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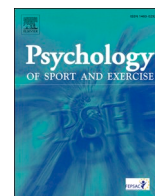
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The impact of living in a bio-secure bubble on mental health: An examination in elite cricket

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ABSTRACT

The COVID-19 pandemic has had a profound impact on many people's lives, including the use of bio-secure environments to facilitate the continuation of professional sport. Although it is well documented that the pandemic has negatively impacted mental health, the impact of bio-bubbles on mental health is yet to be investigated. In the present study we sought to identify the impact of bio-bubbles on the mental health of those residing within, and then to explore the underlying mechanism of any such impact. Individuals ($n = 68$) who resided in England and Wales Cricket Board (ECB) created bio-bubbles between March 2020 and April 2021 provided data, regarding their time inside and outside of bio-bubbles, on measures of mental health and basic psychological need satisfaction and frustration. Analysis revealed that bio-bubbles increased anxiety and depression and reduced wellbeing. Additionally, MEMORE mediation analyses revealed that autonomy frustration mediated the relationship between bubble status and all mental health markers. Furthermore, compared to men, women were more likely to experience elevated levels of anxiety and depression inside the bubble. The findings suggest that bio-bubbles negatively impact mental health and further suggest that satisfaction and frustration of basic psychological needs is a contributing factor. Findings suggest organizations tasked with creating bio-bubbles would do well to tailor their environment with an awareness of the importance of basic psychological needs and sex differences in relation to mental health. To the best of our knowledge, this research represents the first investigation of the impact of bio-bubbles on mental health.

As a consequence of COVID-19, many countries around the world entered into lockdown during 2020. To allow international cricket fixtures to be played during the pandemic and within consequent restrictions, the England and Wales Cricket Board (ECB) created bio-secure bubbles (hereafter *bio-bubbles*); the first to be created in sport. Many other sports subsequently adopted similar environments to enable the continuation of competition. People entered the ECB bio-bubbles after testing and completing a quarantine period to ensure that they were not carrying COVID-19 and they then remained inside the bubble without physical contact with the "outside world". For such bubbles to be effective, players, support staff, officials, and events management were all required to remain within the bio-bubble throughout the event. Friends and family were not permitted within the bubble and individuals were not able to leave without going through a 'bridging' process (quarantine period and testing) before re-entry. Given these restrictions,

in addition to the other pressures of elite sport (Woodman & Hardy, 2001), there was the potential for bubble inhabitants' wellbeing to be detrimentally affected. This research is an investigation of the impact of such an environment on mental health. Specifically, we provide the first exploration of how life in bio-bubbles influences mental health with a concomitant examination of potential mechanisms. We also explore sex differences in mental health markers in the ECB bubbles.

Early research suggested that COVID-19 could negatively impact mental health on a global scale (Torales et al., 2020); a prediction that has since been confirmed, with COVID-related estimated prevalence rates of mental health issues significantly higher than pre-COVID norms (Nochaiwong et al., 2021). For example, in the UK, anxiety and depression levels increased from pre-COVID norms (Jia et al., 2020) whilst subjective wellbeing decreased (Kwong et al., 2021). Although increases in anxiety and depression were observed in both men and

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women, symptoms were higher for women than for men during the first lockdown (Fancourt et al., 2020).

Within sport, early concerns regarding the impact of COVID-19 on athlete mental health (Reardon, Bindra et al., 2021) have been actualized across many studies. Depression (Pillay et al., 2020), anxiety (Chandler et al., 2021), and sleep disruption (Chandler et al., 2021) all increased. Research has also looked beyond prevalence. Facer-Childs et al. (2021) suggested that changes to athlete sleep patterns were a cause of increased depression and anxiety levels, and Pensgaard et al. (2021) evidenced that financial concerns caused by the pandemic contributed to increases in anxiety and depression. Given the initial evidence that the pandemic negatively affected mental health for those in sport, and that bio-bubbles were being proposed as a solution, the current study looked to investigate the specific impact that these unique environments would have on resident wellbeing.

Research suggests that bio-bubbles would negatively impact mental health. For example, quarantine and isolation are known to negatively impact mental health (Henssler et al., 2021). Additionally, living in a bio-bubble for an extended period of time where close family and friends are not permitted could potentially cause loneliness, which can contribute to a range of health problems such as the development of depressive symptoms (Cacioppo et al., 2010), anxiety (Hawley & Cacioppo, 2010), alcoholism, and aggressive behavior (Cacioppo et al., 2015). Moreover, the many restrictions on day-to-day life likely results in individuals experiencing low levels of autonomy, which has been identified within the prison setting as contributing to poor mental health (Awofeso, 2010). Whilst we are not suggesting bio-bubbles are like prisons, the social distancing, isolation, and restricted movement invite comparisons. Consequently, the possibility that bio-bubbles cause loneliness, social isolation, and reduced autonomy leads bubbles to have the potential to exert a significant negative impact on mental health.

With the aforementioned issues in mind, in this study we examined how mental health is impacted by residing in a bio-bubble. We focused on anxiety, depression, and subjective wellbeing as measures of mental health. Measuring anxiety and depression allowed us to quantify the prevalence of two common mental health problems in a new environment which was being proposed as the solution to the continuation of elite sport during the pandemic. Additionally, focusing on these aspects allowed us to add to the aforementioned research regarding the mental health of athletes during COVID-19, which has largely focused on anxiety and depression. Further, as mental health is not merely the absence of mental illness (Westerhof & Keyes, 2010), measuring subjective wellbeing also provides insight into mental health. Due to the multitude of reasons that bio-bubbles might negatively impact mental health and a scarcity of evidence suggesting anything otherwise, we hypothesized that being within bio-bubbles would increase anxiety and depression symptoms and reduce wellbeing.

1. Basic psychological needs and their impact on mental health

A cornerstone of Self Determination Theory (SDT; Deci & Ryan, 2000; Ryan & Deci, 2000) is that the satisfaction of three basic psychological needs (BPN; autonomy, competence, relatedness) is a *sine qua non* of human thriving (Deci & Ryan, 2000). Conversely, the frustration of these BPN results in maladaptive functioning (Vansteenkiste & Ryan, 2013). For example, whilst the experience of connection and intimacy with others satisfies the need for relatedness (Ryan, 1995), need frustration refers to instances where these needs are actively thwarted (Chen et al., 2015). Thus, a lack of intimacy would be regarded as low need fulfilment whilst feelings of loneliness or relational exclusion would be regarded as the need being frustrated (Chen et al., 2015).

Contextualizing satisfaction and frustration of BPN in the prediction of mental health, Chen et al. (2015) found that BPN satisfaction exclusively predicted subjective wellbeing whilst BPN frustration predicted immediate ill-being. Studies have previously revealed a relationship between BPN frustration and mental health in athletes (Bartholomew

et al., 2011) and have also shown that long-term thwarting leads to the development of maladaptive behaviors, such as alcohol use, which in turn contributes to ill-being (Vansteenkiste & Ryan, 2013).

Given that part of the impact of bio-bubbles on mental health is likely to be the forced separation from close family and a lack of control over actions, thwarting of BPN is likely to act as a mechanism for the effect of bio-bubbles on mental illness. Additionally, aligning with the findings of Chen et al. (2015), changes in wellbeing are likely attributable to BPN satisfaction. Consequently, we hypothesized that BPN satisfaction would mediate the negative relationship between being in a bio-bubble and subjective wellbeing and that BPN frustration would mediate the positive relationship between being in a bio-bubble and anxiety and depression.

2. Sex differences

A pre-COVID investigation of mental health in the UK (McManus et al., 2016) found that symptoms of common mental disorders (CMD), including but not exclusively referring to depression and anxiety, were more prevalent for women (19.1%) than for men (12.2%). Women are twice as likely as men to suffer from anxiety or depression as an affective disorder (Altemus et al., 2014) and are more likely to experience anxiety and depression at a sub-clinical level (Hankin, 2009). During the COVID-19 pandemic, research revealed that lockdown measures magnified women's greater susceptibility to mental health problems (see Kwong et al., 2021). This aligns with research conducted prior to the pandemic regarding the effects of quarantining in hospital. Specifically, whilst quarantined, women were at greater risk of suffering from depression and were more likely to experience general mental health impairments (Henssler et al., 2021). As such, women may be more affected than men by bio-bubbles.

In summary, the aim of this study was to investigate whether bio-bubbles have a negative impact on mental health. Based on research conducted in similar environments (hospitals, prisons) and our predictions regarding BPN, we hypothesized that anxiety and depression would increase inside the bubble and that wellbeing would decrease inside the bubble. Following Chen et al. (2015), we also hypothesized that the frustration of autonomy, competence, and relatedness would mediate the relationship between bubble status (in or out) and anxiety/depression, and that the satisfaction of autonomy, competence, and relatedness would mediate the relationship between bubble status and wellbeing. Finally, we hypothesized that sex would moderate the relationship between bubble status and anxiety, depression, and wellbeing. Specifically, given that women are more likely than men to experience psychological impairments when quarantined (Henssler et al., 2021), we hypothesized that women would have significantly higher anxiety and depression and significantly lower wellbeing inside the bubble.

3. Method

3.1. Participants

The sample size was governed by resource constraints (cf. Lakens, 2021). Specifically, the applied implications of possible findings meant completing this research in a timely manner was of importance and prolonging the data gathering period to possibly increase sample sizes was not possible. Additionally, the population from which a sample could be gathered was relatively small. Individuals were eligible if they had spent time in at least one of the bio-bubbles associated with the England and Wales Cricket Board (ECB) between March 2020 and April 2021 and were 18 years old or older. Only individuals whose contact information was held by the ECB were invited to participate. Sixty-eight participants ($M_{age} = 37.88$, $SD = 10.52$; men = 36, women = 31, undisclosed = 1) out of a possible 148 completed the survey. The sample comprised players ($n = 19$), coaches ($n = 11$), medical staff ($n = 11$), other team-specific staff ($n = 9$), events management ($n = 8$), umpires (n

= 6), media (not team-specific; $n = 2$), and other ECB staff members ($n = 2$). Suitable *a-priori* power analysis conducted for each of our proposed analyses indicated a minimal sample size of 53 was required. In all power analyses, power was set at 0.80 and alpha set at 0.05. An effect size of 0.5 was used in the power analysis concerning *t*-tests and repeated measures MANOVA. For mediation analysis, an effect size of 0.59 was used for both the α and β path, as per Fritz and MacKinnon's (2007) empirical estimates of sample size guide. This effect size aligns with the research findings of Sakan et al. (2020).

3.2. Measures

3.2.1. Anxiety

We used the Generalized Anxiety Disorder Scale (GAD-7; Spitzer et al., 2006) to assess anxiety. Initially designed to screen for generalized anxiety disorder (GAD), the GAD-7 has also been identified as capable of identifying panic disorders, post-traumatic stress disorder, and social anxiety (Löwe et al., 2008). The GAD-7 has been evidenced to be effective within general and clinical populations (Löwe et al., 2008) and is also widely used in sport (Reardon, Gorczynski et al., 2021). The GAD-7 uses a four-point Likert scale ranging from 0 (not at all) to 3 (nearly every day).

3.2.2. Depression

We used the Patient Health Questionnaire (PHQ-9; Kroenke et al., 2001) to assess depression. The PHQ-9 is a 9-item scale that can be used to establish a provisional depressive disorder diagnosis as well as to assess the severity of depressive symptoms (Kroenke & Spitzer, 2002). The PHQ-9 is regarded as a reliable and valid unidimensional measure of depression within the general population (Kocalevent et al., 2013). Items are rated on a four-point Likert scale ranging from 0 (not at all) to 3 (nearly every day).

3.2.3. Wellbeing

To measure wellbeing, we used the 5-item World Health Organization Index (WHO-5; World Health Organization, 1998), which is a single-factor scale (de Wit et al., 2007) that has been used extensively in a variety of domains due to its straightforward language and administration (Topp et al., 2015). The five items are positively worded on a scale of 0 (at no time) to 5 (all of the time).

Alpha coefficients for the PHQ-9, GAD-7, and WHO-5 can be found in Table 1.

3.2.4. Basic psychological need satisfaction and frustration

To measure basic psychological needs satisfaction and frustration, we used an abbreviated version of the Basic Psychological Need Satisfaction and Frustration Scale (BPNSFS; Chen et al., 2015). The original six-factor model distinguishes between satisfaction and frustration of autonomy, competence, and relatedness, and has been validated across cultures (Chen et al., 2015).

In this study, we reduced each construct from four items to two. Minimizing the time commitment to complete the survey was an important ethical consideration. From a return-on-investment perspective, minimizing the length of questionnaires where possible in applied research is better for the participant, and most often does not diminish the psychometric integrity of the scale (Horvath & Röthlin, 2018). We chose item pairs taking into account Horvath and Röthlin's (2018) criteria for reducing questionnaires. Specifically, we made sure the items we chose still represented the concepts that we were measuring and we ensured that the items were easy to understand and applicable to the unique setting of a bio-bubble. We used a combination of conceptual relevance and factor loadings from the original paper in making decisions about which items to use (item pairs used can be found in Supplementary Table 1). We chose not to analyze the internal reliability of the BPNSFS using Cronbach's alpha, as this method is not well suited when using item pairs (Gosling et al., 2003). Instead, we adopted a

Table 1
Descriptive statistics and correlations between variables.

Measure	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
1.PHQ-9 Out	-																		
2.PHQ-9 In	.53**	-																	
3.GAD-7 Out	.60**	.42**	-																
4.GAD-7 In	.67**	.47**	.37**	-															
5.WHO-5 Out	.68**	.61**	.37**	.37**	-														
6.WHO-5 In	.58**	.45**	.31**	.31**	.58**	-													
7.Autonomy Satisfaction Out	.80**	.80**	.42**	.42**	.80**	.80**	-												
8.Autonomy Satisfaction In	.80**	.80**	.42**	.42**	.80**	.80**	.80**	-											
9.Autonomy Frustration Out	.67**	.67**	.37**	.37**	.67**	.67**	.67**	.67**	-										
10.Autonomy Frustration In	.67**	.67**	.37**	.37**	.67**	.67**	.67**	.67**	.67**	-									
11.Competence Satisfaction Out	.45**	.45**	.30**	.30**	.45**	.45**	.45**	.45**	.45**	.45**	-								
12.Competence Satisfaction In	.45**	.45**	.30**	.30**	.45**	.45**	.45**	.45**	.45**	.45**	.45**	-							
13.Competence Frustration Out	.45**	.45**	.30**	.30**	.45**	.45**	.45**	.45**	.45**	.45**	.45**	.45**	-						
14.Competence Frustration In	.45**	.45**	.30**	.30**	.45**	.45**	.45**	.45**	.45**	.45**	.45**	.45**	.45**	-					
15.Relatedness Satisfaction Out	.45**	.45**	.30**	.30**	.45**	.45**	.45**	.45**	.45**	.45**	.45**	.45**	.45**	.45**	-				
16.Relatedness Satisfaction In	.45**	.45**	.30**	.30**	.45**	.45**	.45**	.45**	.45**	.45**	.45**	.45**	.45**	.45**	.45**	-			
17.Relatedness Frustration Out	.45**	.45**	.30**	.30**	.45**	.45**	.45**	.45**	.45**	.45**	.45**	.45**	.45**	.45**	.45**	.45**	-		
18.Relatedness Frustration In	.45**	.45**	.30**	.30**	.45**	.45**	.45**	.45**	.45**	.45**	.45**	.45**	.45**	.45**	.45**	.45**	.45**	-	
Mean	2.92	5.34	2.51	4.92	16.30	14.38	7.90	7.34	3.98	5.05	8.11	7.90	4.26	4.69	8.51	7.69	3.46	3.87	3.87
SD	3.17	4.93	3.11	4.67	4.66	5.67	1.73	1.85	1.73	1.91	2.06	2.04	2.45	2.38	1.59	1.92	1.77	1.78	1.78
Alpha		.88		.90		.91													

Note: Means and Standard Deviations (SD) reported for out-of-bubble scores are for the created score, Cronbach's Alpha is not reported for out-of-bubble scores as these were not directly derived from a measure, $p < .05$, $**p < .001$.

similar method to that of Rammstedt and John (2007) and analyzed the factor structure of the shortened BPNSFS to determine whether our item pairs represented the full questionnaire from which they were derived (see Rammstedt & John, 2007). Confirmatory Factor Analysis (CFA) confirmed that the item pairs for basic psychological need satisfaction and frustration had the same factor structure as the BPNSFS. We obtained substantial mean loadings on the intended factor (mean loading = 0.73) and negligible loadings on each of the five unintended factors (loadings less than 0.19). All items were scored on a five-point Likert scale from 1 (*completely untrue*) to 5 (*completely true*).

3.3. Procedure

Following institutional ethical approval, prospective participants were invited via email to complete an online survey (Qualtrics, 2011). The survey was disseminated on February 12th 2021 and available for completion until April 14th 2021. The time between a person residing within a bubble and their taking the survey varied across participants. Specifically, 30 participants reported spending time in bio-bubbles only in the UK during the summer of 2020, 38 participants were in later bubbles (tours abroad during the UK winter), or completed the survey whilst in a bio-bubble. Participants who had experienced multiple bubbles (27 participants were in the UK summer bubbles and part of various touring parties abroad during the 2020–2021 winter) were asked to aggregate their responses (see below for more detail).

After providing informed consent and their *mental health code* (see Referral section for more details of this code), participants completed a series of demographic questions regarding age, sex, team within the bubble, ethnicity, relationship status, parental status, longest amount of time spent in a bio-bubble, role in the bubble, bio-bubbles of which they had been part, and whether they were in a bubble at the time of survey completion. Following the demographics, participants completed the PHQ-9, the GAD-7, the WHO-5, and a reduced version of the BPNSFS. We changed the stem to all questionnaires so that individuals were specifically asked about their time inside bio-bubbles. Following each item, to assess their out-of-bubble experience, individuals were asked to compare their in-bubble answer to their experience outside of the bubble since the pandemic began (March 2020). This was done using a five-point Likert scale from *I have experienced this a lot less* to *I have experienced this a lot more*. For example, for the first item of the PHQ-9, individuals were asked how often during their time in-the-bubble they had “little interest or pleasure in doing things” and responded using a four-point Likert scale ranging from *not at all* to *nearly every day*. Immediately after this Likert scale they were presented with another Likert scale, this time asking them whether they had experienced “little interest or pleasure doing things” out of the bubble *a lot more, a little more, the same, a little less* or *a lot less* than they had in-the-bubble (see Supplementary Information 1 for visual representation of how this was formatted). We deemed this approach the most efficient method of gathering retrospective data for two conditions. It minimized the time taken to complete the survey, aided memory recall, and actively encouraged comparison between the two conditions. Additionally, when conducting preliminary analysis, this dual Likert scale acted as a form of attention checking (see Results section for more details). When completing both the in-bubble and out-of-bubble portions of an item, participants were instructed to aggregate their experiences and refer to their total time inside and outside of bubbles, respectively. This aggregation meant it did not matter whether people were inside or outside of a bubble when completing the survey (which was varied) and allowed us to include past bubbles within our research.

We used this comparison process to create out-of-bubble scores for each individual for every item. For example, if a participant scored 3 for the in-bubble response to a particular item, and then answered the out-of-bubble item with *I have experienced this the same*, their out-of-bubble score for that item would also be 3. However, if they answered, *I have experienced this a little more*, or, *I have experienced this a lot more*, their out

of bubble score for that item was scored at 4 or 5, respectively (i.e., one and two more than their in-bubble score for the item, respectively). Conversely, if participants answered, *I have experienced this a little less* or *I have experienced this a lot less*, then their out-of-bubble value was scored at 2 and 1, respectively. If it was not possible to score two points less than their in-bubble score, they scored one point less. If it was not possible to score one point less (e.g., if the response was *not at all*) then their out-of-bubble score was the same as their in-bubble score – zero. Scores generated from the comparative out-of-bubble Likert scale could not be below zero or exceed the maximum limit possibly scored on the item in the original questionnaire (e.g., the PHQ-9 has a top score of three on each item; see Supplementary Information 1 for a scoring example).

3.4. Data analysis

We used Mplus (Version 8; Muthén & Muthén, 1998 - 2017) to conduct the previously discussed CFA. We analyzed all other data using the Statistical Package for the Social Sciences (SPSS, Version 27). Additionally, to test the mediating role of BPN we used the MEMORE macro designed to test mediation in repeated measures designs (V2.1; Model 1; Montoya & Hayes, 2017). Prior to analysis, we checked all data for missing values and outliers and examined means and standard deviations for demographic information. We analyzed Alpha coefficients for the in-bubble scores of the PHQ-9, GAD-7, and WHO-5. We also conducted paired samples *t*-tests to examine the difference between in-and-out of bubble scores. As noted, we used the MEMORE macro, designed to test mediation in repeated measures designs, to test whether basic psychological needs satisfaction or frustration mediated the relationship between bubble status (out, in) and mental health markers (anxiety, depression, wellbeing). MEMORE allows the within-participant change in variables (e.g., autonomy satisfaction) between two conditions (e.g., being inside and outside of a bio-bubble) to be used as a mediator of within-participant change in an outcome variable (e.g., anxiety), thus enabling mediation analysis with repeated measures data. For each outcome variable we ran two models, one containing the BPN satisfaction variables as the mediators and another containing the BPN frustration variables as the mediators. We used 10,000 bootstrap samples to compute 95% confidence intervals (CI). An effect was significant if the CI did not encompass zero.

We used repeated measures multivariate analysis of variance (MANOVA) to assess whether sex moderated the relationship between bubble status (in, out) and mental health. Alpha levels of 0.05 were used. 2 x 2 repeated measures analysis of variance (ANOVA) further investigated the effect for specific mental health markers, with follow-up paired samples Bonferroni-adjusted *t*-tests.

3.5. Referral

Although research was the primary aim of this data collection, the study provided an opportunity to identify individuals who might need support. To make this support process possible, we pseudo-anonymized participants' data. Specifically, we gave prospective participants a unique code that they inputted at the beginning of the survey. Only the ECB employee who created the codes, the same person who distributed the survey, had access to the document linking codes to individuals. This ECB employee did not have access to the data. If a participant met referral criteria, an automatic email stating which referral criterion had been met was sent from the survey-hosting platform to the aforementioned ECB employee who then referred the individual for appropriate clinical support. Referral criteria and protocol for making a referral were devised by a governance group (consisting of medical personnel and mental health professionals), which was established by the ECB.

4. Results

4.1. Data screening and preliminary analysis

The out-to in-bubble comparison response provided a form of attention check that we used to screen the data. For example, we removed participants if they responded to an item in such a way as to indicate that they had experienced a symptom of mental illness (anxiety or depression) *not at all* whilst inside the bubble, but then claimed that they had experienced this symptom *a little less* whilst outside the bubble. We removed seven participants who provided invalid responses. Descriptive statistics and Pearson correlations are presented in Table 1.

4.2. The impact of bio-bubbles

As hypothesized, paired samples *t*-tests revealed that anxiety, $t(60) = 5.45, p < .001, d = 0.70$, and depression were significantly higher inside the bubble, $t(60) = 4.50, p < .001, d = 0.58$. Also, wellbeing was significantly lower inside the bubble, $t(60) = 3.52, p = .001, d = 0.45$ (see Table 1).

4.3. Basic psychological needs

To test the hypothesis that basic psychological needs (BPN; autonomy, competence, relatedness) satisfaction and frustration would mediate the relationship between bubble status (out, in) and mental health markers (anxiety, depression, wellbeing), we conducted multiple mediation analyses.

4.3.1. The effect of basic psychological needs frustration on the bubble status-anxiety relationship

As depicted in Fig. 1.1, there was a significant positive indirect effect of bubble status on anxiety via autonomy frustration (indirect effect = 1.14, $SE = 0.36, 95\% CI [0.60, 2.01]$). Bubble status was positively associated with autonomy frustration ($B = 1.08, SE = 0.18, 95\% CI [0.71, 1.45]$), and autonomy frustration was positively associated with anxiety ($B = 1.05, SE = 0.26, 95\% CI [0.54, 1.57]$). There was no significant indirect effect of bubble status on anxiety via competence frustration ($B = 0.35, SE = 0.24, 95\% CI [-0.07, 0.84]$) or via relatedness frustration ($B = -0.14, SE = 0.15, 95\% CI [-0.47, 0.15]$). Interestingly, despite the nonsignificant indirect effect via competence frustration,

examination of the separate effects indicated that bubble status was significantly (and positively) associated with competence frustration ($B = 0.43, SE = 0.14, 95\% CI [0.16, 0.71]$) and competence frustration was significantly (and positively) associated with anxiety ($B = 0.81, SE = 0.37, 95\% CI [0.06, 1.55]$). Bubble status was associated with relatedness frustration ($B = 0.42, SE = 0.14, 95\% CI [0.14, 0.69]$) but there was no association between relatedness frustration and anxiety ($B = -0.33, SE = 0.30, 95\% CI [-0.94, 0.28]$). The separate effects from bubble status to mediator reported in this model are the same for all models investigating bubble status on outcomes via BPN frustration and so are not reported further. The direct effect of bubble status on anxiety was significant ($B = 1.11, SE = 0.41, 95\% CI [0.29, 1.93]$).

4.3.2. The effect of basic psychological needs frustration on the bubble status-depression relationship

There was a significant positive indirect effect of bubble status on depression via autonomy frustration (indirect effect = 1.58, $SE = 0.51, 95\% CI [0.81, 2.82]$, see Fig. 1.2). Examination of the separate effects revealed a positive association between autonomy frustration and depression ($B = 1.46, SE = 0.36, 95\% CI [0.74, 2.18]$). There was no significant indirect effect of bubble status on depression via competence frustration ($B = 0.31, SE = 0.27, 95\% CI [-0.19, 0.86]$) or via relatedness frustration ($B = -0.20, SE = 0.20, 95\% CI [-0.63, 0.20]$). Separate effects revealed no significant relationship between competence frustration ($B = 0.71, SE = 0.52, 95\% CI [-0.33, 1.75]$) or relatedness frustration ($B = -0.47, SE = 0.42, 95\% CI [-1.32, 0.37]$) and depression. The direct effect of bubble status on depression was nonsignificant ($B = 0.83, SE = 0.57, 95\% CI [-0.32, 1.97]$).

4.3.3. The effect of basic psychological needs frustration on the bubble status-wellbeing relationship

As depicted in Fig 1.3, there was a significant negative indirect effect of bubble status on wellbeing via autonomy frustration (indirect effect = -1.35, $SE = 0.46, 95\% CI [-2.43, -0.63]$). Examination of the separate effects revealed an association between autonomy frustration and wellbeing ($B = -1.25, SE = 0.41, 95\% CI [-2.07, -0.43]$). There was no significant indirect effect for bubble status on wellbeing via competence frustration ($B = -0.15, SE = 0.29, 95\% CI [-0.73, 0.44]$) or for relatedness frustration ($B = 0.33, SE = 0.25, 95\% CI [-0.12, 0.88]$). Separate effects revealed no association between competence frustration ($B = -0.34, SE = 0.59, 95\% CI [-1.53, 0.85]$) or relatedness frustration

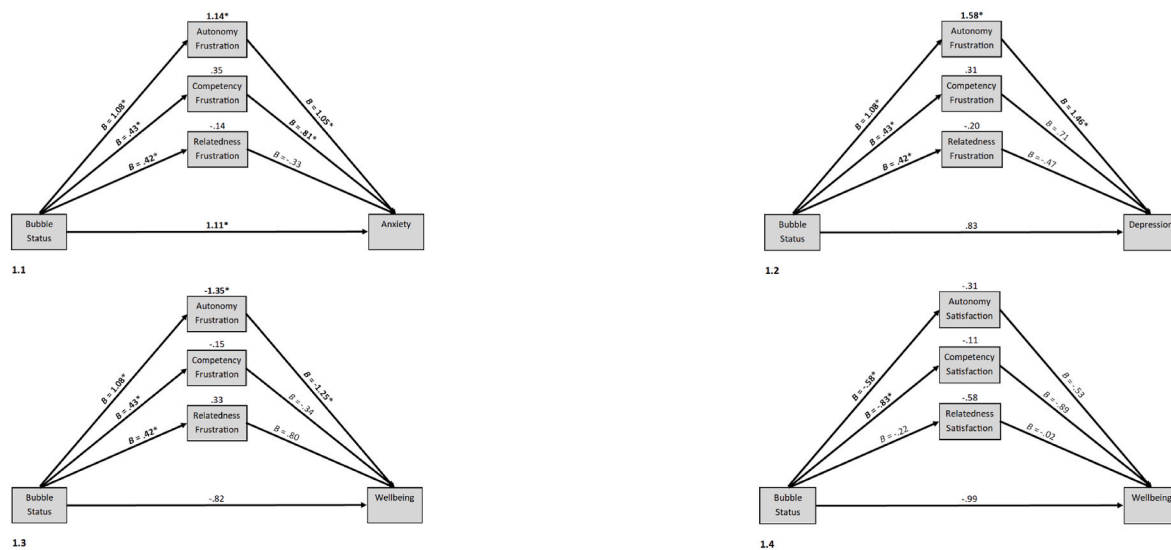


Fig. 1. Multiple Mediation Models. 1.1. Bubble status on anxiety via basic psychological needs (BPN) frustration (upper left quartile); 1.2. Bubble status on depression via BPN frustration (upper right quartile); 1.3. Bubble status on wellbeing via BPN frustration (lower left quartile); 1.4. Bubble status on wellbeing via BPN satisfaction (lower right quartile). * Confidence intervals that did not encompass zero indicating significance ($p < .05$).

($B = 0.80$, $SE = 0.48$, 95% $CI [-0.16, 1.76]$) and wellbeing. The direct effect was nonsignificant ($B = -0.82$, $SE = 0.65$, 95% $CI [-2.12, 0.49]$).

4.3.4. The effect of basic psychological needs satisfaction on the relationship between bubble status and mental health markers

There was no significant indirect effect of bubble status on anxiety, depression, or wellbeing via autonomy satisfaction, competence satisfaction, or relatedness satisfaction (see [Supplementary Table 2](#)). However, there was a significant total indirect effect of bubble status on wellbeing via autonomy satisfaction, competence satisfaction, and relatedness satisfaction (total indirect effect = -1.00 , $SE = 0.48$, 95% $CI [-2.00, -0.144]$; see [Fig. 1.4](#)). For all three models concerning BPN satisfaction, examination of the separate effects indicated that bubble status was negatively associated with autonomy satisfaction ($B = -0.58$, $SE = 0.12$, 95% $CI [-0.88, -0.29]$) and relatedness satisfaction ($B = -0.83$, $SE = 0.21$, 95% $CI [-1.25, -0.41]$) but not competence satisfaction ($B = -0.22$, $SE = 0.12$, 95% $CI [-0.45, 0.02]$). There was no association between any aspect of need satisfaction and anxiety, depression, or wellbeing (see [Supplementary Table 3](#)). There was a significant direct effect of bubble status on anxiety ($B = 1.95$, $SE = 0.48$, 95% $CI [0.98, 2.92]$) and depression ($B = 1.59$, $SE = 0.63$, 95% $CI [0.33, 2.84]$) but no significant direct effect of bubble status on wellbeing ($B = -0.98$, $SE = 0.63$, 95% $CI [-2.25, 0.29]$).

4.4. Sex differences

There was a significant multivariate interaction between sex and bubble status, $F_{2,56} = 5.14$, $p < .01$, $\eta^2 = 0.15$; Wilks' $\Lambda = 0.85$. To probe this omnibus effect, we conducted 2x2 repeated measures analysis of variance for each of the mental health markers, which yielded significant interactions for anxiety, ($F_{1,58} = 6.99$, $p = .01$, $\eta^2 = 0.11$, see [Fig. 2](#)), and depression ($F_{1,58} = 9.00$, $p < .01$, $\eta^2 = 0.13$, see [Fig. 2](#)). Follow-up paired sample Bonferroni-adjusted t -tests revealed that being in the bubble had a greater detrimental effect on mental health for women than for men, consistent with the hypotheses. Regarding wellbeing, there was a significant main effect for sex, $F_{1,58} = 5.97$, $p < .05$, $\eta^2 = 0.09$, and for bubble status $F_{1,58} = 14.73$, $p < .001$, $\eta^2 = 0.20$, and no interaction. WHO-5 scores were significantly lower for women ($M = 14.41$, $SD = 5.01$) than for men ($M = 16.84$, $SD = 4.88$) and were significantly higher outside of the bubble ($M = 16.50$, $SD = 4.41$) than inside the bubble ($M = 14.47$, $SD = 5.67$). See [Supplementary Table 4](#) for means, standard deviations, and follow-up tests.

5. Discussion

The aim of the present study was to investigate the effect of bio-bubbles on mental health. We found that anxiety and depression significantly increased inside the bubble and that wellbeing significantly decreased. We also found support for basic need frustration and

satisfaction as mediators of this relationship. As hypothesized, autonomy frustration significantly mediated the relationship between bubble status and anxiety and depression whilst autonomy satisfaction, competence satisfaction, and relatedness satisfaction collectively mediated the relationship between bubble status and wellbeing. Additionally, autonomy frustration significantly mediated the relationship between bubble status and wellbeing, which was not hypothesized. Sex moderated the relationship between bubble status and anxiety and depression, as hypothesized. Conversely, sex did not moderate the relationship between bubble status and wellbeing.

5.1. Impact of bio-bubbles on mental health

Some research has suggested that the return to sport during the pandemic might positively impact mental health ([Grimson et al., 2021](#); [Pillay et al., 2020](#)). The data from the present study revealed that being in a bio-bubble had a substantial negative effect on mental health. Although a return to sport is a step toward pre-pandemic norms and sport participation benefits wellbeing ([Silva et al., 2020](#)), a return to sport facilitated by bio-bubbles creates a plethora of additional stressors, which are not typically associated with elite sport ([Woodman & Hardy, 2001](#)). Further, for bio-bubbles to exist, people other than athletes (e.g., support staff) have to reside in them. For these non-players, it is possible that bio-bubbles simply create stressors that are additional to the typical touring stressors, and without the positive benefits of sport participation. For example, in the present study, medical staff had to monitor adherence to social distancing measures – something they were only tasked with because they were in bubbles. As sample constraints in the present study made investigating such differences not viable, future research concerning restrictive environments may wish to explore possible differing impacts due to role (e.g., athlete or non-athlete). Regardless, these results demonstrate that bio-bubbles can negatively impact mental health and therefore indicate that bio-bubbles should be used with caution and only when the threat of not residing within a bio-secure environment outweighs the potential detrimental impact of bio-bubbles on mental health.

5.2. The influence of basic psychological needs on mental health

Autonomy frustration emerged as the predominant mediating variable. As we hypothesized, autonomy frustration mediated the relationship between bubble status and anxiety and depression. However, it also mediated the relationship between bubble status and wellbeing. This finding aligns with [Awofeso's \(2010\)](#) suggestion that the lack of autonomy within the prison setting is a cause of mental health problems for prisoners. This finding suggests that autonomy, as it pertains to the frustration of needs, plays a more central role for mental health than do the needs for competence and relatedness. This suggestion is also supported by [Glendinning et al. \(2021\)](#), who found that the importance of

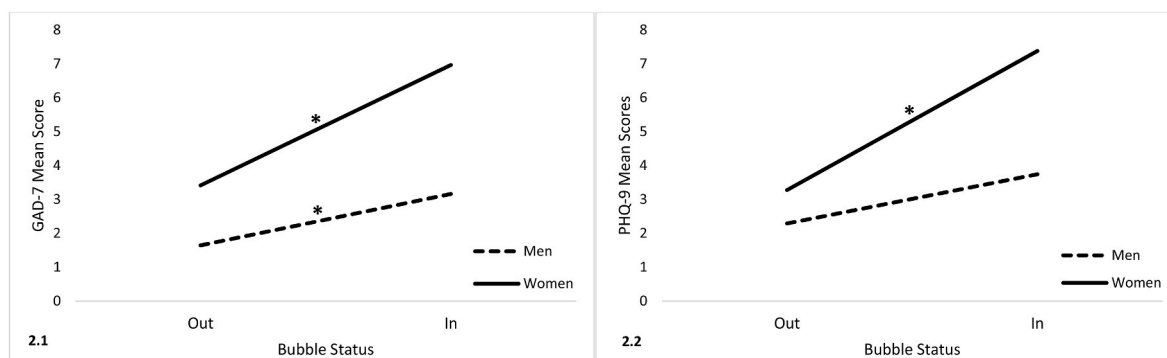


Fig. 2. 2.1. The relationship between bubble status and anxiety is moderated by sex (left graph); 2.2. The relationship between bubble status and depression is moderated by sex (right graph). *A significant change from out-of-bubble to in-bubble score.

autonomy, competence, and relatedness varied for individuals in certain circumstances, and that satisfying the most important basic need had the strongest effects on subsequent wellbeing. Thus, it is possible that those who had the strongest need for autonomy were most affected by bio-bubbles. Specifically, our findings and those of Glendinning et al. suggest that if a person's strongest need is for autonomy, their mental health is likely to be most affected by bio-bubbles. However, those whose strongest need is for competence or relatedness may still have been able to satisfy their strongest need and consequently bio-bubbles may have had a limited impact on their mental health. Such a proposition would be worthy of future investigation.

More broadly, our findings regarding BPN frustration support research regarding the impact of need-thwarting environments (Vansteenkiste & Ryan, 2013). Research has predominantly focused on children within these settings (e.g., Joussemet et al., 2008) and the long-term impact of continuous BPN frustration. However, the present research demonstrates that environments indicative of need thwarting may also have immediate negative implications for mental health in adults. Although bio-bubbles are uncommon habitual environments, the present findings clearly indicate that need-thwarting environments can have a significant negative impact on mental health. As such, researchers would do well to investigate the impact of need-thwarting climates on mental health in more common environments both inside (e.g., World Cups, Olympics) and outside (e.g., school, workplace) of sport.

Chen et al. (2015) previously found that frustration of BPN exclusively predicted ill-being and satisfaction of BPN exclusively predicted wellbeing. However, we also found an association between BPN frustration and wellbeing. It is possible that this finding may be due to the unique setting of bio-bubbles or the context within which they were created. It is important to remember that these bio-bubbles were created in a time where the outside landscape was atypical; that is, most of the sample's nation (i.e., the UK) was in lockdown and the pandemic presented many challenges and uncertainties. Regardless, the findings suggest that BPN frustration may predict wellbeing as well as ill-being in certain circumstances. As such, further exploration regarding BPN frustration and wellbeing is warranted.

5.3. Sex differences

Our findings regarding sex differences in the experience of mental health problems inside the bubble partially supported our predictions. Women showed substantially greater increases in anxiety and depression when inside the bubble compared to out and generally had lower wellbeing than men. Collectively, these findings are supportive of research regarding sex differences experienced during the COVID-19 pandemic (Kwong et al., 2021) and before (McManus et al., 2016). It has been suggested that one of the reasons women are more likely to experience anxiety or depression is their increased sensitivity to things such as separation and isolation (Altemus et al., 2014). Given that the purpose of a bio-bubble is to create separation and isolation (on a physical level), it is thus perhaps unsurprising that women's mental health displayed a greater susceptibility to these bio-bubble environments. Separation and isolation certainly seem to be strong mediator candidates for further exploring our understanding of the causes of sex differences in mental health.

5.4. Applied implications

Applied implications abound from this study. First, the decision to use bio-bubbles to facilitate the continuation of events would clearly benefit from considering the potential impact of such environments on mental health. The balance of such decision-making processes is a fine one. For example, organizations may need to balance the potentially harmful mental health effects of a bio-bubble environment with the alternative risks of not residing in a bio-bubble (e.g., catching a virus or

not playing sport, which carries its own concomitant potential detrimental effects on mental health). Second, if residing within bubbles is deemed necessary, then our findings suggest that mental health needs to be monitored, with appropriately trained individuals on hand to provide support. Third, the extent to which a bio-bubble meets or frustrates basic psychological needs (BPN) may play a pivotal role in reducing the negative impact that bubbles might have on mental health. Thus, if bio-bubbles are seen as a necessary precaution, we suggest that those tasked with creating the bubble consider how the environment can be developed to allow those within the bubble to satisfy their psychological needs, and to explore ways in which need frustration can be prevented, on an individual-by-individual basis (see Glendinning et al., 2021). Finally, in the present study, women were more at risk than men of suffering from anxiety or depression as a result of residing within a bio-bubble. However, men's health was also affected by being in the bio-bubble. We suggest that those creating and monitoring future bubbles be conscious of sex differences in relation to the mental health consequences of bio-bubbles and provide tailored support where needed.

The unique socio-cultural climate that led to the creation of bio-bubbles suggests that generalizing the present findings should be done with caution. Nonetheless, it is possible that similar environments exist beyond those associated with the COVID-19 pandemic. Specifically, within sport, international events such as tours, World Cups, and the Olympics/Paralympics require people to reside in artificially-created environments for a sustained period of time. Although each environment is different and the context within which people enter is unique to them, the common trait of all these environments is they are often foreign to the residents and there are often restrictions on movement outside of hotels or training bases. This lack of familiarity and any associated restriction on movement may also be need thwarting, which, as evidenced within our research, can significantly impact mental health. Consequently, the points raised regarding the applied implications of this research may also be applicable to more common sporting environments as well as other potentially need-thwarting settings. Given this potential generalizability and the significant decreases in people's mental health, empirical research is certainly required to examine whether settings such as sporting tours abroad have a similarly detrimental impact on mental health and wellbeing.

It is important to note that the England and Wales Cricket Board (ECB) commissioned this research with a view to understanding the impact of bio-bubbles on the mental health of its members with a view to implementing learnings for the benefit of all players and staff. Such an initiative is itself clearly positive. Equally, the rules surrounding bio-bubbles (e.g., social distancing, family not being allowed to enter) are such that they remove autonomy. As such, it will be an ongoing challenge for all organizations to work within the societal, government, and sporting regulations while also attempting to optimize the mental health of its members. Allowing greater flexibility on the bio-bubble rules is a parsimonious implication of the current data, and the ECB have already made many changes in light of the present findings. Such a stance is a clear step forward for the mental health of ECB members. Equally, the risk of contracting a physical disease such as COVID-19 is a clear health risk of such a strategy and all organizations would do well to balance such risks and benefits in this way. We view the ECB's position as constructively evolutionary by shining a light on its members' mental health during a global pandemic and beyond.

5.5. Limitations

It would clearly have been preferable to collect data from participants in a prospective repeated-measures in- and out-of-bubble framework. However, due to the nature of the COVID-19 pandemic and the subsequent implementation of bio-bubbles, a reflective approach to data collection was the only method possible for the present study. To limit the possible negative impact of the approach taken, we asked

participants to think carefully about their experience as a whole and gave them as much time as they needed to complete the survey. Although asking them to think about all their bubble experiences allowed us to gather data for multiple bubbles, comparison between bubble environments (which were not identical) may have added contextual relevance. Furthermore, we invited direct in- and out-of-bubble comparisons and we were able to identify and remove individuals who gave answers that were not possible, possibly caused by memory recall issues. Even if such a limitation impacted the in- and out-of-bubble differences, they would not explain the mediation of basic psychological needs or indeed the sex differences. Finally, we reduced to item pairs each construct of the Basic Psychological Need Satisfaction and Frustration Scale, which one might view as a limitation despite the retained factor integrity across the scales. Nonetheless, given the clear importance of psychological need satisfaction/frustration, future research would benefit from retaining complete measures when assessing BPN.

5.6. Conclusion

To the best of our knowledge, the present study is the first investigation of the impact of bio-bubbles on mental health. Using established measures of anxiety, depression, and wellbeing, this study has identified bio-bubbles as a potential risk to mental health and has laid the foundation for future research in the specific domain of bio-bubbles and other domains where psychological needs might be compromised (e.g., tours, large events). Basic psychological needs appear to be key mechanisms for explaining the relationship between bubble status and mental health, offering guidance to policy makers and those wishing to create interventions aimed at mitigating the unintended risk of bio-bubbles and isolating environments. Additionally, women were identified as suffering from greater increases in depression and anxiety inside the bubbles, which requires careful consideration in preparing and monitoring isolating environments.

Declaration of competing interest

Given their roles as an Editorial Board Members Woodman T., had no involvement in the peer-review of this article and had no access to information regarding its peer-review. All other The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Co-authors worked for the institution responsible for the bio-bubbles and spent time in the bio-bubbles. However, we do not view this as a conflict of interests. - TW, PS, NP.

Data availability

The data that has been used is confidential.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.psychsport.2023.102447>.

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