental Health, and (d) Steps Per Day and Mental Health



Note. PA was broken down into planned/unplanned dimensions, as well as daily step counts. All associations were examined pre- and during the initial UK lockdown. PA = physical activity; Reg. = regulation.

Figure 2

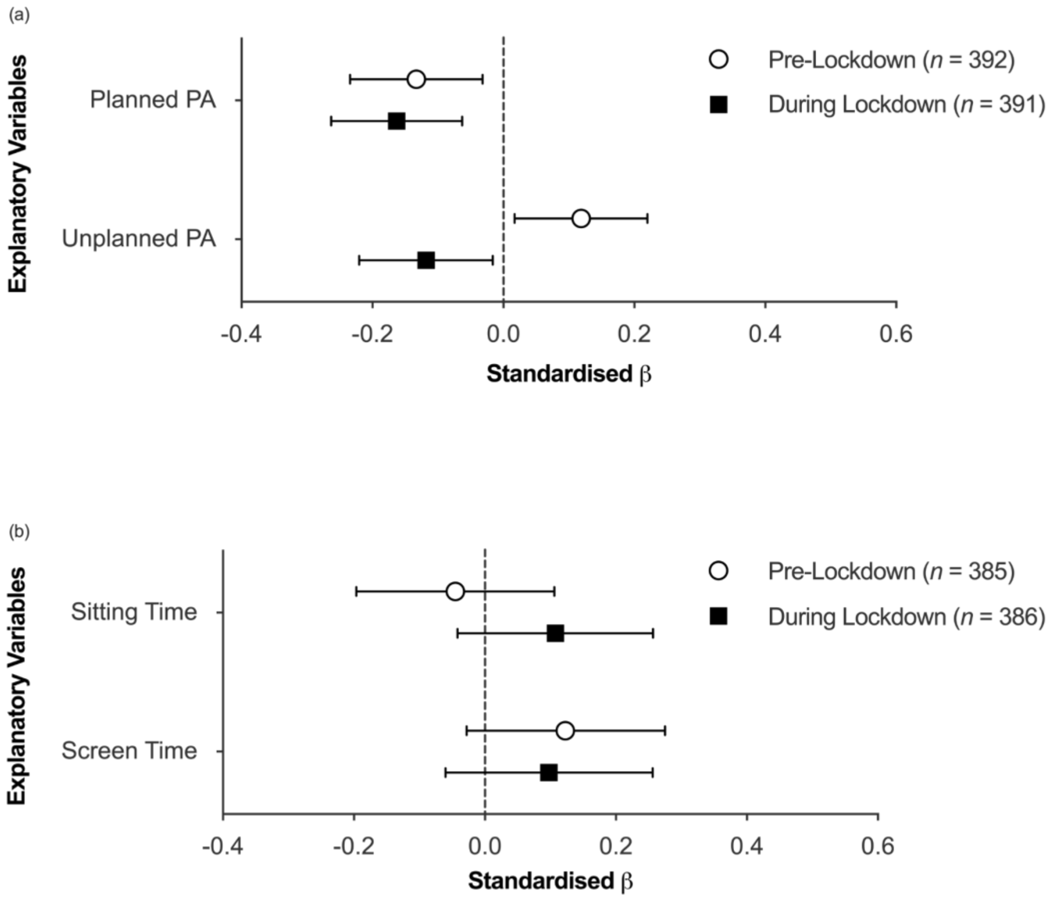
Standardised β Coefficients from Hierarchical Multiple Regression, Pre- and During Lockdown for the Explanation of (a) Planned Physical Activity, (b) Unplanned Physical Activity, and (c) Steps Per Day, Using Behavioural Regulations as Explanatory Variables



Note. Standardised β coefficients for body mass index are not plotted, as they were entered into each hierarchical multiple regression as a potential confound. Error bars represent 95% CIs. Reg. = regulation.

Figure 3

Standardised β Coefficients from Hierarchical Multiple Regression, Pre- and During Lockdown for the Explanation of Mental Health Using (a) Physical Activity and (b) Sedentary Behaviour



Note. Standardised β coefficients for age are not plotted, as they were entered into each hierarchical multiple regression as a potential confound. Higher scores for mental health (i.e., GHQ-12 scores) denote compromised mental health. Error bars represent 95% CIs. PA = physical activity.