The effect of COVID-19 restrictions on physical activity levels and mental well-being in adult females living in New Zealand

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Abstract

Background: Previous research has suggested positive associations between physical activity (PA), mental health (MH) and well-being, however the current literature also suggests that females are less active than males. With the arrival of Coronavirus (COVID-19), containment strategies were implemented to minimise the global spread of COVID-19, with varying degrees of physical containment and social isolation. These containment strategies have impacted individuals' 'normal' daily routines and social lives, changed the way we work and reduced opportunities in typical avenues of PA including gyms, recreational facilities and sport. The impact of such restrictions on PA levels in females, and the effect on MH and well-being has not been described in the research to date. Therefore, the purpose of this study was to understand the effect of the New Zealand Government's COVID-19 containment strategies on adult females' PA and mental well-being. The researchers also sought to identify factors that influenced PA participation during these periods of social isolation and physical containment.

Methods: Adult females residing in New Zealand (n = 1504; mean ± SD : age 48 ± 14 years, 83.4% New Zealand European) were recruited through a combination of convenience and snowball sampling and completed two amalgamated anonymous online surveys during Level 4 (L4) lockdown and Level 2 (L2) restrictions (Qualtrics; Survey 1 - 10-29th April 2020; Survey 2 - 5-18th June 2020) to assess PA via the International Physical Activity Questionnaire – short form (IPAQ-SF), MH via the Depression Anxiety Stress Scales-9 (DASS-9) and well-being via the World Health Organization Five Well-Being Index (WHO-5). PA level was classified as high (≥3000 $MET \cdot min \cdot wk^{-1}$), moderate (≥600 to 2999 $MET \cdot min \cdot wk^{-1}$) or low (<600 $MET \cdot min \cdot wk^{-1}$). Factors that influenced PA participation were assessed as to whether they had no influence or some influence on PA participation.

Results: Our participants were sufficiently physically active to meet the WHO and New Zealand PA guidelines, and more met the PA guidelines during L4 (94.1%) than pre COIVD-19 (79.4%) or during L2 (85%). Although PA was higher during L4, sitting time was also significantly higher when compared to L2 (449 ± 169 vs 426 ± 189 $min \cdot wk^{-1}$). Well-being scores (WHO-5) were higher at L4 (59 ± 20) than at L2 (57 ± 20). DASS-Anxiety scores were lower at L4 (0.5 ± 1.1) than at L2 (0.6 ± 1.2), whereas DASS-Depression and -Stress scores were higher at L4 (Depression 1.9 ± 1.8, Stress

1.9 ± 1.6) than at L2 (Depression 1.6 ± 1.7, Stress 1.7 ± 1.6). Compared to those who participated in lower levels of PA (according to IPAQ classification), those who participated in higher levels of PA had higher WHO-5 scores at both L4 (66.3 ± 19.3, $p < 0.001$) and L2 (62.9 ± 19.6). The high IPAQ group also had lower DASS-Depression, -Anxiety and -Stress scores ([1.5 ± 1.6, $p < 0.001$][0.3 ± 0.9, $p < 0.001$][1.6 ± 1.5, $p < 0.001$]) compared to those in the low group. The major factors that influenced PA participation were time available, working situation and MH.

Conclusions: These results support previous findings on the positive association between PA, MH and well-being in females and illustrates the importance of maintaining adequate PA levels during times of mental unease, such as during a global pandemic or periods of social isolation. Governments and public health advisers are encouraged to use the findings and recommendations in this report to encourage and promote PA in the event a situation such as COVID-19 was to arise again in the future in order to best preserve the mental well-being of females and other New Zealanders.

Keywords: Physical activity, well-being, mental health, COVID-19, coronavirus, females, New Zealand.

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List of Abbreviations

L2	Level 2
L4	Level 4
ANOVA	Analysis of variance
CHD	Coronary heart disease
COVID-19	Coronavirus
CVD	Cardiovascular disease
DASS-9	Depression Anxiety Stress Scales-9
DASS-21	Depression Anxiety Stress Scales-21
DASS-42	Depression Anxiety Stress Scales-42
HR	Heart rate
IPAQ	International Physical Activity Questionnaire
IPAQ-SF	International Physical Activity Questionnaire – short form
MET	Metabolic Equivalent Task
MH	Mental health
MoH	Ministry of Health
MVPA	Moderate to vigorous physical activity
PA	Physical activity
SARS-CoV	Severe acute respiratory syndrome coronavirus
SARS-CoV-2	Severe acute respiratory syndrome coronavirus 2
SD	Standard deviation
T2DM	Type 2 diabetes mellitus
UK	United Kingdom
US	United States
WFH	Work from home
WHO-5	World Health Organization Five Well-Being Index
WHO	World Health Organization

Chapter 1: Introduction

1.1 Background

In December 2019, the emergence of the first case of novel Coronavirus (COVID-19) was reported in Wuhan, China (Sibley et al., 2020). COVID-19, also known as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has presented a unique significant global challenge and threat due to its rapid transmission, spread and infection even during its 'incubation period'(World Health Organization, 2020). The World Health Organization (WHO) declared COVID-19 as a global pandemic on the 11th of March, 2020. In response to this declaration, and to the rapid spread, documented number of deaths globally and its predicted exponential growth, countries around the world, including New Zealand, entered lockdowns and lifestyle restrictions (New Zealand Government, 2020; World Health Organization, 2020). The characteristics of lockdowns and restrictions vary by jurisdiction, but generally mandate staying at home, the closure of businesses and schools and avoiding physical contact with other individuals (McKibbin & Fernando, 2020). On the 25th of March, 2020, the New Zealand Government imposed a nation-wide lockdown termed Alert Level 4 (L4) that encompassed significant restrictions with regard to how individuals and communities moved about and interacted with one another (New Zealand Government, 2020). Alert L4 lockdown required individuals to stay isolated within their household and only interact with those inside their 'bubble' (New Zealand Government, 2020). This meant that individuals should only leave their homes to access essential services such as supermarkets, banks, pharmacies and seeking healthcare treatment, exercising in their local area and travelling to work as an 'essential worker'. Furthermore, a recommendation to maintain a 2-metre distance from all other individuals when outside of your 'bubble' i.e. when not at home, was put in place (New Zealand Government, 2020). After seven weeks, the level was lowered to Alert Level 2 (L2) restrictions, where life returned to relative normality with the exception of closed borders (New Zealand Government, 2021a).

Prolonged self-isolation coupled with watching the pandemic unfold has been correlated with negative impacts on one's psychological well-being, stimulating feelings of stress, anxiety and depression (Lippi et al., 2020; McKibbin & Fernando, 2020; Sibley et al., 2020). A large body of evidence has demonstrated that individuals who experience and live through community disasters such as wars and natural disasters are faced with an increase in mental and psychological burdens (Bonanno et al., 2010; Norris et al., 2002). More recently, research completed in China concluded that high levels of anxiety and depression were experienced and were associated with the COVID-19 pandemic, especially in individuals who perceived themselves to be in poor health prior to the outbreak (Qiu et al., 2020; Wang et al., 2020). Other early research into the effects of the COVID-19 outbreak revealed that some individuals experienced posttraumatic stress symptoms, with evidence that females were affected to a greater degree than males (Liu et al., 2020). An abundance of literature confirms that mental and psychological well-being are positively affected by physical activity (PA) (Marquez et al., 2020; Mikkelsen et al., 2017; Wiese et al., 2018). Regular PA, a significant health behaviour, not only has a positive impact on health and health outcomes but also has a role to ameliorate the feelings of stress, anxiety and depression (Fox, 1999; McMahon et al., 2017; Paluska & Schwenk, 2000; Peluso & Andrade, 2005). Just 21 minutes of exercise per day has been associated with decreased anxiety levels, and as little as five minutes of outdoor exercise per day has been shown to improve self-esteem and mood (Barton & Pretty, 2010; Petruzzello et al., 1991).

Regular PA plays a vital role in the prevention and management of chronic disease and associated health outcomes (Brown et al., 2006; Fentem, 1994; Karacabey, 2005; Russell et al., 2014). In New Zealand, the Ministry of Health (MoH) recommends adults take part in at least 150 minutes of moderate or 75 minutes of vigorous intensity PA per week (Ministry of Health, 2020). This recommendation mirrors that from the WHO (World Health Organization, 2010) and many other countries (Australian Government Department of Health, 2014; Department of Health and Social Care, Llywodraeth Cymru Welsh Government, & Department of Health Northern Ireland and the Scottish Government, 2019; U.S. Department of Health and Human Services, 2018), and has been associated with numerous health benefits (McIntyre & Dutton, 2015). However, despite these widespread recommendations, and the proven health benefits of PA, more than 50% of the adult population in many countries, including New Zealand, Australia and the United States (US) are insufficiently physically active and failed to achieve the recommended PA guidelines, even prior to the COVID-19 disruption (Australian Bureau of Statistics, 2013; Centers for Disease Control and Prevention, 2014; Ministry of Health, 2016). Across most countries, females tend to be less active than males. The global average of inactive females is 31.7% in comparison to 23.4% for inactive males (The Lancet Public Health, 2019). In New Zealand specifically, the 2020/21 New Zealand Health Survey revealed that 36.4% of females were inactive (<30 min·wk^{-1} PA) and only 49% achieved the recommended PA guidelines across all age and ethnic groups (Ministry of Health, 2021a).

Prolonged physical inactivity is associated with a number of adverse health outcomes such as increased risk of cardiovascular disease (CVD), hypertension, diabetes mellitus (T2DM), osteoporosis, premature ageing and muscular atrophy (Pedersen & Saltin, 2006, 2015; Romeo et al., 2010; Warburton, 2006; Wu et al., 2019). Restrictions to human movement and prolonged self-isolation like that seen in the COVID-19 pandemic have been linked with a reduction in PA and an increase in sedentary behaviour (Lippi et al., 2020). In saying this, the lockdowns and restrictions imposed by the New Zealand Government differed somewhat to other countries. In New Zealand, experts and government officials advocated to be physically active for as often and for as long as they liked either at home (e.g. yoga, bodyweight workouts) or outdoors (e.g. walking, running, cycling), with the only restriction on outdoor PA being that it must be 'local', within one's 'bubble' and maintaining a 2-metre distance from others (New Zealand Government, 2020). In contrast, residents in many other countries were permitted to exercise outdoors only once per day (e.g. UK) (Strain et al., 2022) or within one's property (e.g. Italy) (Zaccagni et al., 2021). Under normal circumstances (i.e. prior to the COVID-19 pandemic), participation in PA is largely influenced by factors such as time, care giving responsibilities, financial status, access to recreation centres and equipment and social influence (Ford et al., 1991; Seefeldt et al., 2002; Williams et al., 2008). Females may be more prone to fulfil multiple roles (such as being caregivers and mothers) and tend to be responsible for an assortment of tasks (household chores, childcare and meal preparation) all of which may impact time available for participation in PA (Brown et al., 2001; Cramp & Bray, 2011; Eyler et al., 1998; Mailey et al., 2014; Sanderson et al., 2002). Currently, there is no scientific insight on how and if New Zealand females changed their PA levels and patterns due to the initial lockdown (L4) and following restrictions (L2).

Therefore, the purpose of this thesis is to analyse and examine whether New Zealand females participated in more or less PA during L4 lockdown and L2 restrictions, paying attention to the factors that may have influenced PA participation. Furthermore, the psychological and mental well-being of New Zealand females will be analysed at L4 lockdown and after seven weeks when containment levels were decreased to L2. The findings from this study will provide important information to ensure we are well prepared to support and maintain the optimal health and well-being of New Zealanders in the event that a pandemic such as COVID-19 was to arise again in the future. Furthermore, the results will recognise whether the New Zealand Government's strategy to counteract COVID-19 provides an incentive for people to engage in more PA.

Throughout this thesis, the period before the COVID-19 pandemic i.e. life before COVID-19, will be referred to as 'pre COVID-19'; the initial 'lockdown' period that stretched from the 25th of March, 2020 to 12th of May, 2020 will be referred to as L4 lockdown; and the 'less severe restrictions' that took place from 13th of May, 2020 to 8th of June, 2020 will be referred to as L2 restrictions.

1.2 Aims and Objectives

Aim

To understand the effect of the New Zealand Government's COVID-19 containment strategies on adult females' PA and mental well-being via a longitudinal study.

Objectives

- To analyse and compare PA levels pre COVID-19, during L4 lockdown and L2 restrictions.
- To analyse and compare mental well-being status during L4 lockdown and L2 restrictions.

- To examine the relationship between PA and mental well-being during L4 lockdown and L2 restrictions.
- To analyse and compare the factors that influenced PA participation during L4 lockdown and L2 restrictions.

Hypothesis

We hypothesised that adult females living in New Zealand who were participating in higher levels of PA during the imposed COVID-19 lockdown and restrictions would exhibit better mental well-being compared to those who were participating in lower levels of PA.

1.3 Contributors to the research

Researchers	Contributions
Haya Awsi	Main researcher, data analysis, statistical analysis, interpretation and discussion of results, author of thesis.
Dr Wendy O'Brien	Main academic supervisor, ethics application, research design, participant recruitment, data collection, guidance with thesis design, interpretation of results, provided feedback, revision, and final approval.
Dr Claire Badenhorst	Academic co-supervisor, ethics application, research design, participant recruitment, data collection, guidance with thesis design, interpretation of results, provided feedback and revision.

1.4 Thesis Structure

This thesis has been structured into four chapters and three appendices. Chapter 1 provides an introduction, research overview, and the justifications for conducting the study. Chapter 2 is a narrative literature review that addresses the epidemiology and pathophysiology of COVID-19, health consequences, government mandated lockdown and restrictions, and prior research that has investigated the impact of the COVID-19 pandemic on PA and mental well-being. Chapter 3 presents the results of the study and is formulated as a manuscript for publication in a peer-reviewed journal. The manuscript contains an abstract, introduction, methods, results, discussion, and conclusion. Chapter 4 provides an overview and final conclusions of the research, along with strengths, limitations and recommendations for future research. Appendix A contains the New Zealand COVID-19 Alert Levels Summary, Appendix B contains Supplementary Tables 1 and 2 which summarise the relationships between PA and MH and well-being respectively. Appendix C contains the Participant Information Sheet used in the study.

Chapter 2: Review of Literature

Chapter 2 describes the current literature that has investigated the impact of COVID-19 on health inclusive of physical and mental health (MH) related behaviours. This chapter will be divided into five parts. 1) Epidemiology of COVID-19 and its Pathophysiology, 2) Lockdown and restrictions as a means of controlling the spread of COVID-19, 3) COVID-19 and PA, 5) COVID-19 and mental well-being.

2.1 COVID-19

The first case of the novel COVID-19 was reported by health officials in Wuhan China in December, 2019, following an outbreak of viral pneumonia with an unknown origin (Fauci et al., 2020; Velavan & Meyer, 2020). COVID-19, has presented an extraordinary threat to global public health, and since its emergence has spread to over 200 countries and territories and across all seven continents worldwide, including Antarctica (World Health Organization, 2020). The COVID-19 outbreak is now widely considered to have started with a zoonotic origin from the seafood markets in Wuhan, China and has subsequently spread rapidly across the globe (Binny et al., 2020; Riou & Althaus, 2020; Shereen et al., 2020). As of January 1st, 2021, around 95 million cases have been reported globally with upwards of two million confirmed deaths and more than 25 million cases still currently active worldwide (World Health Organization, 2020). A pandemic of this size and magnitude has not been seen since the Spanish Flu epidemic in 1918 where it was estimated that 500 million people were infected with an estimated death toll of between 20 and 50 million people, thus reinforcing the extraordinary global threat COVID-19 poses as a highly transmissible virus in the 21st century (Martini et al., 2019; Trilla et al., 2008; World Health Organization, 2021b).

2.1.1 Worldwide Pandemic

COVID-19 was broadcasted as a global public health emergency on the 30th January, 2020 and was later declared as a pandemic on the 11th of March, 2020 by the WHO (World Health Organization, 2020). Following the outbreak in China, the US, India, Brazil, Russia and the United Kingdom (UK) have become the worst affected countries worldwide, with the US now accounting for around 25% of all cases and 20% of all reported deaths (Worldometer, 2021). In Oceania, the impact of COVID-19 was dampened in part by geographical location and by travel and movement restrictions put in place by local governments (Binny et al., 2020). As of January 2021, Australia has reported a total of 28,708 confirmed cases of COVID-19 and 909 deaths with a death rate of 3.2% (Worldometer, 2021). New Zealand reported its first case of COVID-19 on the 28th of February, 2020, two months after the emergence of the disease, and as of January 2021, had increased to a total of 2222 confirmed and probable cases nationwide with a total of 25 reported deaths and a death rate of 1.1% (Ministry of Health, 2021c; Worldometer, 2021). In New Zealand, the majority of cases in persons aged 20-29 years old age (23.8%), followed by 30-39 years (18.5%) and 50-59 years (14.5%) (*Figure 1*) (Ministry of Health, 2021b). COVID-19 has demonstrated a disproportionate burden toward the elderly and those living with existing health conditions such as CVD, hypertension, chronic obstructive pulmonary disease and T2DM with those aged 65 years and over accounting for 92% of deaths in New Zealand (*Figure 1*) (Ministry of Health, 2021c).

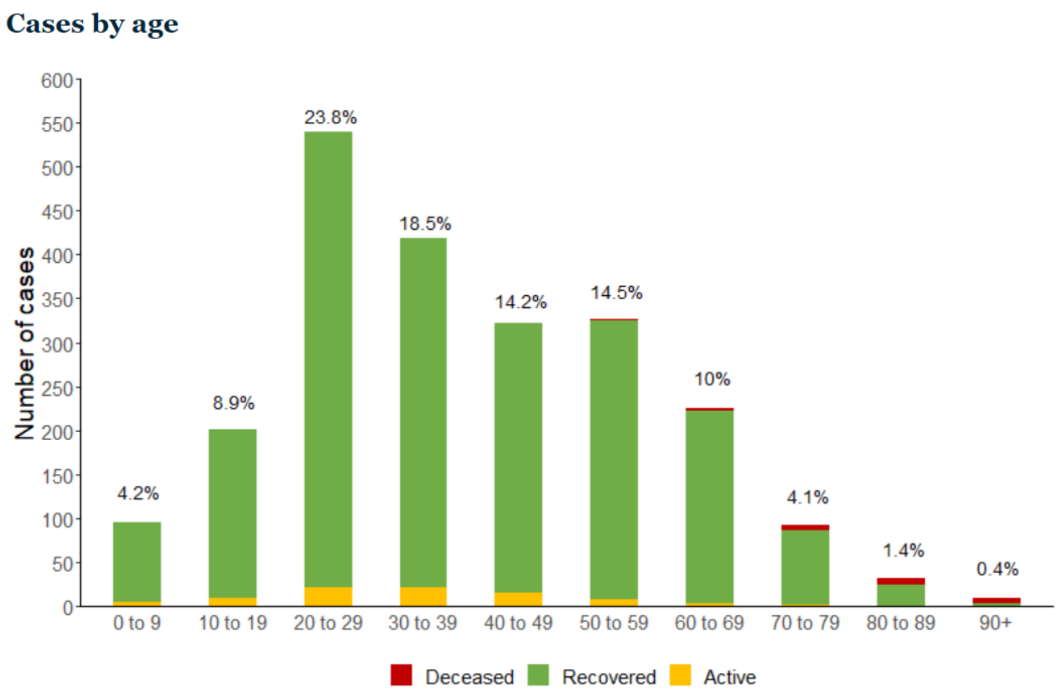

Figure 1. Number of active, recovered and deceased COVID-19 cases in New Zealand distributed by age. Adapted from the Ministry of Health, retrieved January 2021.

Global trends have shown only a small difference in COVID-19 confirmed case incidence with respect to gender, with a ratio of 52.3% females and 47.7% males in the US, a ratio of 51.3% females and 48.7% males in Australia and a ratio of 52% females and 48% males within New Zealand (Australian Government Department of Health, 2020; CDC, 2020; Ministry of Health, 2021c). Mortality rates however have been found to be higher in males when compared to females in the US, 53.9% and 46.1% respectively and in New Zealand data (56% males and 44% females), however no such relationship has been found in Australia (48.5% males and 51.5% females) (Australian Government Department of Health, 2020; CDC, 2020; Ministry of Health, 2021b, 2021c). Early analysis of the greater mortality burden of COVID-19 in men has been attributed to both biological (immune response) and behavioural risk factors such as increased engagement in high-risk behaviours, such as lower rates of handwashing, proactively seeking medical help and cigarette smoking (Griffith et al., 2020; White & Kirby, 2020).

Belonging to the Coronaviridae family, the SARS-CoV-2 is responsible for causing the novel COVID-19 disease (Parasher, 2020; Yuki et al., 2020). These viruses are capable of infecting humans and other mammals such as cattle and birds, consequently giving rise to respiratory, gastrointestinal and neurological diseases (Weiss & Leibowitz, 2011; Zhu et al., 2020). The SARS-CoV-2 is highly homologous to the severe acute respiratory syndrome coronavirus (SARS-CoV) (~80%) and is not the first coronavirus that has posed risk to humans (Ksiazek et al., 2003; Yuki et al., 2020). COVID-19 is primarily transmitted from human to human through direct, indirect or close contact (within ~1 metre) with an infected individual via respiratory droplets, which are exhaled when an infected individual actively coughs, sneezes, breathes heavily, speaks or sings (Chan et al., 2020; Chu et al., 2020; Huang et al., 2020; Lee & Hsueh, 2020; Liu et al., 2020; Pung et al., 2020). The infected respiratory droplets reach the exposed mucosal surfaces such as the nose, mouth and eyes of the predisposed individual and can cause an infection (Chan et al., 2020; Huang et al., 2020; Liu et al., 2020; Parasher, 2020). The damage caused by COVID-19 significantly impacts human health, predominately affecting the respiratory system and other organ systems including compromising the immune system. Furthermore, the virus exacerbates underlying medical conditions and ultimately can cause systematic failure and death (Woods et al., 2020). A typical profile of a COVID-19 patient may present with the symptoms of fever, dry cough, dyspnea, rhinorrhoea, myalgia, fatigue, sore throat and headaches (Guan et al., 2020; Richardson et al., 2020; Yang et al., 2020). Some patient may also exhibit gastrointestinal symptoms such as diarrhoea and vomiting (Cheung et al., 2020; Zhao et al., 2020) .With this being said, it is worth noting that patients may present as asymptomatic or with mild, moderate or severe states of the disease (Donnelly et al., 2003; Goyal et al., 2020; Guan et al., 2020; Young et al., 2020). The progression of COVID-19 appears to be enhanced in the elderly, and poorer clinical outcomes have been associated with the disease's severity; giving rise to complications such as acute respiratory distress syndrome, arrhythmia, shock (Wang et al., 2020), acute kidney injury, acute cardiac injury, liver dysfunction, pneumonia, respiratory failure, multiple organ failure and death (Huang et al., 2020). Due to its very high transmission rate, heterogeneous symptoms and a wide range of complications, COVID-19 has posed a substantially greater risk to public health compared to any other disease. To combat this, many countries have implemented social distancing and lockdown measures to mitigate further spread.

2.2 Government Mandated Self-Isolation in response to COVID-19

As a result of the high transmissibility of COVID-19 from human to human, health officials and governments around the world responded with attempts to contain the spread of the virus. The New Zealand Government adopted an early non-pharmaceutical intervention that involved a combination of border restrictions and a four-tiered Alert Level System (from Level 1 with life as normal but with border restrictions, through to Level 4 with severe containment, i.e., lockdown) (*Appendix A)* (Jefferies et al., 2020; New Zealand Government, 2021a). The New Zealand border was closed on the 19th of March, 2020 to everyone except returning citizens and residents (New Zealand Government, 2021b). Similarly, Australia, Canada and Germany all closed their borders around this time (18th to 20th of March, 2020) (Australian Government Department of Health, 2021; Government of Canada, 2020; The Federal Government of Germany, 2020). In contrast, countries like the US and the UK elected to keep their borders open and consequently had some of the highest COVID-19 case numbers worldwide as a result of unprecedented community transmission (Centers for Disease Control and Prevention, 2020). New Zealand Prime Minister, Jacinda Ardern, announced the plan to move quickly up alert levels to Alert L4 (Lockdown) on the 25th of March, 2020, just two days after the Alert Level System was introduced, solidifying New Zealand's "go hard, go early" approach to the COVID-19 pandemic (New Zealand Government, 2020). Without an effective management strategy, experts forecasted that COVID-19 would spread rapidly throughout New Zealand, overwhelm the national health care system and disproportionately burden Māori and Pacific peoples (Mazey & Richardson, 2020; Steyn et al., 2020).

The L4 lockdown in New Zealand limited social interaction and promoted social distancing, where a 2-metre distance from other individuals outside of one's household 'bubble' was implemented (New Zealand Government, 2020). Businesses, schools and public places were closed, and individuals were only permitted to interact with those inside their immediate household or their 'bubble'. Individuals were able to leave their homes only for essential work and to perform essential activities (lifeline utilities, supermarkets, petrol stations, pharmacies and clinics). The only other reason individuals were allowed to leave homes was for exercise within their local neighbourhood and only with members of their 'bubble' (New Zealand Government, 2020). In providing this exception to exercise relatively freely, the New Zealand Government acknowledged the importance of being physically active for both health and well-being and conveyed these messages to the public. After seven weeks at Alert L4 lockdown with this being the most severe level of restriction, New Zealand moved down to Alert L2 restrictions on the 13th of May, 2020, and was declared to have no active cases of COVID-19 by the MoH on the 8th of June, 2020 (New Zealand Government, 2020). Since that time, a number of mainly isolated outbreaks of community transmission have occurred, however, this review and subsequence study in Chapter 3 relate to this early period of COVID-19 in New Zealand spanning from the 25th of March, 2020 (L4) to the 8th of June, 2020 (end of L2).

Although New Zealand's approach to the COVID-19 pandemic was recognised and praised across the globe for its swift and efficient strategy (Robert, 2020), there is no doubt that it accounted for significant lifestyle changes and disruption to daily life routines. Many individuals were either working from home or not working, due to losing jobs or being unable to perform their job from home (e.g. hairdressers, hospitality, tourism and retail), (Hargreaves et al., 2021). Furthermore, the closure of schools led to parents assisting in home schooling while potentially also fulfilling their own work obligations. Exercise and recreation centres were closed, club and community sport was cancelled, and outdoor exercise was limited to low-risk activities in the local neighbourhood (Cheval et al., 2020; Hargreaves et al., 2021). These unprecedented circumstances represent a population level "life-change event" (Engberg et al., 2012), defined as *''those occurrences, including social, psychological and environmental, which require an adjustment or effect a change in an individual's pattern of living"* (Engberg et al., 2012). Life-change events not only disrupt normal daily routines, but could also give rise to emotional distress and influence an individual's ability to engage in PA (Engberg et al., 2012). This life-change event may have reduced normal PA levels due to the closure of exercise and recreation centres, increased childcare and household demands or COVID-19 related anxiety, stress and depression (Engberg et al., 2012; Hargreaves et al., 2021). It was initially proposed that PA levels may decline as a consequence of the imposed lockdowns and associated restrictions (Ammar et al., 2020; Cheval et al., 2020; Papaioannou et al., 2020; Xiang et al., 2020), however counter arguments suggested a possible increase in PA levels due to disruption in sedentary work routines and habits (e.g. sitting at the desk for too long) (Constandt et al., 2020). On the other hand, this life-change event may have reduced physical inactivity and encouraged regular participation in PA, likely due to the removal of time related and work barriers to PA (Engberg et al., 2012; Hargreaves et al., 2021).The physiological and psychological benefits of PA are well established within the literature, and recently more distinct benefits related to the effects associated with the COVID-19 lockdowns have been proposed. In particular, prolonged self-isolation coupled with the pandemic unfolding has been correlated with negative impacts on psychological well-being, stimulating feelings of stress, anxiety and depression (Lippi et al., 2020; McKibbin & Fernando, 2020; Sibley et al., 2020), all of which are known to be reduced by PA.

2.3 Physical Activity

2.3.1 Definitions

PA is one of the most modifiable lifestyle risk factors for reducing the occurrence of chronic diseases, and is a fundamental component to enhancing one's health status (Ng et al., 2020). PA is defined as *"any bodily movement produced by skeletal muscles that results in energy expenditure"* (Caspersen et al., 1985) and can be categorised into incidental, such as walking up the stairs, grocery shopping or doing chores around the house. Or it may be planned, and involve exercises such as weight lifting, gym classes, or going for a walk, jog or run (Caspersen et al., 1985). The absolute intensity of PA is typically expressed using the metabolic equivalent task (MET) or more simply the metabolic equivalent, and is defined as *"the ratio of metabolic rate during a specific PA to a reference metabolic rate of 1.0 (4.184 kJ) kcal·kg·h^{-1}"* (Ainsworth et al., 2000). A single MET is the amount of oxygen consumed at rest, sitting quietly in a chair. It follows that 2 METs requires twice the oxygen than that of resting metabolism (2.0 kcal·kg·h^{-1}) (Ainsworth et al., 2000). METs can be used to quantify the intensity of physical activities from sleeping (0.9 METs) to running at 17.5 km·h^{-1} (18 METs) (Ainsworth et al., 2000), and have been used in previous research to classify PA intensity as sedentary, light, moderate, vigorous or moderate-to-vigorous (MVPA) (Table 1) (Ekelund et al., 2006).

For this thesis, it is important to clarify the distinction between the term 'sedentary behaviour' and 'physical inactivity'. These terms have been controversially used within the literature, and many authors have advocated for the necessity to refine these definitions (Pate et al., 2008;

Yates et al., 2011). Due to the awareness of these inconsistencies, the Sedentary Behavior Research Network proposed a definition of sedentary behaviour as, *"any waking behaviour characterised by energy expenditure ≤1.5 MET"* (METs; see table 1 for further explanation of METs), or whilst being in a sitting, reclining or supine position (Bames et al., 2012; Owen et al., 2010; Pate et al., 2008; Tremblay et al., 2010). In contrast, physical inactivity is described as the participation in PA that is insufficient to achieve the global recommended PA guidelines (Bames et al., 2012; Lee et al., 2012). Despite some opposing opinions (Viir & Veraksitš, 2012), an accumulating number of researchers endorse the Sedentary Behavior Research Network definitions (Dogra & Stathokostas, 2012; Kim et al., 2013; Spittaels et al., 2012) and therefore, the above definitions of physical inactivity and sedentary behaviour presented here will be abided by throughout this thesis.

Table 1. Classification of PA intensities using METs

PA intensity	METs	Description	Examples
Sedentary	≤1.5	Any waking activity characterised by energy expenditure greater than resting in a sitting or reclining posture.	Watching TV, non-active commuting, sitting at work, reading.
Light	1.6–2.9	Activities that do not increase breathing significantly or cause a noticeable increase in heart rate.	Light walking, shopping, housework (i.e. washing dishes, folding laundry, ironing)
Moderate	3.0–5.9	Activities that require moderate effort, but conversation can still be maintained while performing these.	Brisk walking, tennis, gardening.
Vigorous	≥6.0	Activities that require a large amount of effort, causing rapid breathing in which conversation cannot be maintained.	Running, fast swimming, team/competitive sports (i.e. rugby, football, basketball).

Abbreviations: PA, physical activity; METs, metabolic equivalent of tasks (Ainsworth et al., 2011; Ministry of Health, 2020).

2.3.2 Physical Activity Measures

Measuring PA levels in both research and clinical populations is common practice, although challenging (Thomas et al., 2015; van Poppel et al., 2010). Several methods to measure and estimate PA levels exist including direct observation, questionnaires, self-reported PA diaries, direct and indirect calorimetry, and motion detection devices such as pedometers, accelerometers, and heart rate (HR) monitors. Each of these PA measures are recognised for their own advantages and disadvantages in a research setting (Bassett et al., 2017; Helmerhorst et al., 2012; Montoye et al., 1983; Skender et al., 2016; van Poppel et al., 2010).

Objective measures such as accelerometers, pedometers and global positioning system wearables have been used to estimate PA in research as early as the 1960s (Higuchi et al., 2011). Such devices have been widely utilised due to their practicality and ability to continuously monitor, for extended periods of time in a free-living environment. They have been used as an alternative to traditional self-reporting, which can be notorious for inaccuracy, inconvenience and high participant burden (Helmerhorst et al., 2012; Higuchi et al., 2011; Skender et al., 2016). In recent years, accelerometers have become highly popular in both the commercial and private markets. Accelerometers rely on motion-sensing technologies within the wearable device, most commonly attached to either the subject's wrist or hip, that detect changes based on movements that are classified according to the anatomical planes of the human body (Montoye et al., 1983). Movements within these planes are then represented as counts, that are not physiologically meaningful but are indicative of movement intensity, and therefore, can be used to estimate energy expenditure such as METS or kilocalories using linear regression equations (Mathie et al., 2001; Sasaki et al., 2016). Despite the various benefits of accelerometers and recent advances in wearable technology for the estimation of energy expenditure and PA levels, the cost and complexity of these devices and issues with wearing compliance can act as a draw back in research involving large numbers of participants.

Subjective measures such as questionnaires and self-reported PA diaries are extensively used as a feasible and cost-effective method to assess PA in large scale studies. However, their low cost and convenience often comes at the price of measurement error or bias through misreporting, either deliberately (social desirability bias) or as a result of cognitive limitations in recall or comprehension (Helmerhorst et al., 2012; Skender et al., 2016; van Poppel et al., 2010). Despite recent advances in technology that have made objective measures more practical and accessible in the research setting, it is acknowledged that PA questionnaires continue to hold their place as a practical assessment of PA, particularly in instances where objective measures are inappropriate or not well suited, such as large scale population studies (Helmerhorst et al., 2012; van Poppel et al., 2010). Typically, PA questionnaires are designed to measure several dimensions of PA that may include, type, time, location, context and intensity of the activities undertaken across a given period of time (e.g., day, week, month). The International Physical Activity Questionnaire – Short Form (IPAQ-SF) is a shortened and more convenient alternative to the longer International Physical Activity Questionnaire (IPAQ), one of the most widely used questionnaires to estimate PA levels in a research setting due to its validity and convenience (Hagströmer et al., 2006). The IPAQ-SF provides reporting on the type and intensity of PA and sedentary time of individuals to give an estimation of total PA in $MET \cdot min \cdot wk^{-1}$. Available in multiple languages, the 7-item IPAQ-SF assesses an individual's previous seven days of PA. The IPAQ-SF has been found to have acceptable validity when used for population surveillance purposes with reference to accelerometer data ($p = 0.30$, 95% CI 0.23–0.36). (Craig et al., 2003; Hagströmer et al., 2006; Lee et al., 2011; Wolin et al., 2008).

2.3.3 Physical activity guidelines

In recognition of the importance of PA in relation to long term health, many countries worldwide have implemented PA guidelines. Current PA guidelines are homogenous across various countries, including the UK, US, Australia and New Zealand (Australian Government Department of Health, 2014; Department of Health and Social Care, Llywodraeth Cymru Welsh Government, & Department of Health Northern Ireland and the Scottish Government, 2019; Ministry of Health, 2020; U.S. Department of Health and Human Services, 2018) and are based on the WHO guidelines for both aerobic and muscle strengthening PA (World Health Organization, 2010). The recommended guidelines for a healthy adult is the equivalent of ≥150 $min \cdot wk^{-1}$ moderate intensity aerobic exercise or ≥75 $min \cdot wk^{-1}$ vigorous intensity aerobic exercise, with resistance exercise at least two days a week (World Health Organization, 2010). This level of activity is a minimum for achieving optimal health and evidently improves cardiorespiratory and muscular fitness and bone health; reduces the risk of non-communicable diseases; improves symptoms of anxiety and depression; and prevents weight gain and premature death (Australian Government Department of Health, 2014; Department of Health and Social Care, Llywodraeth Cymru Welsh Government, & Department of Health Northern Ireland and the Scottish Government, 2019; Ministry of Health, 2020; U.S. Department of Health and Human Services, 2018; World Health Organization, 2010). Additional health benefits are gained by pursuing ≥300 $min \cdot wk^{-1}$ moderate intensity aerobic exercise or ≥150 $min \cdot wk^{-1}$ vigorous intensity aerobic exercise. The guidelines also incorporate advice to "Sit less and move more" and to "break up long periods of sitting" in order to gain the health benefits of PA, which will be discussed in further detail in the section below (Australian Government Department of Health, 2014; Department of Health and Social Care, Llywodraeth Cymru Welsh Government, & Department of Health Northern Ireland and the Scottish Government, 2019; Ministry of Health, 2020b; U.S. Department of Health and Human Services, 2018).

2.3.4 Health Benefits of Physical activity

The health benefits of PA are extensive and well defined in the literature and include significantly reducing the risk of major non-communicable diseases such as CVD, T2DM and various cancers (e.g. breast and colon). Additionally, PA is strongly linked with positive effects on mental well-being and the maintenance of a healthy body weight (Brown et al., 2013; Chimen et al., 2012; Lee et al., 2012; Penedo & Dahn, 2005; Warburton, 2006). Despite these known benefits, more than 50% of the adult population in countries like New Zealand, Australia and the US are consistently insufficiently physically active and fail to achieve the minimal recommended PA guidelines (Australian Government Department of Health, 2014; Ministry of Health, 2020; U.S. Department of Health and Human Services, 2018). Physical inactivity accounts for 6–10% of the burden of the major non-communicable diseases, 9% of premature mortality globally, and is liable for more than 5.3 million deaths a year (Lee et al., 2012). In New Zealand, physical inactivity is linked to 12.7% of all deaths, and contributes to CVD (7.9%), T2DM (9.8%), breast cancer (13.1%) and colon cancer (14.1%) (Lee et al., 2012; Ministry of Health, 2020). Across most countries, females tend to be less active than males, with the global average for inactivity among females being 31.7%, in contrast to 23.4% among males (The Lancet Public Health, 2019). Likewise, the 2018/19 New Zealand Health Survey revealed that less females (47.1%) than males (54.7%) achieved the recommended guidelines across all age and ethnic groups (Ministry of Health, 2019). Globally, the trend for PA continues to decrease, which may be predisposing individuals to developing chronic health conditions, which otherwise may have been prevented.

There appears to be a relationship between PA and a reduced risk of CVD, especially in females (Oguma & Shinoda-Tagawa, 2004). In a study of 27,055 apparently healthy females (Mora et al., 2007), reductions in key markers for the development of cardiovascular-related diseases were demonstrated with exercise >20.5 MET hour·wk^{-1}when compared to the reference group who exercised <2.8 MET hour·wk^{-1} (Mora et al., 2007). Markers that were improved with the higher level of exercise included glycated haemoglobin, blood pressure, body mass index, total and low-density lipoprotein cholesterol and inflammatory biomarker C-reactive protein. A 2011 meta-analysis of 33 studies examining associations between PA and coronary heart disease (CHD), demonstrated that those who engaged in the equivalent of 150 or 300 min·wk^{-1} of moderate intensity PA had a 14% and 20% lower risk of CHD respectively, in comparison to those who were physically inactive (Sattelmair et al., 2011). Although this relationship was present for both sexes, the association for reduced risk of CHD was stronger in females (20%) compared to males (9%) (Sattelmair et al., 2011). Research has suggested that for females just one hour of walking per week was associated with a reduced risk for CHD (40%), stroke (12%) and overall CVD (20%). The participants in this study were extremely inactive (e.g. 0-1 hour·wk^{-1} walking), therefore the results appear to provide strong evidence that even slight increases in PA levels (e.g. >1 hour·wk^{-1}) is sufficient to improve overall cardiovascular risk in females (Oguma & Shinoda-Tagawa, 2004).

Participation in PA, even that of moderate intensity and duration has been found to be directly related to a reduction in the incidence of T2DM after adjusting for age, smoking, alcohol consumption and other contributing factors for CVD (Hu et al., 1999; Manson et al., 1991; Weinstein et al., 2004). Intensity of exercise also seems to influence the degree to which PA protects against T2DM; for example, vigorous exercise reduced T2DM risk to a greater extent (39%) than walking (15%) (Aune et al., 2015). Furthermore, the protective effects of PA on T2DM risk have been reported in both males and females and across most body fat profiles (Aune et al., 2015; Ekelund et al., 2016; Grontved et al., 2014). Body composition changes (especially reduced adiposity and increased lean mass) from habitual exercise may account for 20-30% of the association between PA and T2DM risk reduction, and are independent of the other metabolic factors that are improved with PA (Aune et al., 2015). Females fulfilling PA guidelines with a combination of resistance and aerobic training reduced their risk of T2DM by 33% relative to inactive females (Grontved et al., 2014). Despite of the extensive benefits of PA, several factors may influence PA participation and may play a role in preventing or encouraging individuals to engage in PA.

2.3.5 Factors that influence females participation in physical activity

Factors such as time, care giving responsibilities, financial status, access to recreation centres, equipment, and social support may influence PA participation (Ford et al., 1991; Seefeldt et al., 2002; Williams et al., 2008). The relevance and impact of these factors on PA participation will vary between females and males. Females may be more inclined to fulfil multiple roles such as being caregivers, mothers and employees, and are often considered as the primary caregiver and manager of the household, responsible for a range of tasks (e.g. cleaning, childcare, laundry and meal preparation), that may limit their time available for engagement in structured PA (Brown et al., 2001; Cramp & Bray, 2011; Eyler et al., 1998; Mailey et al., 2014; Sanderson et al., 2002). A strong correlation between tiredness or lack of energy and physical inactivity in females of all ethnic groups has been demonstrated (Heesch et al., 2000). Likewise, various studies have demonstrated that lack of time is one of the biggest barriers to females participating in PA, in which work schedules, family and caregiving responsibilities were principal factors affecting time availability (Adachi-Mejia et al., 2010; Booth et al., 1997; Hoare et al., 2017; Joseph et al., 2015; King et al., 2000; Moreno & Johnston, 2014; Reichert et al., 2007; Sit et al., 2008). In New Zealand females, lack of time is reportedly the biggest barrier to PA participation (Grant et al., 2007; Schluter et al., 2011; Shirakawa et al., 2009; Sport New Zealand, 2016; Sullivan et al., 2003). Cost, affordability, access and availability of recreation centres, support (i.e. lacking a partner to exercise with, having a trainer to teach exercises) as well as the environment (e.g. dog nuisance) are other barriers that appear to impede participation in PA for New Zealand females (Grant et al., 2007; Schluter et al., 2011; Sport New Zealand, 2016; Sullivan et al., 2003). The gendered division of carer responsibility prior to the COVID-19 pandemic was unbalanced and this trend was reported to continue during the lockdown (Czymara et al., 2020; Manzo & Minello, 2020). Females were more likely to be balancing work, household, childcare and caregiving responsibilities and in some instances, sacrificed their work time to accomplish these tasks (Czymara et al., 2020; Manzo & Minello, 2020). Many of the known barriers to PA participation among females (e.g. access to facilities), and additional barriers to time (e.g. home schooling pressure) may have created or exacerbated existing barriers for PA completion during lockdown. Taken together, these various factors combined with disruption to daily routines may have reduced time for females to be physically active, and also potentially significantly impacted the MH and well-being of females in New Zealand.

2.4 Mental well-being

Depression, anxiety and stress are a constellation of MH disorders that influence one's mental well-being, an umbrella term for both hedonic (happiness, life satisfaction and affect) and eudaimonic (positive functioning, sense of purpose and self-acceptance) well-being (Chand & Arif, 2021). Quality of life, well-being, social functioning, recovery and physical health are all key markers that contribute to an individual's overall MH status and have become a key area of emphasis in the treatment of individuals with MH conditions (Connell et al., 2014). It is now widely recognised that a holistic approach to MH is more beneficial for patient outcomes than symptom focused interventions (Hogan, 2003). The global burden of MH conditions such as depression, anxiety and stress are increasing at an alarming rate and are a major contributor to premature death, disability, lost productivity and global government health expenditure (World Health Organization, 2021a). Therefore, improving one's overall MH status may be a viable method of positively influencing an individual's quality of life.

Depression is defined as a mood disorder and can be further classified into one of the following disorder categories; disruptive mood dysregulation, major depressive, persistent depressive (dysthymia), premenstrual dysphoric and depressive disorder due to another medical condition. Although each of these categories of depression differ in their specific presentation, onset and symptomology, they all share common features such as sadness, emptiness and irritable mood that is accompanied by cognitive and somatic changes affecting an individual's ability to function (American Psychiatric Association, 2013).

Anxiety, also referred to as generalised anxiety disorder, produces symptoms such as worry, fear and feeling constantly overwhelmed, and is characterised by unrealistic, excessive, and persistent worry about everyday things (Munir & Takov, 2021). The diagnostic criteria for generalised anxiety disorder includes, excessive anxiety and worry that is difficult to control and lasts at least six months, or anxiety that is not attributable to any physical cause or results in significant distress or impairment in social and occupational areas (American Psychiatric Association, 2013). Anxiety diagnosis may also be associated with restlessness, feeling keyed up or on edge, being easily fatigued, difficulty concentrating or mind going blank, muscle tension, sleep disturbance and irritability (American Psychiatric Association, 2013).

Throughout history there have been several different definitions of stress proposed. First defined by Hans Selye in 1936 as *"the non-specific response of the body to any demand for change"* and stressors being *"that which produce stress"*. Later, Richard Lazarus (1966) proposed a definition of stress *"as a relationship between the person and the environment that is appraised as personally significant and as taxing or exceeding resources for coping"*. Yaribeygi and colleagues in 2017 simplified the definition of stress as *"any intrinsic or extrinsic stimulus that evokes a biological response is known as stress"* (Yaribeygi et al., 2017). Some of the key effects or symptoms associated with stress include physical inactivity, disordered eating and the engagement in high-risk behaviours such as substance abuse (Araiza & Lobel, 2018; Cheval et al., 2020; Ogden et al., 2014; Porcelli & Delgado, 2009; Sinha, 2001).

2.4.1 Measuring mental well-being

The gold standard for the diagnosis of MH conditions such as depression, anxiety and stress is a structured clinical interview conducted by a Clinical Psychologist (Davison et al., 2009). In the research setting, this method is costly and unfeasible, therefore validated self-reported MH questionnaires are often utilised to quantify the presence of significant emotional changes (Uher et al., 2012). The Depression Anxiety Stress Scales-9 (DASS-9) is a short form of both the original 42-item (DASS-42) and 21-item (DASS-21) short form self-report measure of depression, anxiety and stress. The DASS-9 has been widely used in both clinical and non-clinical populations to assess a broad range of symptoms associated with psychological distress over the previous week, with a primary purpose to identify emotional disturbance (Yusoff, 2013). The DASS-42 and DASS-21 have both shown a high level of reliability in healthy general population samples and good validity when compared to other established questionnaires such as the Beck Depression Inventory, Positive and Negative Affect Scale and the Hospital Anxiety and Depression Scale (Crawford & Henry, 2003; Lovibond & Lovibond, 1995; Musa et al., 2007). The DASS-9 has shown acceptable reliability and construct validity when compared to the DASS-42 and DASS-21 and is often used as an alternative when a larger 42 or 21-item scale is inappropriate (Henry & Crawford, 2005).

Introduced in 1998, the World Health Organization Five Well-Being Index (WHO-5) is a short, self-reported questionnaire that measures subjective well-being over the previous 14 days using five positively phrased items, e.g. "I have felt cheerful and in good spirits" (Topp et al., 2015; World Health Organization, 1998). Responses from each item range from 0 (at no time) to 5 (all of the time) and scores are summed (raw score) and transformed into a percentage score by multiplying the raw score by 4 (Topp et al., 2015; World Health Organization, 1998). Resulting scores range from 0 being absence of well-being contrasted to 100, representing best possible well-being. The percentage score is used to monitor changes, where a 10% change indicates a significant change in well-being (Topp et al., 2015; World Health Organization, 1998). At present, the WHO-5 has been translated into more than 30 languages and is widely validated in the literature with respect to both clinical and psychometric validity in a range of populations (Bech et al., 2003; Ellervik et al., 2014) . In an evaluation by a panel of experts of 85 different questionnaires assessing health related quality of life, the WHO-5 was determined to be acceptable and among the top 20 scales in the sample (Topp et al., 2015). The WHO-5 has also been found to have a sensitivity of 0.93 and a specificity of 0.83 in the detection of depression with reference to the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (Löwe et al., 2004; Topp et al., 2015).

2.4.2 Mental well-being and health outcomes

Mental illness is a global health issue and carries with it a high economic burden. Depression is estimated to affect 264 million people worldwide and is one of the main causes of disability, affecting more females than males (World Health Organization, 2021a). Depression alone has a higher global disease burden than CHD, cerebrovascular disease and tuberculosis (Murray & Lopez, 1997). Likewise, mental disorders are a leading cause of lost years of healthy life, particularly for females between the ages of 15 and 44 years. Of all causes of disease burden, mental disorders make up three of the top 10 in low and middle income countries and four of the 10 top in high income countries (Mathers et al., 2008).

The prevalence of MH disorders and poor mental well-being in New Zealand has increased over the past several decades, with trends suggesting they are most apparent in females and young adults. According to the New Zealand MH Survey in 2003/04, approximately 47% of New Zealanders have experienced a mental disorder (e.g. depression, anxiety) within their lifetime (Oakley-Browne et al., 2006). More recently, the 2019 New Zealand Health Survey demonstrated that 10.4% of females in comparison to 5.9% males had experienced high or very high levels of psychological or mental distress (i.e. experienced symptoms such as anxiety, depression and psychological fatigue) (Ministry of Health, 2019). Even more alarming was the prevalence for diagnosed depression, being 20.3% for females and 11% for males. Similarly, 14.8% of females had an anxiety disorder compared to only 7.4% for males (Ministry of Health, 2019). The prevalence of compromised MH, especially in females, is cause for concern as depression and anxiety are considered major causes of morbidity and premature mortality (Ministry of Health, 2018) and are associated with impaired quality of life and social functioning. MH disorders have been linked to poor health behaviours such as altered caloric intake, physical inactivity, smoking and substance abuse, leading to an increased risk of adverse health outcomes (Ingram et al., 2020). It is common for physical and mental illness to coexist, thus, the identification and treatment of MH disorders would appear to be imperative in improving overall health status and may aid in maintaining PA levels. Alternatively, regular PA may serve as a form of MH treatment and management.

2.4.3 The relationship between mental well-being and physical activity

The effect of PA on mental and psychological well-being has been long established in the literature, with regular PA identified as a significant health behaviour. Not only does PA have a positive impact on physical health outcomes but it also plays a role in ameliorating the feelings of stress, anxiety and depression (Fox, 1999; McMahon et al., 2017; Paluska & Schwenk, 2000; Peluso & Andrade, 2005). Numerous studies investigating the key components of PA such as duration, intensity, modality, and setting have demonstrated a positive correlation between PA participation and symptoms associated with mental illness, across various population groups (Farmer et al., 1988; Martinsen et al., 1985; Schuch et al., 2018; Teychenne et al., 2020; Wilmore, 1990) (Appendix B).

Numerous studies have demonstrated a strong relationship between PA and enhanced MH (Bize et al., 2007; Brown et al., 2000; Holstila et al., 2017; O'Connor et al., 2010; Penedo & Dahn, 2005; Södergren et al., 2008; Wiese et al., 2018), particularly in reducing the risk of depression and anxiety (Bames et al., 2012; Janssen & LeBlanc, 2010). One review concluded that leisure time PA (i.e. activities outside of daily living) is strongly associated with reduced depression (Teychenne et al., 2008). Likewise, other studies have demonstrated a positive association with different types of leisure time PA (e.g. walking, outdoor and indoor activities) on mental well-being in various age groups (Chang et al., 2019; Pietilä et al., 2015), whereas, sedentary behaviour is negatively associated with mental well-being and subjective health outcomes (De Rezende et al., 2014; Hamer et al., 2010). PA may also positively impact psychological factors including self-esteem, body-image, perceived competence and self-mastery, which consequently have been shown to enhance mental well-being (Kamimura et al., 2014; Kwan et al., 2012; McPhie & Rawana, 2012; Valois et al., 2008). In social settings such as in groups, clubs and team sports, PA creates an opportunity for social interactions and therefore may improve MH by augmenting social support, network and connectedness (Faulkner & Carless, 2006; Holt et al., 2020; McHugh & Lawlor, 2012). High levels of connectedness strengthen the ability of individuals to manage their own emotions via cognitive processes (Tesser, 1991) which may be protective against anxiety (Lee & Robbins, 1998) and depression (Armstrong & Oomen-Early, 2009). PA has also been identified as a coping strategy (Southwick et al., 2005) that can facilitate long lasting resilience to stress (Appendix B).

PA intensity is a modifiable contributor to PA participation, and its effect on mental well-being and mood have been researched extensively. Evidence for the effect of intensity on mood improvement is mixed. For aerobic exercise such as cycling, running and swimming there is substantial evidence to suggest that intensity is not related to mood improvements (Bixby et al., 2001; Dishman et al., 2010; Steptoe et al., 1993). However, there is also research to suggest superior improvement in mood with high intensity exercise (>80% maximum HR) (Balchin et al., 2016; Cox et al., 2004) and following moderate intensity exercise (50-80% maximum HR) (Brown et al., 2006; Ensari et al., 2017) compared to exercise of lower intensity (<50% maximum HR). The great deal of inconsistency in the literature indicates that alone, intensity of exercise may not be sufficient to consistently result in improvements in MH, but instead, is part of the multifactorial experience that also includes duration and modality of the exercise task. Improvements in self-esteem and mood have been found to be associated with as little as 5 minutes of outdoor exercise per day (Barton & Pretty, 2010). Although very small doses of PA and exercise have been shown to elicit improvements in mental well-being, it is a general consensus within the literature that between 10-15 minutes is sufficient to provide a significant improvement in mood, with the greatest improvements typically seen with ~30 minutes daily (Daley et al., 2004; Hansen et al., 2001; Petruzzello et al., 1991; Rejeski et al., 1995). However, the relationship between PA and duration is nonlinear and presents with a 'U' shaped relationship, with research findings by Woo et al. (2009) demonstrating that psychological vigour increased after 30 minutes of exercise but not after 15 or 45 minutes. Although these findings tend to suggest that longer durations of exercise only provide a smaller additional benefit if any on MH and well-being, it is worth noting that this is likely individual dependent and the dose and effect relationship is relative to the level of activity an individual is used too (i.e. their fitness level and previous training). Exercise type, also referred to as modality, and its effects on one's mood and MH have been debated in the literature for some time. The comparisons between aerobic (such as walking, running, and cycling) and anaerobic exercise (such as weight training, sprinting and calisthenics) are well documented. Anaerobic exercise has consistently been found to be beneficial in improving mood, whereas aerobic exercise is more ambiguous and its impact on MH is far less defined (Chan et al., 2018). Overall, the available evidence strongly suggests that PA, regardless of duration, intensity and modality, improves feelings of depression, anxiety and stress and may play a role as an effective treatment for individuals with mild to moderate depressive symptoms (North et al., 1990). The literature suggests that individuals who are depressed typically engage in less leisure time PA than the general population (Eisemann, 1985) and therefore incorporating exercise therapy into standard care for MH conditions could provide some additional benefit alongside traditional treatment strategies (Appendix B).

2.4.4 Physical activity and mental well-being during the COVID-19 pandemic

Restrictions to human movement and prolonged self-isolation like those seen during the COVID-19 pandemic have been found to be linked with a reduction in PA levels and an increase in sedentary behaviour (Lippi et al., 2020). Globally within the last two years, researchers have investigated how the pandemic has affected PA participation, with mixed findings. Social isolation as a consequence of lockdowns in continents such as Asia, Africa and Europe, has limited the ability for individuals in these locations to engage in PA and has been correlated with the feelings of depression, anxiety and stress (Ammar et al., 2020; Constandt et al., 2020). Since the onset of the COVID-19 pandemic, significant reductions in PA levels have been observed in adults residing in the UK (63%) (McCarthy et al., 2021) and Australia (48.9%) (Stanton et al., 2020). Research in Spain demonstrated that PA participation decreased during the first week of lockdown but then steadily increased as individuals adapted to life in lockdown (López-Bueno et al., 2020). In France and Switzerland, an overall decrease in vigorous PA and an increase in sedentary behaviour (~75 $min \cdot day^{-1}$) was reported in comparison to pre COVID-19, whereas time spent walking and completing moderate intensity PA increased (~10 $min \cdot day^{-1}$) (Cheval et al., 2020). Early data from New Zealand suggested that overall weekly participation in PA increased, although participation in sports and other activities decreased relative to the same period from 2017, 2018 and 2019. Additionally, the proportion of individuals participating in <30 $min \cdot wk^{-1}$ dropped significantly from 23% to 20% (Sport New Zealand, 2020).

The effects of the COVID-19 pandemic and restrictions have been correlated with negative impacts on psychological well-being, stimulating feelings of stress, anxiety and depression

(Lesser & Nienhuis, 2020; Lippi et al., 2020; Maugeri et al., 2020; McKibbin & Fernando, 2020; Pillay et al., 2020; Shanahan et al., 2020; Sibley et al., 2020; Stanton et al., 2020). In a study examining the MH and well-being of UK adults at three time points across six weeks following the first COVID-19 lockdown, 26.1% (wave one), 24.3% (wave two) and 23.7% (wave three) of participants experienced moderate to severe levels of depression symptoms. In wave one, approximately 21% experienced moderate to severe levels of anxiety, which decreased to 16.8% by wave three (O'Connor et al., 2020). Nonetheless, these rates were higher than the estimated general population norm that is typically 5%, with research also suggesting that levels of mental well-being among females were lower in comparison to the overall population (O'Connor et al., 2020). Females reported higher levels of depressive symptoms (33.0%) compared to males (17.6%) and were more likely to have higher anxiety than males, 27.5% vs 13.0% respectively (wave one) (O'Connor et al., 2020). A study in Australia examining the MH of 5070 adults during the COVID-19 pandemic concluded that, regardless of prior MH diagnoses, the COVID-19 pandemic had a significant effect on participants' MH (Newby et al., 2020). The results of this study found that 37.1%, 29.1% and 33.6% of participants were classified in the moderate range for depression, anxiety and stress respectively, and 24.1%, 20.3% and 20.4% were found to be classified as severe or extremely severe for depression, anxiety and stress using the DASS-21 (Newby et al., 2020). Likewise, another study in Australia observed that during the lockdown restrictions levels of depression, anxiety and stress in individuals with no pre-existing MH conditions were approximately three times higher than previously existing population norms. Those with pre-existing MH conditions had over five times higher levels of depression, anxiety and stress than population norms during the initial stages of the COVID-19 pandemic (Rossell et al., 2021). Similar findings of elevated psychological distress have been reported in Spain (Ausín et al., 2021; Pérez et al., 2020), China (Wang et al., 2020), US and Canada (Klaiber et al., 2021; McGinty et al., 2020). Research completed in China concluded that individuals experienced high levels of anxiety and depression because of the COVID-19 pandemic, especially in those who perceived themselves to be in poor health prior to the outbreak (Qiu et al., 2020; Wang et al., 2020).

Additional research reported that individuals displayed symptoms of posttraumatic stress as a result of the COVID-19 pandemic, with some evidence that females were more affected than men (Liu et al., 2020). Females have also been reported to feel high levels of negative emotions throughout the pandemic (Lu et al., 2020; Wang et al., 2020; Zhang et al., 2020), possibly due to multifactorial reasons including but not limited to, managing work and increased childcare duties, greater risk of becoming unemployed and/or greater likelihood of infection as a result of being an ‘essential’ worker (Rossell et al., 2021). Individuals who lived alone, particularly older adults exhibited feelings of loneliness, which has been associated with accelerating physical and cognitive decline (Goethals et al., 2020). A number of researchers have demonstrated a strong link between pandemic related psychiatric morbidity and psychological distress (Gómez-Salgado et al., 2020; Smith et al., 2020).

Despite responses to the COVID-19 pandemic differing by country and additional differences in culture, social norms and local laws and legislation, the overarching findings of the above research suggests that the COVID-19 pandemic greatly elevated negative emotions across the population as a whole. Coinciding with this, a large body of evidence demonstrated that individuals who experience and live through community disasters such as wars and natural disasters are faced with an increase in mental and psychological burden (Bonanno et al., 2010; Norris et al., 2002). The increased prevalence of stress and anxiety related disorders during the COVID-19 pandemic have been found to be associated with the perception of fear, that either oneself or a loved one may contract the virus, and uncertainty concerning the future (Troyer et al., 2020; Violant-Holz et al., 2020). Higher risk groups such as females, the elderly, and individuals with chronic health conditions have frequently displayed higher levels of depression, anxiety and stress during the COVID-19 pandemic and periods of social isolation (Antunes et al., 2020; Shechter et al., 2020; Stanton et al., 2020). Overall, it is clear that the COVID-19 pandemic and its resultant containment strategies have impacted PA participation and the MH of individuals across the globe. There has also been an identified disproportionate burden towards females, individuals with pre-existing MH conditions, the elderly and individuals living alone.

Summary

COVID-19 is a major global public health crisis associated with substantial morbidity and mortality. Current evidence suggests that self-isolation strategies such as lockdowns have been effective at managing the spread of COVID-19, yet, the physical and mental implications of these measures are currently not fully understood. Regular PA has numerous physiological and psychological benefits, however, in a scenario such as COVID-19 where lockdowns and associated restrictions have limited human movement and access to recreational facilities and reduced social interaction, it is currently undefined as to how this may interrupt individuals' normal PA patterns and behaviours. To date, there is no scientific insight on how New Zealand females changed their PA levels and patterns due to the initial nationwide L4 lockdown and subsequent restrictions at L2. We also currently do not know if the lockdown and restrictions impacted the mental well-being of female New Zealanders or if there is an association between their mental and physical health during this period. Thus, a comprehensive examination of the physical and mental characteristics of human behaviour in response to such restrictions is imperative for managing the optimal health and well-being of New Zealand females. Such insight will also allow for optimal management of the current pandemic and for effective planning in the event that a global public health emergency such as COVID-19 was to arise again in the future.

Chapter 3: The effect of COVID-19 restrictions on physical activity levels and mental well-being in adult females living in New Zealand.

3.1 Abstract

Background: Containment strategies to minimise the global spread of COVID-19 have impacted individuals' 'normal' daily routines, changed the way we work and reduced opportunities for PA participation. Females more so than males may have experienced a greater impact of the COVID-19 restrictions, exaggerating the multiple roles they fulfil. The positive association between PA and MH and well-being is well established and the purpose of this study was to understand the effect of the New Zealand Government's COVID-19 containment strategies on adult females' PA and mental well-being and the factors that influenced PA participation.

Methods: Adult females in New Zealand (n=1504: age 48±14 years 83.4% New Zealand European) completed two amalgamated anonymous online surveys (Qualtrics) during L4 and L2 to assess PA (IPAQ-SF), MH (DASS-9) and well-being (WHO-5). PA level was classified as high (≥3000 $MET \cdot min \cdot wk^{-1}$), moderate (≥600 to 2999 $MET \cdot min \cdot wk^{-1}$) or low (<600 $MET \cdot min \cdot wk^{-1}$). Factors that influenced PA participation were assessed as to whether they had no influence or some influence on PA participation.

Results: PA was higher during L4 compared to L2. WHO-5 scores were higher at L4 (59±20) than at L2 (57±20). DASS-Anxiety scores were lower at L4 (0.5±1.1) than at L2 (0.6±1.2), whereas DASS-Depression and -Stress scores were higher at L4 (Depression 1.9±1.8, Stress 1.9±1.6) than at L2 (Depression 1.6±1.7, Stress 1.7±1.6). Those who participated in higher levels of PA had higher WHO-5 scores at both L4 (66.3±19.3, $p<0.001$) and L2 (62.9±19.6, $p<0.001$) compared to those who participated in lower levels. The high IPAQ group had lower DASS-Depression, -Anxiety and -Stress scores ([1.5±1.6, $p<0.001$][0.3±0.9, $p<0.001$][1.6± 1.5, $p<0.001$]) compared to those in the low group. The major factors that influenced PA participation were time available, working situation and MH.

Conclusions: Results support the positive relationship between PA, MH and well-being in females and illustrates its importance during times of mental unease such as during a global pandemic or periods of social isolation. Governments and public health advisers are encouraged to use these findings to promote PA in the event a situation such as COVID-19 was to arise again to best preserve the mental well-being of females and other New Zealanders.

Keywords: Physical activity, well-being, mental health, COVID-19, coronavirus, females, New Zealand.

3.2 Introduction

COVID-19 is a highly transmissible disease which was declared as a global pandemic by the WHO on the 11th of March, 2020 (World Health Organization, 2020), In response to its rapid spread even during its 'incubation period', and along with the predicted exponential growth in cases and deaths, government bodies of respective countries worldwide implemented a range of containment strategies in an attempt to combat the spread of the virus (Burtscher et al., 2020). The characteristics of these strategies varied by jurisdiction, but generally included the closure of businesses, schools and recreational centres, self-isolation, home confinement and social distancing (Ammar et al., 2020; McKibbin & Fernando, 2020). In New Zealand, the government implemented a 4-tiered Alert Level System on the 21st of March, 2020, as a form of containment strategy (New Zealand Government, 2021a). On the 25th March, 2020, New Zealand moved into the highest alert level, L4 (lockdown). After 50 days, the alert level was lowered to L2, where life returned to relative normality with the exception of closed borders (New Zealand Government, 2021a). Alert L4 required individuals to self-isolate and to interact only with those from their household i.e. those within their 'bubble' (New Zealand Government, 2020) and to maintain a 2-metre distance from all other individuals when outside of ones' 'bubble'. Individuals were permitted to leave their homes only for activities deemed essential such as accessing medical care and supermarkets, travelling to work as an essential worker, and for exercise (New Zealand Government, 2020). Importantly, the New Zealand Government acknowledged the importance of PA and advocated for residents to safely exercise locally whilst maintain physical distancing rules (New Zealand Government, 2020).

PA is associated with numerous health benefits including reducing the risk of T2DM, various cancers, CVD and associated risk factors, and mitigating anxiety, stress and depressive symptoms (Hamburg et al., 2007; Homer et al., 2019; Physical Activity Guidelines Advisory Committee, 2018). However, participation in PA is influenced by a number of factors including time, care giving and family responsibilities, financial status, access to recreation centres, equipment and social influence (Ford et al., 1991; Seefeldt et al., 2002; Williams et al., 2008). These barriers to PA participation may be more pronounced among females, who are more likely than males to fulfil multiple roles (such as being caregivers and mothers) and take on a range of tasks (e.g. maintaining the household, childcare and meal preparation) whilst also balancing employment commitments (Brown et al., 2001; Cramp & Bray, 2011; Eyler et al., 1998; Mailey et al., 2014; Sanderson et al., 2002). Indeed, across most countries, females are less active than males (The Lancet Public Health, 2019). In New Zealand, only 49% of females compared to 57.2% of males achieve the PA guidelines of 150 minutes of moderate PA or 75 minutes of vigorous PA per week (Ministry of Health, 2021a).

Considering the substantial health benefits of PA, it follows that health may be compromised when an individual's ability to be physically active is restricted (O'Brien et al., 2021). Consequences of the restrictive measures imposed to combat COVID-19, including the closure of sport facilities (e.g. gyms and club sports) may have had detrimental effects on physical and mental well-being (Faulkner et al., 2021; Fitbit, 2020). Data from the early stages of the COVID-19 pandemic indicated significant declines in PA levels following the enforcement of restrictions in many countries (Constandt et al., 2020; Gallo et al., 2020; Lesser & Nienhuis, 2020; Rhodes et al., 2020). A large descriptive study of 455,404 participants from 187 countries demonstrated a 5.5% and 27.3% decrease in daily step counts, a proxy for PA, after 10 and 30 days respectively, following the start of the COVID-19 pandemic (Tison et al., 2020). Similarly, data collected from 30 million Fitbit users globally during March 2020 demonstrated a significant reduction in daily steps, ranging from 7% to 38% compared to the same period in 2019 (Fitbit, 2020). Some studies have also reported that the COVID-19 pandemic and its associated restrictions have had a negative effect on MH and well-being, especially symptoms associated with anxiety and depression (Antunes et al., 2020; Hu et al., 2020; Stanton et al., 2020b; Suzuki et al., 2020). Investigations into the relationship between PA and well-being during the COVID-19 pandemic have found that decreased PA and increased sedentary behaviour have been correlated with poorer MH (Colley et al., 2020; Duncan et al., 2020; Jacob et al., 2020; Pieh et al., 2020; Qi et al., 2020)

Understanding how PA and mental well-being levels changed in New Zealand females as a result of the enforced lockdown and restrictions by the New Zealand Government will provide a valuable insight into the consequences for health-related behaviours. Therefore, the purpose of this paper is to analyse and examine whether New Zealand females participated in more or less PA during L4 lockdown and L2 restrictions, paying attention to the factors that may have influenced PA participation. Furthermore, the psychological and mental well-being of New

Zealand females will be analysed at L4 and after seven weeks when containment levels were decreased to L2.

3.3 Methods

Study Design

The present study was part of a larger multinational longitudinal research study conducted in New Zealand, Australia, Ireland and the UK to assess these countries' respective government approaches to counteract the COVID-19 pandemic. Online surveys were conducted at two time points (during L4 lockdown and L2 restrictions) to assess the effects of COVID-19 containment restrictions on PA and mental well-being, as well as factors that influenced PA participation during this time.

Participants

The larger multinational study included males (n = 2432) and females (n = 5952). The current study looks only at the 1504 New Zealand females who completed both surveys *(Figure 2)*. The inclusion criteria were: 1) Being female, 2) Aged 18 years and over, 3) Living in New Zealand for the duration of the lockdown restrictions, 4) Completing Survey 1 (during the March 2020 L4 lockdown) and Survey 2 (during the June 2020 L2 restrictions). Participants were recruited through convenience and snowball sampling via social media, university campus communications, national media coverage (e.g. Stuff, New Zealand Herald, Radio New Zealand) and established research email lists. The study was deemed a low-risk notification by Massey University Human Ethics Committee (Approval number 4000022445) on the 8^{th} of April, 2020. All participants provided online informed consent prior to completing the surveys.

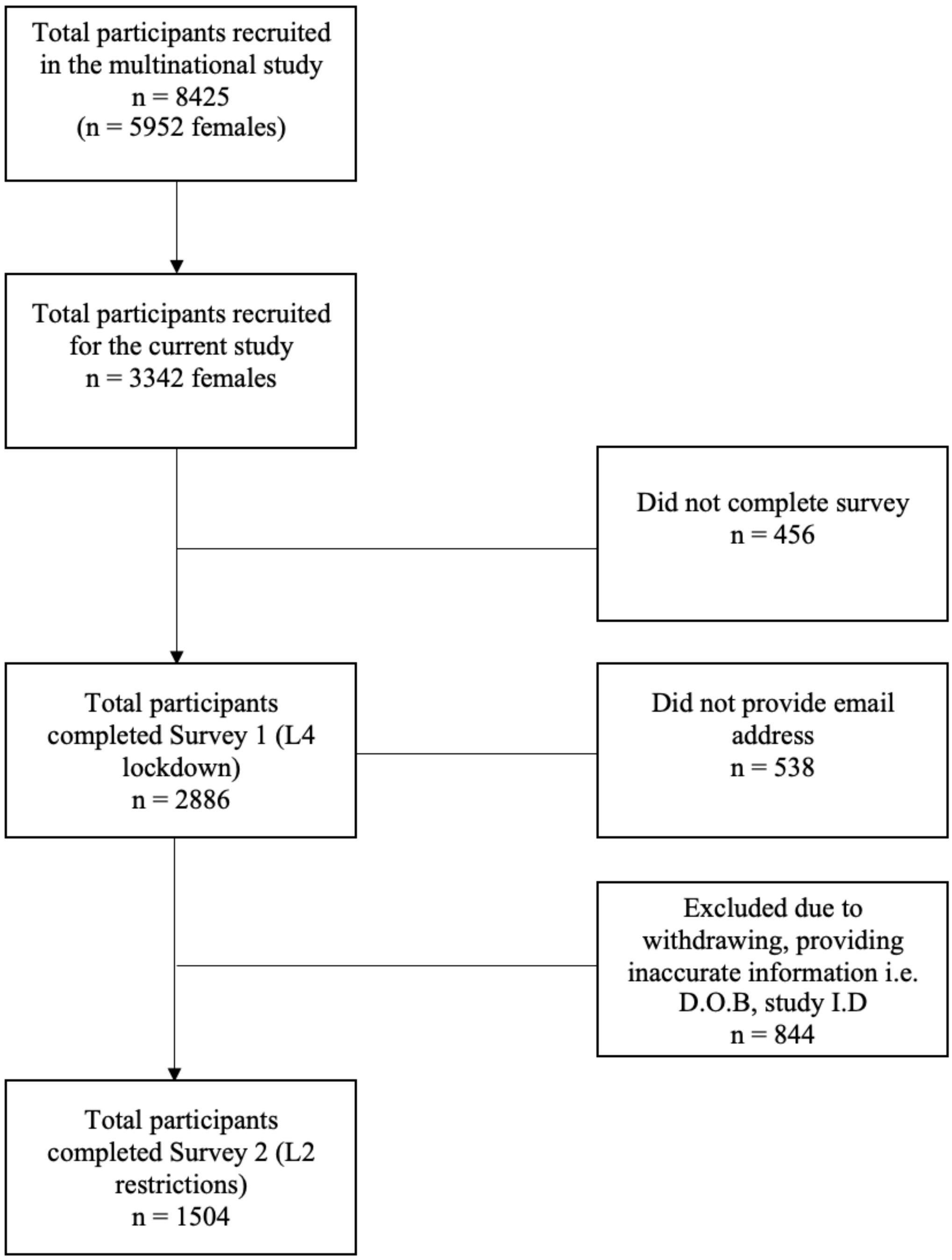

Figure 2. Flow diagram outlining the process of participant recruitment and flow through the study procedures.

Data collection

The survey used in this study was developed from several validated questionnaires and was administered online using Qualtrics (London, UK) survey software. Participants completed the survey at two time points: Survey 1 during L4 lockdown (lockdown; severe restrictions) was available from 10-29th April, 2020 and Survey 2 during L2 restrictions (reduce; relaxed restrictions) was available from 5-18th June, 2020. Participants had the option to provide their email address at the end of Survey 1 if they wished to be contacted for subsequent surveys. These participants were then emailed a link to Survey 2 during L2. The online questionnaire was completed by the participants at their own leisure and was designed to take no longer than 15 minutes. In Survey 1, participants self-reported their socio-demographic information and completed sections relating to PA, MH and well-being. Survey 1 also retrospectively assessed data from February 2020 (prior to the L4 lockdown was enforced) including information on living situation and whether participants achieved the recommended PA guidelines. Survey 2 consisted of the same questions as Survey 1, with the addition of sections relating to factors that influenced participation in PA.

Measures

Socio-demographic

Socio-demographic questions assessed age, gender, living situation, perceived income security, employment status (essential or non-essential), and comorbidities (whether these were present and affected PA).

Physical activity

PA was assessed using the IPAQ-SF (International Physical Activity Questionnaire, 2005). The IPAQ-SF consists of 7 items asking participants to self-report their PA during the last seven days (days per week, total minutes and hours per day), measuring information on moderate- and vigorous-intensity physical activities, walking and average daily sitting time to give an estimation of total PA in $MET{\cdot}min{\cdot}wk^{-1}$. The following classifications were used to classify physical activity as low (achieving < 600 $MET{\cdot}min{\cdot}wk^{-1}$), moderate (five days or more of any combination of walking, moderate or vigorous intensity physical activity achieving ≥ 600 to 2999 $MET{\cdot}min{\cdot}wk^{-1}$) and high (seven or more days of any combination of walking, moderate or vigorous intensity physical activity achieving ≥ 3000 $MET{\cdot}min{\cdot}wk^{-1}$). Participants also self-reported whether they achieved the New Zealand PA guidelines (≥150 minutes of moderate to vigorous intensity PA each week) (Ministry of Health, 2020) in February 2020 (Pre COVID-19).

Mental well-being

Mental well-being was assessed using the WHO-5 (Topp et al., 2015). The WHO-5 is a short global rating scale used to measure positive psychological well-being and includes the following items: i) 'I have felt cheerful and in good spirits', ii) 'I have felt calm and relaxed', iii) 'I have felt active and vigorous', iv) 'I woke up feeling fresh and rested' and v) 'My daily life has been filled with things that interest me'. Responses for each item range from 0 to 5, with scores then summed and transformed to a percentage to obtain a score ranging from 0 to 100, where 0 presents the worst in comparison to 100, representing the best possible level of well-being. The WHO-5 has been demonstrated to have good validity and can be used in both clinical and research practices (Topp et al., 2015).

Mental health

MH was assessed using the DASS-9 (Yusoff, 2013). The DASS is a widely used self-reported scale that simultaneously assesses the emotional states of depression, anxiety and stress. The DASS-9 was empirically derived from the DASS-21 and uses three subscales (depression, anxiety and stress), where each subscale contains 3 items. An example of one of the questions is "Over the past week, I felt that I had nothing to look forward to". The question could be answered from 0, indicating that it did not apply at all, up to 3, indicating that it applied very much, or most of the time. The total score ranges from 0-27 (sum of depression, anxiety and stress scores); where higher scores indicate higher overall depression, anxiety and stress scores. Depression scores are categorised as normal (0-1), mild (2), moderate (3), and extremely severe (4 and above); Anxiety scores are categorised as normal (0-3), moderate (4), severe (5) and extremely severe (6 and above); Stress scores are categorised as normal (0-3), moderate (4), severe (5) and extremely severe (6 and above) (Yusoff, 2013). The DASS-9 has been demonstrated to show more than adequate internal reliability and its validity is comparable to the DASS-21 (Kyriazos et al., 2018; Yusoff, 2013).

Factors influencing PA participation

Factors known to influence PA participation were assessed as to whether they had some influence or no influence on PA levels. In New Zealand females, lack of time, affordability, support (i.e. lacking a partner to exercise with), childcare responsibilities are some of the key barriers to PA participation (Sport New Zealand, 2016). Other barriers that appear to impede participation in PA include accessibility and availability of recreation centres and the environment (Grant et al., 2007; Schluter et al., 2011; Sullivan et al., 2003). Therefore, the factors assessed in this study were time available, working situation and location, financial situation (e.g. available money), weather, neighbourhood environment (e.g. nearby parks), opportunity to exercise (e.g. free online classes or closure of fitness facilities), physical health (e.g. illness) and MH (e.g. levels of anxiety).

Statistical and Data analysis

Data obtained from the IPAQ-SF were coded and analysed using the recommended IPAQ guidelines (International Physical Activity Questionnaire, 2005). Using the IPAQ scoring system, total minutes per week of PA at different intensities were calculated and classified as moderate- and vigorous-intensity activity along with walking and sitting (International Physical Activity Questionnaire, 2005). MVPA was calculated by adding together ($min \cdot wk^{-1}$) moderate- and vigorous-intensity, and walking according to author guidelines (International Physical Activity Questionnaire, 2005). After scoring, all survey data were entered into IBM SPSS version 26 (IBM Corporation, New York, USA) which was used for all statistical analysis. Prior to conducting the analysis, the Shapiro-Wilk Test was used to assess normality and data was assumed to be normally distributed under the Central Limit Theorem. All values are presented as mean ± standard deviation (SD). Changes in the time spent in each of the PA intensities between L4 and L2 were assessed using repeated measures analysis of variance (ANOVA). Likewise, to compare changes in WHO-5 and total DASS-9 scores between L4 and L2, a repeated measures ANOVA was conducted. Following the ANOVA tests, the post-hoc Bonferroni procedure was used to determine where the significant difference laid in variables between L4 and L2. To compare changes in mental well-being scores at different IPAQ classifications during L4 lockdown and L2 restrictions, a Welch's ANOVA was conducted as the homogeneity of variances was violated under the conditions of the repeated measures ANOVA. Following this, a Games-Howell post hoc procedure was used. Effect sizes (partial eta squared [η_p^2]) were classified as small (0.01), medium (0.06) or large (0.14) (Cohen, 1988). The factors influencing PA participation were converted into binary variables, indicating that each factor had either no influence or some influence on PA participation. Independent t-tests were conducted individually at L4 and L2 for each of these factors to determine whether they significantly influenced the time spent at the different PA intensities. A *p*-value ≤ 0.05 was set to indicate statistical significance for all tests.

3.4 Results

Of the 1504 participants, the mean age was 48 ± 14 years with the majority of participants (46.6%) between 40 and 59 years and 83.4% identified as New Zealand European (Table 2). Within our participant cohort, 18.0% were essential workers and 24.6% had comorbidities that affected PA engagement.

Table 2. Demographic data (n =1504)

Variables		n	%
Age group (years)	18-29	178	11.8
	30-39	265	17.6
	40-49	341	22.7
	50-59	359	23.9
	60-69	246	16.4
	70-79	109	7.2
	80+	6	0.4
Ethnicity	New Zealand European	1254	83.4
	Māori	49	3.3
	Samoan	2	0.1
	Cook Island Māori	2	0.1
	Niuean	3	0.2
	Chinese	14	0.9
	Indian	10	0.7
	Other European	136	9.0
	Multiple ethnic groups	5	0.3
	Other Asian	10	0.7
	Other	19	1.3
Essential worker	Yes	270	18
	No	1102	73.3
	N/A	132	8.8
Comorbidity affecting engagement in physical activity	Yes	370	24.6
	No	1070	71.1
	N/A	64	4.3
Living situation	Alone	210	14.0
	Couple	503	33.4
	Two parent family	407	27.1
	Single parent family	54	3.6
	Extended	212	14.1
	Flatting	118	7.8
	Residential care	0	0

Using data from the dichotomous question "Did you regularly meet the New Zealand physical activity guidelines of participating in at least 150 minutes of moderate intensity physical activity each week?", 79.4% of the participants reported achieving the PA guidelines pre COVID-19. The number of participants achieving the guidelines increased by 14.7% to 94.1% during L4 lockdown and decreased by 9.1% (relative to L4 lockdown) to 85% at L2 restrictions (Table 3).

Table 3. PA guidelines achieved by participants (pre COVID-19 and during L4 lockdown and L2 restrictions)

	Pre COVID-19		L4 lockdown		L2 restrictions	
	n	%	n	%	n	%
Guidelines achieved						
Yes	1199	79.4	1416	94.1	1279	85
No	311	20.6	88	5.9	225	15

The results from the repeated measures ANOVA for changes in PA levels are presented in Table 4. There was a significant main effect of the time (i.e. different restriction periods) on sitting and all levels of PA (Table 4). The Bonferroni post-hoc test showed that sitting and all levels of PA were significantly higher during L4 lockdown compared to L2 restrictions (MVPA [F (1,1503) = 19.85, $p < 0.001$, $\eta_p^2 = 0.013$], vigorous PA [F (1,1503) = 9.78, $p = 0.002$, $\eta_p^2 = 0.006$], moderate PA [F (1,1503) = 100.18, $p < 0.001$, $\eta_p^2 = 0.062$], walking [F (1,1503) = 57.70, $p < 0.001$, $\eta_p^2 = 0.037$] and sitting [F (1,1503) = 26.36, $p < 0.001$, $\eta_p^2 = 0.017$]). There was a small main effect for MVPA, vigorous, walking and sitting and a medium main effect for moderate PA.

Table 4. PA levels during L4 lockdown and L2 restrictions

	L4 lockdown	L2 restrictions
Vigorous PA (min·wk^{-1})	147 ± 179	131 ± 193*
Moderate PA (min·wk^{-1})	185 ± 220	123 ± 184*
Walking (min·wk^{-1})	296 ± 238	244 ± 261*
MVPA (min·wk^{-1})	629 ± 432	497 ± 421*
Sitting (min·day^{-1})	449 ± 169	426 ± 189*

All values are reported as mean ± SD. * indicates significantly different to L4 (p <0.05)
Abbreviations: PA (physical activity); min·wk^{-1} (minute per week); min·day^{-1} (minute per day); MVPA (moderate to vigorous physical activity).

The results from the repeated measures ANOVA for mental well-being scores are presented in Table 5. There was a significant main effect of the time (i.e. different restriction periods) on total WHO-5 scores [F (1,1503) = 18.19, p < 0.001, η_p^2 = 0.012]. The Bonferroni post-hoc test showed that total WHO-5 scores during L4 lockdown were significantly higher (i.e. better well-being) than L2 restrictions. For the DASS scores, there was a significant main effect of the different restriction periods on total depression [F (1,1503) = 45.76, p < 0.001, η_p^2 = 0.030], anxiety [F (1,1503) = 14.12, p < 0.001, η_p^2 = 0.009] and stress [F (1,1503) = 14.24, p < 0.001, η_p^2 = 0.009] scores. There was a small main effect for both WHO-5 and DASS scores. The Bonferroni post-hoc test showed that total depression and stress scores during L4 lockdown were significantly higher (i.e. more elevated negative emotional states) than L2 restrictions, whilst total anxiety scores were significantly higher during L2 than L4 (Table 5).

Table 5. Mental well-being scores during L4 lockdown and L2 restrictions

	L4 restrictions	L2 restrictions
WHO-5	59 ± 20	57 ± 20*
DASS- Depression	1.9 ± 1.8	1.6 ± 1.7*
DASS- Anxiety	0.5 ± 1.1	0.6 ± 1.2*
DASS-Stress	1.9 ± 1.6	1.7 ± 1.6*

All values are reported as mean ± SD. * indicates significantly different to L4 (p < 0.05)
Abbreviations: WHO-5 (The World Health Organisation- Five Well-Being Index); DASS (depression anxiety stress scales).

During L4 lockdown

There was a statistically significant difference in WHO-5 scores between IPAQ classification groups during L4 lockdown as determined by Welch's ANOVA [$F = 79.20$, (2,1501) df, $p < 0.001$]. A Games-Howell post hoc test revealed that WHO-5 scores were significantly higher for those in the moderate (56.7 ± 19.5, $p < 0.001$) and high (66.3 ± 19.3, $p < 0.001$) IPAQ groups, compared to those in the low group (42.8 ± 20.4, $p < 0.001$). The high IPAQ group also had significantly higher WHO-5 scores when compared to the moderate IPAQ group ($p < 0.001$). There were also significant differences in DASS-Depression ($F = 29.2$, (2,265) df, $p < 0.001$), DASS-Anxiety ($F = 12.5$, (2,256) df, $p < 0.001$) and DASS-Stress ($F = 13.3$, (2,266) df, $p < 0.001$) scores between the IPAQ groups. A Games-Howell revealed that DASS-Depression, -Anxiety and -Stress scores were significantly lower for those in the moderate ([2.0 ± 1.7, $p < 0.001$][0.5 ± 1.0, $p = 0.002$][1.9 ± 1.7, $p = 0.009$]) and high ([1.5 ± 1.6, $p < 0.001$][0.3 ± 0.9, $p < 0.001$][1.6 ± 1.5, $p < 0.001$]) IPAQ groups, compared to those in the low ([3.1 ± 2.2, $p < 0.001$][1.1 ± 1.8, $p = 0.002$][2.6 ± 2.0, $p = 0.009$]) group. Again, all DASS-scores (Depression, anxiety, stress) were significantly lower in the high IPAQ group compared to the moderate group ($p \leq 0.009$) (Table 6).

During L2 restrictions

There was a statistically significant difference in WHO-5 scores between IPAQ classification groups during L2 restrictions as determined by Welch's ANOVA [$F = 60.6$, (2,1501) df, $p < 0.001$]. A Games-Howell post hoc test revealed that WHO-5 scores were significantly higher for those in the moderate (57.7 ± 20.5, $p < 0.001$) and high (62.9 ± 19.6, $p < 0.001$) IPAQ groups, compared to those in the low group (46.3 ± 20.8, $p < 0.001$). WHO-5 scores were also significantly higher in the high IPAQ group compared to the moderate group ($p < 0.001$). There was also a significant difference between IPAQ classification groups for the DASS-Depression scores ($F = 22.5$, (2,1501) df, $p < 0.001$), in which, a Games-Howell post hoc test revealed that DASS-Depression scores were significantly lower for those in the moderate (1.6 ± 1.6, $p < 0.001$) and high (1.3 ± 1.5, $p < 0.001$) IPAQ groups, compared to those in the low group (2.2 ± 2.1, $p < 0.001$). The high IPAQ group, also had lower DASS-Depression scores compared to the moderate group ($p = 0.010$). The Welch's ANOVA revealed that there was no significant difference between IPAQ classification groups for DASS-Anxiety scores ($p = 0.077$). For the DASS-Stress scores, these were significantly lower in the moderate (1.7 ± 1.6, $p = 0.009$) and high (1.5 ± 1.6, $p < 0.001$) IPAQ groups when compared to the low group (2.0 ± 1.7, $p = 0.009$), but there was no significant difference between the moderate and high IPAQ groups ($p = 0.255$) (Table 6).

Table 6. Comparisons of mental well-being scores at different IPAQ classifications during L4 lockdown and L2 restrictions

	L4 lockdown			L2 restrictions		
IPAQ classification of PA level	Low n = 101	Moderate n = 857	High n = 546	Low n = 297	Moderate n = 749	High n = 458
WHO-5	42.8 ± 20.4	56.7 ± 19.5 [a]	66.3 ± 19.3 [ab]	46.3 ± 20.8	57.7 ± 20.5 [c]	62.9 ± 19.6 [cd]
DASS- Depression	3.1 ± 2.2	2.0 ± 1.7 [a]	1.5 ± 1.6 [ab]	2.2 ± 2.1	1.6 ± 1.6 [c]	1.3 ± 1.5 [cd]
DASS- Anxiety	1.1 ± 1.8	0.5 ± 1.0 [a]	0.4 ± 0.9 [ab]	0.7 ± 1.3	0.6 ± 1.2	0.6 ± 1.3
DASS-Stress	2.6 ± 2.0	1.9 ± 1.7 [a]	1.6 ± 1.5 [ab]	2.0 ± 1.7	1.7 ± 1.6 [c]	1.5 ± 1.6 [c]

All values are reported as mean ± SD
[a]Significantly different to low during L4 lockdown
[b]Significantly different to moderate during L4 lockdown
[c]Significantly different to low during L2 restrictions
[d]Significantly different to moderate during L2 restrictions

Factors influencing PA participation

Factors were examined at different PA intensities via independent t-tests during L4 lockdown and L2 restrictions individually and results are presented in Table 7 and 8.

Time available

At L4, time available had no significant influence on PA participation at any of the of the PA intensities. In comparison, at L2, those whose time available did not influence PA participation, had higher levels (min·wk^{-1}) of vigorous PA (152 ± 204 vs 119 ± 185; $t = 3.03$, 1037 df, $p = 0.002$), moderate PA (139 ± 200 vs 113 ± 175; $t = 2.58$, 1006 df, $p = 0.010$), walking (276 ± 272 vs 225 ± 254; t = 3.56, 1061 df, $p < 0.001$) and MVPA (567 ± 440 vs 458 ± 406; $t = 4.75$, 1048 df, $p < 0.001$) compared to those whose time available did have an influence on PA participation. Time available had no significant influence on time spent sitting at L4 or L2.

Working situation

During L4, those whose working situation did not influence PA participation had higher levels of (min·wk^{-1}) moderate PA (210 ± 242 vs 174 ± 207; $t = 2.84$, 807 df, $p = 0.005$), walking (317 ± 257 vs 286 ± 228; $t = 2.22$, 829 df, $p = 0.027$) and MVPA (676 ± 448 vs 607 ± 422; $t = 2.85$, 875 df, $p = 0.005$) compared to those whose working situation did have an influence on PA participation. Working situation did not appear to be a significant factor contributing to the amount of vigorous PA completed by the participants each week. Similarly, at L2, those whose working situation did not influence PA participation had higher levels of (min·wk^{-1}) of vigorous PA (142 ± 196 vs 122 ± 190; $t = 2.05$, 1502 df, $p = 0.040$), moderate PA (134 ± 198 vs 113 ± 171; $t = 2.19$, 1373 df, $p = 0.029$), walking (273 ± 280 vs 218 ± 242; t = 4.02, 1374 df, $p < 0.001$) and MVPA (549 ± 443 vs 453 ± 398; $t = 4.41$, 1399 df, $p < 0.001$) compared to those whose working situation did have an influence on PA participation. At both L4 and L2, sitting (min·day^{-1}) levels were higher for those whose working situation did have an influence on sitting (463 ± 164 vs 420 ± 175; $t = -4.57$, 1502 df, $p < 0.001$) (437 ± 197 vs 412 ± 179; $t = -2.63$, 1502 df, $p = 0.009$) compared to those whose working situation did not influence sitting.

Financial situation

Financial situation had no significant influence on vigorous PA, walking and MVPA at L4 and on any of the PA intensities at L2. At L4, those whose financial situation did have an influence on PA participation, completed higher levels (min·wk^{-}1) of moderate PA (221 ± 247 vs 180 ± 215; t = -2.23, 247 df, p = 0.026) compared to those whose financial situation did not influence PA participation. Additionally, sitting (min·day^{-1}) levels were higher for those whose financial situation did not influence sitting (453 ± 170 vs 427 ± 155; t = 2.14, 278 df, p = 0.033).

Weather

At L4, weather had no significant influence on moderate PA, walking, MVPA and sitting. However, those for whom weather did not influence PA participation had higher levels (min·wk^{-1}) of vigorous PA (157 ± 189 vs 137 ± 166; t = 2.16, 1502 df, p = 0.031) PA compared to those who reported that weather did have an influence on PA participation. At L2, participants who reported that weather did not influence PA participation had higher levels of (min·wk^{-1}) of vigorous PA (161 ± 215 vs 96 ± 156; t = 6.87, 1465 df, p < 0.001), moderate PA (135 ± 193 vs 109 ± 172; t = 2.76, 1500 df, p = 0.006), walking (271 ± 283 vs 212 ± 230; t = 4.47, 1500 df, p < 0.001) and MVPA (567 ± 458 vs 416 ± 357; t = 7.17, 1490 df, p < 0.001). Weather did not appear to significantly influence the amount of time participants spent sitting.

Neighbourhood environment

The neighbourhood environment had no significant influence on vigorous PA, moderate PA, MVPA and sitting at L4. Those who reported that the neighbourhood environment did have an influence on PA participation completed a higher level (min·wk^{-1}) of walking (307 ± 239 vs 282 ± 236; t = -2.02, 1502 df, p = 0.044) compared to those who reported that the neighbourhood environment did not influence PA participation. At L2, the neighbourhood environment had no significant influence on vigorous PA, moderate PA, walking and MVPA. However, participants who reported that the neighbourhood environment did not influence PA participation spent more time sitting (min·day^{-1}) (432 ± 188 vs 408 ± 193; t = 2.25, 1502 df, p = 0.024) compared to participants who reported that the neighbourhood environment did have an influence on PA participation.

Opportunity to exercise

At L4, opportunity to exercise had no significant influence on any PA intensities. At L2, those who reported that opportunity to exercise did influence PA participation, had higher levels ($min{\cdot}wk^{-1}$) of vigorous PA (150 ± 212 vs 117 ± 176; $t = -3.18$, 1182 df, $p = 0.002$) compared to participants whose opportunity to exercise did not influence PA participation. Walking ($min{\cdot}wk^{-1}$) was higher among participants who reported that opportunity to exercise did not influence PA participation (256 ± 273 vs 227 ± 244; $t = 2.17$, 1424 df, $p = 0.030$) compared to those who reported that opportunity to exercise did influence PA participation.

Physical health

At L4, physical health had no significant influence on any PA intensity. At L2, participants whose physical health did not influence PA participation had higher levels ($min{\cdot}wk^{-1}$) of vigorous PA (138 ± 197 vs 105 ± 173; $t = 2.99$, 600 df, $p = 0.003$), walking (251 ± 262 vs 218 ± 260; $t = 2.00$, 1502 df, $p = 0.045$) and MVPA (516 ± 427 vs 430 ± 395; $t = 3.32$, 1502 df, $p = 0.001$) compared to participants whose physical health did have an influence on PA participation. Physical health did not appear to influence the amount of moderate intensity and sitting during L2.

Mental health

At L4, MH had a significant influence on all PA intensities. Participants whose MH did not influence PA participation completed higher levels of ($min{\cdot}wk^{-1}$) of vigorous PA (158 ± 183 vs 134 ± 173; $t = 2.59$, 1502 df, $p = 0.010$), moderate PA (202 ± 229 vs 165 ± 206; $t = 3.26$, 1502 df, $p = 0.001$), walking (315 ± 252 vs 273 ± 217; $t = 3.41$, 1502 df, $p = 0.001$) and MVPA (674 ± 441 vs 571 ± 413; $t = 4.63$, 1502 df, $p < 0.001$) compared to participants whose MH did have an influence on PA participation. Similarly, at L2, participants whose MH did not influence PA participation had higher levels of ($min{\cdot}wk^{-1}$) of moderate PA (129 ± 190 vs 106 ± 169; $t = 2.30$, 842 df, $p = 0.022$), walking (259 ± 263 vs 202 ± 252; $t = 3.88$, 785 df, $p < 0.001$) and MVPA (521 ± 425 vs 435 ± 405; $t = 3.45$, 1502 df, $p < 0.001$) compared to participants whose MH did have an influence on PA participation. MH did not have a significant influence on the amount of vigorous intensity PA completed at L2. Sitting ($min{\cdot}day^{-1}$) levels for both

L4 and L2 were higher for participants whose MH did influence PA participation ([460 ± 166 vs 440 ± 170; t = -2.31, 1502 df, p = 0.021][445 ± 203 vs 418 ± 184; t = -2.35, 693 df, p = 0.019).

Table 7. The influence of factors on time spent at the different PA intensities during L4 lockdown

Physical activity intensity (min·wk^{-1}; Sitting min·day^{-1})							
L4 lockdown							
Factors	Influence of factors	n	Vigorous	Moderate	Walking	MVPA	Sitting
Time available	No influence	358	148 ± 193	184 ± 230	294 ± 243	626 ± 436	453 ± 180
	Some influence	1146	147 ± 174	186 ± 216	297 ± 236	629 ± 430	448 ± 165
Working situation	No influence	475	149 ± 188	210 ± 242*	317 ± 257**	676 ± 448**	420 ± 175
	Some influence	1029	147 ± 175	174 ± 207	286 ± 228	607 ± 422	463 ± 164**
Financial situation	No influence	1304	146 ± 178	180 ± 215	293 ± 239	620 ± 423	453 ± 170**
	Some influence	200	152 ± 186	221 ± 247**	314 ± 230	688 ± 478	427 ± 155
Weather	No influence	794	157 ± 189**	187 ± 226	295 ± 241	639 ± 442	451 ± 174
	Some influence	710	137 ± 166	183 ± 213	297 ± 234	617 ± 420	447 ± 162
Neighbourhood environment	No influence	657	152 ± 184	181 ± 219	282 ± 236	615 ± 423	454 ± 175
	Some influence	847	144 ± 175	189 ± 220	307 ± 239**	639 ± 438	446 ± 163
Opportunity to exercise	No influence	569	142 ± 191	187 ± 226	310 ± 259	639 ± 456	445 ± 173
	Some influence	935	151 ± 171	185 ± 216	287 ± 223	623 ± 416	452 ± 166
Physical health	No influence	1116	149 ± 179	185 ± 219	300 ± 243	635 ± 432	449 ± 170
	Some influence	388	141 ± 179	185 ± 223	284 ± 221	611 ± 429	451 ± 165
Mental health	No influence	839	158 ± 183**	202 ± 229**	315 ± 252**	674 ± 441**	440 ± 170
	Some influence	665	134 ± 173	165 ± 206	273 ± 217	571 ± 413	460 ± 166**

All values are reported as mean ± SD. * Indicates significant difference ($p < 0.05$) between some influence and no influence for each factor at a given PA intensity. ** Indicates significant difference ($p<0.01$) between some influence and no influence for each factor at a given PA intensity within each level. *Abbreviations*: MVPA (moderate to vigorous PA).

Table 8. The influence of factors on time spent at the different PA intensities during L2 restrictions

			Physical activity intensity ($min \cdot wk^{-1}$; Sitting $min \cdot day^{-1}$)				
			L2 restrictions				
Factors	Influence of factors	n	Vigorous	Moderate	Walking	MVPA	Sitting
Time available	No influence	542	152 ± 204**	139 ± 199**	276 ± 272**	567 ± 440**	426 ± 183
	Some influence	962	119 ± 185	113 ± 175	225 ± 254	458 ± 406	425 ± 193
Working situation	No influence	690	142 ± 196**	134 ± 198**	273 ± 280**	549 ± 443**	412 ± 179
	Some influence	814	122 ± 190	113 ± 171	218 ± 242	453 ± 398	437 ± 197**
Financial situation	No influence	1366	131 ± 190	125 ± 187	244 ± 260	499 ± 423	427 ± 187
	Some influence	138	135 ± 220	100 ± 156	242 ± 280	477 ± 409	409 ± 209
Weather	No influence	811	161 ± 215**	135 ± 193**	271 ± 283**	567 ± 458**	418 ± 188
	Some influence	693	96 ± 156	109 ± 172	212 ± 230	416 ± 357	434 ± 190
Neighbourhood environment	No influence	1096	133 ± 195	123 ± 186	250 ± 268	506 ± 431	432 ± 188**
	Some influence	408	126 ± 187	121 ± 180	227 ± 243	475 ± 396	408 ± 193
Opportunity to exercise	No influence	880	117 ± 176	120 ± 190	256 ± 273**	494 ± 430	428 ± 192
	Some influence	624	150 ± 212**	126 ± 176	227 ± 244	502 ± 410	422 ± 185
Physical health	No influence	1171	138 ± 197**	127 ± 189	251 ± 262**	516 ± 427**	426 ± 189
	Some influence	333	105 ± 173	106 ± 166	218 ± 260	430 ± 395	423 ± 190
Mental health	No influence	1087	133 ± 190	129 ± 190**	259 ± 263**	521 ± 425**	418 ± 184
	Some influence	417	127 ± 198	106 ± 169	202 ± 252	435 ± 405	445 ± 203**

All values are reported as mean ± SD. * Indicates significant difference ($p < 0.05$) between some influence and no influence for each factor at a given PA intensity. ** Indicates significant difference ($p<0.01$) between some influence and no influence for each factor at a given PA intensity within each level. *Abbreviations*: MVPA (moderate to vigorous PA).

3.5 Discussion

A potential consequence of physical distancing and prolonged self-isolation may imply a radical change in lifestyle behaviours, poor lifestyle practices such as a reduction in PA, an increase in sedentary behaviour and energy consumption and a decline in mental well-being, all of which increase the risk of negative health outcomes and the development of chronic health conditions. Results from the present study relate to data obtained during New Zealand's initial L4 lockdown in March 2020 and the lesser L2 restrictions in May 2020. These results indicate that females in New Zealand participated in higher levels of PA during L4 lockdown compared to L2 restrictions and pre COVID-19 (i.e. February 2020). Our findings demonstrate that PA levels (vigorous and moderate PA, walking and total MVPA) were significantly higher at L4 when compared to L2. Despite participation across all PA intensities increasing during L4, sitting time was also significantly higher when compared to L2 (449 ± 169 vs 426 ± 189 $min \cdot wk^{-1}$). Although the present study depicts an increase in PA during L4 lockdown, findings within the literature are heterogenous (Ernstsen & Havnen, 2021; Lesser & Nienhuis, 2020). Data collected in individual countries and in previously active individuals have demonstrated a significant decrease in PA (up to 53% reduction) and an increase in sedentary behaviour during the COVID-19 confinement strategies (Ammar et al., 2020; Barkley et al., 2020; Castañeda-Babarro et al., 2020; Cheval et al., 2021; Deschasaux-Tanguy et al., 2021; Fearnbach et al., 2021; Giustino et al., 2020; Luciano et al., 2020; Meyer et al., 2020; Stanton et al., 2020).

New Zealand literature shows a similar trend for PA levels during the initial COVID-19 lockdown. Hargreaves and colleagues (2021) showed a reduction in vigorous and moderate intensity and total PA during L4 when compared to pre COVID-19. However, despite this reduction, on average the participants were still exceeding the recommended PA guidelines (Ministry of Health, 2020). These findings were somewhat mirrored by Meiring and colleagues (2021) who also found that only 50% of their 196 participants maintained their pre COVID-19 PA levels during L4 lockdown. In contrast, a large Spanish study with 2,741 participants (51.8% females) concluded that PA initially decreased during the first week of restrictions and gradually increased from week two onwards as individuals adjusted to the restrictions (López-Bueno et al., 2020). Similarly, a Canadian study comprised predominantly of females (90.2%)

reported a sharp decline across all PA intensities immediately following the pandemic announcement, however, PA levels returned to pre pandemic levels six weeks later (Di Sebastiano et al., 2020). When comparing our data to these international findings, it is possible that timing of survey distribution may have been a contributing factor to our higher reported PA levels at L4. Survey 1 was available for completion between the 10-29th of April 2020, over 2 weeks after the enforcement of L4 lockdown. At this point, our participants may have already established new routines and adjusted to the lifestyle restrictions and as a result increased their PA levels. Similarly, Survey 2 was available from 5-18th June 2020, over 3 weeks after easing into L2 restrictions, which could mean our participants had again adjusted their behaviours to accommodate commuting to work, social responsibilities and resuming 'normal' routines resulting in lower PA levels comparative to L4.

Participants in our study were sufficiently active according to the New Zealand PA guidelines (Ministry of Health, 2020). The percentage of our participants meeting the PA guidelines was 79.4% pre COVID-19, 94.1% at L4 lockdown and 85% at L2 restrictions; all which exceed the 49% of New Zealand adults reported in the New Zealand Health Survey that achieved the PA guidelines during non-pandemic situations. Our findings are consistent with other New Zealand data (Hargreaves et al., 2021; Meiring et al., 2021) and appear to be contrary to what has been reported overseas (Bourdas & Zacharakis, 2020; Füzéki et al., 2021; Martínez-de-Quel et al., 2021). A probable explanation for these findings could be due to the different rules around outside exercise during lockdowns. The New Zealand Government's COVID-19 containment strategy allowed individuals to participate in daily physical activities or exercise and placed no limitations on how often or for how long individuals could leave their homes to participate in PA as long as they remained within their local areas. In contrast, in many European countries, time outside the house to exercise was strictly limited (e.g. only once per day for no more than one hour) (Government of United Kingdom., 2020) or was completely forbidden (Zaccagni et al., 2021). This freedom offered to New Zealanders meant that individuals were able to choose the timing, frequency, duration, and to some extent the type of their PA or exercise, all which may have contributed to their ability to achieve the recommended PA guidelines. It is both interesting and important to note that, although PA decreased across all intensities during L2 restrictions in comparison to L4 lockdown, the majority of the participants were still exceeding the recommended PA guidelines. The unique approach of the New Zealand Government in relation to movement restrictions and its encouragement to remain physically active during all levels of restrictions may have contributed to the increase in PA reported in our study. This despite some traditional methods of PA for many being unavailable such as gyms, team sports and group exercise.

Under pre COVID-19 conditions, lack of time, childcare and employment responsibilities have been some of the most commonly reported barriers to PA participation among females in many countries (Grant et al., 2007; Hoare et al., 2017; Moreno & Johnston, 2014; Sport New Zealand, 2016). The COVID-19 pandemic has drastically altered all aspects of our work and home lives, frequently blurring the distinction between the two for prolonged period of time. Many workplaces quickly transitioned their employees to work from home (WFH) in response to the government mandated physical containment strategies (Galanti et al., 2021; Savić, 2020). Normal daily routines were disrupted and opportunities for regular PA that would normally form part of an individual’s work routine may have been reduced, e.g. walking during the commute to work or during lunch and between meeting locations in the office (Michie et al., 2020; Xiao et al., 2021). Our results show that time available, working situation and MH were the predominant factors that influenced PA participation during L4 lockdown and L2 restrictions. Despite the enforced restrictions during L4, our participants were more active at this time than when they returned to the “new normal” at L2. Time available for PA had no influence on any PA intensity at L4, but did influence vigorous and moderate PA, walking and total MVPA at L2. At L2, participants for whom time available had no influence on PA participation appeared to perform more PA across all intensities (except sitting) than participants who suggested that time available did influence on PA participation. Similarly, participants whose working situation had no influence on PA at L4 and L2 completed more moderate PA, walking and MVPA compared to participants whose working situation had some influence on PA. A probable explanation for higher PA levels in those whose working situation did not influence PA participation could be that, as our population was already highly physically active and likely had established PA routines, the disruptions in working situation likely did not impact their abilities or intention to participate in PA. Additionally, although there was no access to recreational centres, or sport, gym and swimming facilities during L4 lockdown, WFH provided its own unique opportunities to “escape” the home and “get outside” for permitted activities (Hargreaves et al., 2021) and to participate in alternative avenues of PA such as online exercise classes, home workouts (e.g. yoga) and the ability to utilise local outdoor facilities (e.g. parks, fields). Previous research with females, has indicate that when compared to males, females are more likely to exercise regularly in a home-setting environment and practice a variety of activities e.g. yoga, Pilates and circuit workouts including weight training (Li et al., 2017; Markland & Hardy, 1993). Females are also more likely to undertake higher levels of non-exercise associated thermogenesis such as housework and cleaning activities/chores (e.g. washing, gardening and vacuuming) than males (Kaur & Sharma, 2020) which, although is not structured exercise, does contribute to daily PA. WFH allowed schedule flexibility and eliminated commuting time, and may have allowed employees to individualise their work-life balance. These changes may have promoted the adoption of a healthier lifestyle including regular PA breaks, a benefit that can be seen for both physical and MH (Xiao et al., 2021). An alternative explanation for the reduction in PA at L2 and the lower levels of PA seen in those individuals whose time available and working situation had some influence on PA participation could be the return to “normal” and the reversal of the COVID-19 lifestyle changes (e.g. changes in employment status or work place location, childcare responsibilities and the return to the daily commute to and from work) that promoted PA during L4. These theories are supported by findings from Hargreaves et al. (2021) who found that 57% of their participants reported less time available for PA at L2 when compared to L4.

Our results show that at L4, weather did not influence time spent in moderate PA, walking and MVPA. During L2, participants for whom the weather did not influence their PA participation performed more vigorous and moderate PA, walking and MVPA than participants for whom the weather did influence their PA levels. It is possible that the summer-like weather experienced in many parts of New Zealand during L4 lockdown (Campbell, 2020) enabled a continuation of summer activities. In contrast, L2 restrictions occurred during the New Zealand winter, where less favourable weather conditions and temperature may have limited PA participation for some individuals (Hargreaves et al., 2021). Physical environments such as proximity to walking trails, parks, beaches and PA infrastructure promote and encourage PA participation (Duncan & Mummery, 2005). It is therefore interesting to note that participants in the current study for whom the neighbourhood environment had some influence on walking at L4, participated in more total minutes when compared to participants who stated that the neighbourhood environment did not influence walking. It is possible that with the closure of other PA infrastructure (e.g. gyms, organised sport) some participants took up walking as an alternative form of PA. Overall, our results demonstrate a constellation of interconnected factors that influenced how active New Zealand females were during New Zealand's COVID-19 containment strategy. Further research is needed in this area to broaden our understanding of how these factors interact and how they may be key drivers for behavioural and lifestyle change with regards to PA participation.

The restriction measures implemented worldwide to counteract the spread of COVID-19 have had an undeniable negative impact on psychological well-being. Continuously evolving research in this area has illustrated an increased incidence of pandemic-related psychological distress and morbidity (Gómez-Salgado et al., 2020; Smith et al., 2020). The higher incidence of stress- and anxiety-related disorders is presumably pandemic-related (i.e. the perception of fear associated with either oneself or a close family member contracting the virus and uncertainty concerning the future) (Troyer et al., 2020) and coupled with pandemic-related changes such as increased physical inactivity, sedentary behaviour and high energy consumption (Ozdemir et al., 2020). A major finding of our study was the apparent dose-dependent relationship between PA levels and mental well-being scores. Indeed, well-being scores (WHO-5) were on average 23.5 and 16.6 points higher at L4 and L2, respectively, in participants performing higher levels of PA compared to those performing lower levels of PA based on their IPAQ classification. Parallel to this we found lower depression, anxiety and stress scores (DASS-9) in those individuals performing higher levels of PA when compared to those doing less.

These findings align with research from both before (Rebar et al., 2015) and during (Meyer et al., 2020) the COVID-19 pandemic, which exemplify the importance of regular PA on overall positive mental well-being, a relationship that is indisputable in the field of modern medicine. A recent study by Carriedo et al. (2020) demonstrated that older adults who achieved the WHO PA guidelines during COVID-19 restrictions had lower depressive symptoms, higher resilience and overall better mental well-being than those who did not achieve the PA guidelines. Prolonged reductions in regular movement can give rise to a myriad of negative health outcomes (Wilke et al., 2021). According to Stubbs et al. (2017), who analysed data from the World Health Survey, individuals with low PA levels (vs. high PA) had an odds ratio of 1.32 for anxiety. A meta-analysis grouping the results from 49 prospective studies (median proportion of females being 53%) found individuals (youth, adults and elderly) with low PA levels have an increased incidence of developing depressive symptoms or a depression diagnosis (Schuch et al., 2018). Further, a study in the UK of 902 adults (63.8% female) found a strong negative association between self-reported moderate to vigorous PA and negative MH during the COVID-19 confinement strategies (Jacob et al., 2020). Similarly, a Brazilian study of 1853 individuals (59.9% female) found a greater presence of the symptoms of moderate/severe depression and anxiety in those with low PA levels (Puccinelli et al., 2021). In line with these results, a study consisting of roughly 1.2 million participants concluded that individuals who exercised regularly (e.g. participated in running, golf, gardening, or walking) exhibited reduced days (43.2%) of poor MH in the previous month compared to those who did not exercise frequently (Chekroud et al., 2018). This positive relationship between PA and mental well-being also held true after adjusting for age, gender, race, income and modality of exercise (Chekroud et al., 2018). Therefore, regular PA does not only positively influence psychological well-being but is considered to be protective against the development of mental disorders (van Minnen et al., 2010), while also enhancing self-esteem and sense of well-being (Maugeri et al., 2020).

When considering MH as a factor that influences PA participation, our findings suggest that participants whose MH had no influence on PA were performing higher levels of PA than participants whose MH had some influence on PA levels. A potential explanation for this could be that individuals who are in good MH may not participate in exercise specifically to improve or maintain their MH, but may instead participate for pure enjoyment, physical health and training purposes (Wankel, 1993). Conversely, individuals who have poorer MH typically engage in low levels of PA and may have poor adherence to PA interventions. This behaviour may have been heightened due to the unfamiliarity and uncertainty of the COVID-19 pandemic. However, it is important to note that overall, the MH scores seen in our results were within the normal range and are better when compared to research conducted internationally (Fiorillo et al., 2020; Wang et al., 2020). Therefore, our findings add to the growing body of evidence that emphasises the importance of regular PA on supporting positive mental well-being, particularly during a global pandemic such as COVID-19. Pandemics such as COVID-19 are in themselves associated with negative impacts on mental well-being and when combined with sedentary behaviour and physical inactivity, may lead to compounding detrimental effects on mental well-being. Importantly, these findings highlight the fundamental need for enabling and encouraging individuals to continue engagement in regular PA during pandemics and periods of social isolation or physical containment to support mental well-being.

There are several strengths to note in this study. The use of validated questionnaires such as WHO-5, DASS-9 and IPAQ-SF provide good validity and reliability to our results. All three of these questionnaires are widely utilised in the literature that has investigated PA levels and mental well-being. The research encompassed a large sample size, enabling us to obtain data with a wide age and geographical spread within New Zealand. Administering the surveys during L4 lockdown and L2 restrictions enabled us to capture individuals' experiences as they occurred rather than relying on retrospective recall.

This study also has limitations that must be acknowledged. Baseline data for IPAQ determined PA and MH scores were not collected prior to restriction enforcement i.e. pre COVID-19. This meant that we were unable to compare the measures at L4 and L2 relative to normal, pre COVID life. The use of convenience and snowball sampling as a recruitment method meant that our findings potentially were limited to a subgroup of the population and not representative of the New Zealand population as a whole. Similarly, the voluntary nature of data collection for this PA related study may have been biased toward participants who were already adequately physically active and may have swayed our results. The population sample was predominantly New Zealand European and thus, it would be useful for future research to have a more diverse sample, including more participants of Māori, Pacific, and Asian ethnicities. The use of self-reported questionnaires may subject our results to a potential recall bias as we are relying on participants memory, honesty, and interpretation of the questions.

3.6 Conclusion

In conclusion, our findings emphasise the undeniable positive relationship between PA and mental well-being in females and the important role PA plays during a global pandemic or other periods of prolonged social isolation. As hypothesised, we were able to identify that females who participated in more PA during both L4 lockdown and L2 restrictions had better MH scores than those who were performing less PA during these times. This relationship was found to be dose-dependent where the more PA an individual participated in the greater their MH scores. We also found that time available, working situation and MH were the major factors that influenced PA participation at both L4 lockdown and L2 restrictions in females. Unexpectedly, we found that despite the closure of typical avenues for PA such as recreational centres, gyms and sporting facilities, our participants were participating in more moderate and vigorous PA, walking and MVPA at L4 lockdown than they were during L2 restrictions. These findings add substantial value to the growing body of evidence supporting the necessity to include PA promotion and recommendations to policy, not only during periods of physical containment and social isolation but also upon the return to normality after such periods. As the world continues to adapt and move toward our "new normal" of the COVID-19 pandemic, these findings should be considered by governments, employers and individuals when moving forward with a new hybrid style of working to promote better mental and physical health and well-being.

3.7 Acknowledgments

We would like to thank all of the females who participated and completed all aspects of the study, contributing to this research.

3.8 Conflicts of interest

The authors declare no conflict of interest

Chapter 4: Conclusion and Recommendations

4.1 Research Outcomes

The aim of the present study was to understand how New Zealand's COVID-19 containment strategies affected the PA levels and mental well-being of adult females in New Zealand and to identify key factors that influenced PA participation during L4 lockdown and L2 restrictions. We found that there was a relationship between PA levels and mental well-being of females, whereby females who performed the most PA had better mental well-being and the lowest levels of depression, stress and anxiety across both alert levels (L4 and L2). Contrary to similar research overseas, but in line with local data, we found that our participants were in fact undertaking greater levels of vigorous and moderate PA, total MVPA and walking during L4 than at L2. We attributed this increase in PA during L4 lockdown to the New Zealand Government's containment strategy, allowing individuals to continue to participate in PA outside their homes, with the encouragement to do so. Reductions in daily commuting time during this period and the shift to WFH may have provided additional opportunities to increase habitual PA. We were also able to identify that time available and working situation were two of the major factors that influenced PA participation in New Zealand females both during L4 and L2. Future research is needed in this area to explore how and why these factors influenced PA participation and the interrelationships underpinning these changes. Our findings reaffirmed the positive impact PA has on an individual's mental well-being and recognises the importance of not only continual encouragement to engage in regular PA during a pandemic or times of social isolation and physical containment but also once these restrictions are lifted during the return to normality.

4.2 Strengths and Limitations

4.2.1 Strengths

There are several strengths to note in this study. First and foremost, our study describes how PA levels and mental well-being scores varied under L4 lockdown and L2 restrictions. Secondly, it supports the previously defined dose-dependent relationship between PA and mental well-being. In addition, both Survey 1 and 2 used validated and widely adopted questionnaires; WHO-5, DASS-9 and IPAQ-SF, suggesting that our results are valid and reliable. A large sample size was attained, allowing a wide age and geographical spread throughout New Zealand, strengthening our confidence in our findings. The surveys were administered at the time of the L4 lockdown and L2 restrictions, allowing the researchers to grasp an *in situ* insight of what individuals were experiencing at the time rather than retrospectively.

4.2.2 Limitations

A major limitation to our study was that we did not obtain data prior to the COVID-19 containment strategies. This meant that we did not have a baseline of PA levels and MH scores under normal circumstance (i.e. pre COVID-19). Our recruitment process relied on convenience and snowball sampling methods. This phenomenon is prone to sampling bias, where individuals with similar interests, traits or characteristics will participate in the research and thus could limit our findings to only a small subgroup of the population. Similarly, the data was collected via a voluntary online survey, which could also result in selection bias e.g. the voluntary nature of the participants could have led those who were already sufficiently physically active to partake in the survey. Our population sample is predominantly New Zealand European (83.4%). Both of these biases may have influenced our findings as they may not be reflective of New Zealand's general population during the initial L4 lockdown (March 2020) and L2 restrictions (May 2020). Future research should aim to recruit a more representative sample of the New Zealand population as a whole. Additionally, all data was collected via self-reported questionnaires, which assumes a thorough understanding of the questions along with sufficient memory recall in order to provide honest and accurate responses. Utilising self-reported questionnaires also meant that we were relying on an individual's interpretation of the type, mode and intensity of PA they were participating in. It is also important to acknowledge that the questions asked within the two surveys were different e.g. some questions were asked retrospectively which is known to have limited validity and recall accuracy.

4.3 Practical Recommendations

Based on our findings, the author recommends the following;

1. The results from the present study add compelling evidence to the growing body of literature supporting the positive effects of regular PA on MH and well-being, a relationship that we have found holds true even during periods of social isolation and physical containment. Based on our findings we suggest females follow the New Zealand PA guidelines of at least 150 minutes of moderate or 75 minutes of vigorous PA per week, to gain the associated benefits of PA on MH and well-being. We also encourage females who are participating in low levels of PA or who are sedentary to increase the duration, frequency and intensity of their current PA habits, as engaging in any PA could be protective against psychological distress. For females who are already highly active and are exceeding the New Zealand PA guidelines, maintaining their regular PA patterns has the greatest benefit to MH and well-being.

2. To aid female New Zealanders in reaching these PA recommendations we suggest government and public health advisers disseminate our findings and encourage PA through various platforms such as the news, radio, television, social and print media and digital promotion, as well as more specific and targeted dissemination (e.g. such as culturally appropriate promotion for ethnic minorities such as Māori and Pacific peoples). During the COVID-19 pandemic, screen time (60% of males and 66% of females) and internet usage (63% of males and 69% of females) was found to increase (Colley et al., 2020). Thus, by using digital marketing and promotion strategies in the event that a pandemic was to arise again in the future, our results would be made widely available to the general population. In addition, we recommend the promotion of digitally based PA, such as online fitness classes and PA smart phone applications during a time where traditional methods of PA become unavailable. It is also worth noting that our recommendations could be used under normal non-pandemic conditions as a relatively cheap and time efficient option to increase participation in individuals who are time poor or are looking for cost-effective PA alternatives.

3. We recommend businesses that continue to adopt a flexible working environment and enable employees to WFH for extended periods of time, to consider implementing recommendations or guidelines that promote regular participation in PA to aid positive mental well-being, and to reduce stress and anxiety. This can include regular virtual sessions allowing employees to take part in group exercise or activities, PA incentives and increasing the visibility of PA promoting material specific to the WFH environment (e.g. get moving at your desk, move every hour or take walking conference calls or meetings).

4. Our results highlighted a reduction in PA levels when moving from L4 lockdown to L2 restrictions, when females returned to their 'normal' daily routines, increased social commitments and resumed their daily commutes to work. These findings suggest that the continued promotion of PA, via methods mentioned in point number two should be implemented not only during periods of social isolation and physical containment, but also once these restrictions are lifted in the effort to maintain PA levels.

5. We identified time available, working situation and mental health were the main factors that influenced females' PA participation during New Zealand's COVID-19 L4 lockdown and L2 restrictions. Governments and public health advisers should be aware of such factors when designing promotional campaigns for the encouragement of PA during these periods and should endeavour to include strategies for how individuals can overcome barriers relating to time available, working situation and MH and disseminate them appropriately i.e. recommendations should be different for shift workers vs those who work 9-5pm and different for those who are labourers vs office workers.

Based on the above recommendations our findings have important implications for governments, policy makers and businesses that may be able to use these suggestions to adapt and refine their guidelines around PA promotion. These recommendations apply equally to times of social isolation and physical containment as they do to normal life and may help to improve the MH and well-being of all New Zealanders, not just females.

4.4 Future Research

Although our research has added to the rapidly expanding body of evidence on the positive effects of PA on MH and well-being during the initial L4 lockdown and L2 restrictions, there are still a number of questions left unanswered. Firstly, we were able to identify that time available, working situation and MH were the greatest contributing factors that influenced New Zealand females' participation in PA during L4 lockdown and L2 restrictions. However, we still do not know in which direction these factors influenced their PA participation (e.g. we know time availability had some influence on PA participation for our participants but we do not know in what direction). Future research should focus on identifying how and why these factors influenced PA participation and the interrelationship underpinning these changes. New Zealand is a small and isolated country with a population of just over five million people including a wide range of ethnicities and minority groups such as indigenous Māori, Asians and non-Māori Pacific Islanders. In our study we were unable to obtain sufficient data from many of these smaller ethnic groups meaning that, at present we are unaware if the COVID-19 pandemic and its resultant containment strategies had any influence on the PA levels and mental well-being of these minority groups. The absence of pre COVID-19 baseline data in our study made it difficult for us to make strong linkages between or to determine difference that the pandemic and its containment strategies had on our participants PA participation and mental well-being. Future research should look to quantify the pre, -during- and post COVID-19 link. At present the COVID-19 pandemic is very dynamic and is continuing to evolve and develop. This means our work and home environments are highly reactive and currently we do not know the long term implications of this. Future research is therefore needed to understand the ongoing impact of COVID-19 on PA participation and mental health post the initial response. As we continue to adapt to life as the COVID-19 pandemic plays out, longitudinal studies are needed to continue to explore and understand the relationship between PA and mental well-being.

4.5 Authors Statement

During the time of writing this thesis, there were a large degree of changes worldwide including the implementation of high vaccine rates, a number of different variants emerging and a shift in New Zealand's containment strategies; from one of elimination to one of living with the virus, but reducing its spread. However, the primary focus of this research was to address the effects of the initial COVID-19 L4 lockdown (March 2020) and L2 restrictions (May 2020) on PA and mental well-being in adult females.

Appendices

Appendix A: New Zealand COVID-19 Alert Levels Summary

New Zealand COVID-19 **Alert Levels Summary**

Unite against COVID-19

- The Alert Levels are determined by the Government and specify the public health and social measures to be taken in the fight against COVID-19. Further guidance is available on the **Covid19.govt.nz** website.
- The measures may be updated based on new scientific knowledge about COVID-19, information about the effectiveness of control measures in New Zealand and overseas, or the application of Alert Levels at different times (e.g. the application may be different depending on if New Zealand is moving down or up Alert Levels).
- Different parts of the country may be at different Alert Levels. We can move up and down Alert Levels.
- Services including supermarkets, health services, emergency services, utilities and goods transport will continue to operate at any level. Employers in those sectors must continue to meet health and safety obligations.
- Restrictions are cumulative (e.g. at Alert Level 4, all restrictions from Alert Levels 1, 2 and 3 apply).

Updated 14 December 2020

ELIMINATION STRATEGY – New Zealand is working together to eliminate COVID-19

Alert Level	Risk Assessment	Range of Measures (can be applied locally or nationally)	
Level 4 – Lockdown Likely the disease is not contained	• Sustained and intensive community transmission is occurring. • Widespread outbreaks.	• People instructed to stay at home in their bubble other than for essential personal movement. • Safe recreational activity is allowed in local area. • Travel is severely limited. • All gatherings cancelled and all public venues closed.	• Businesses closed except for essential services (e.g. supermarkets, pharmacies, clinics, petrol stations) and lifeline utilities. • Educational facilities closed. • Rationing of supplies and requisitioning of facilities possible. • Reprioritisation of healthcare services.
Level 3 – Restrict High risk the disease is not contained	• Multiple cases of community transmission occurring. • Multiple active clusters in multiple regions.	• People instructed to stay home in their bubble other than for essential personal movement – including to go to work, school if they have to, or for local recreation. • Physical distancing of two metres outside home, or one metre in controlled environments like schools and workplaces. • People must stay within their immediate household bubble, but can expand this to reconnect with close family / whānau, or bring in caregivers, or support isolated people. This extended bubble should remain exclusive. • Schools (years 1 to 10) and Early Childhood Education centres can safely open, but will have limited capacity. Children should learn at home if possible. • People must work from home unless that is not possible. • Businesses cannot offer services that involve close personal contact, unless it is a supermarket, primary produce retailer, pharmacy, petrol station or hardware store providing goods to trade customers, or it is an emergency or critical situation.	• Other businesses can open premises, but cannot physically interact with customers. • Low risk local recreation activities are allowed. • Public venues are closed (e.g. libraries, museums, cinemas, food courts, gyms, pools, playgrounds, markets). • Gatherings of up to 10 people are allowed but only for wedding services, funerals and tangihanga. Physical distancing and public health measures must be maintained. • Healthcare services use virtual, non-contact consultations where possible. • Inter-regional travel is highly limited (e.g. for critical workers, with limited exemptions for others). • People at high risk of severe illness (older people and those with existing medical conditions) are encouraged to stay at home where possible, and take additional precautions when leaving home. They may choose to work.
Level 2 – Reduce The disease is contained, but the risk of community transmission remains	• Limited community transmission could be occurring. • Active clusters in more than one region.	• People can reconnect with friends and family, and socialise in groups of up to 100, go shopping, or travel domestically, if following public health guidance. • Keep physical distancing of two metres from people you don't know when out in public or in retail stores. Keep one metre physical distancing in controlled environments like workplaces, where practicable. • No more than 100 people at gatherings, including weddings, birthdays and funerals and tangihanga. • Businesses can open to the public if following public health guidance including physical distancing and record keeping. Alternative ways of working encouraged where possible. • Hospitality businesses must keep groups of customers separated, seated, and served by a single person. Maximum of 100 people at a time. • Sport and recreation activities are allowed, subject to conditions on gatherings, record keeping, and – where practical – physical distancing. • Public venues such as museums, libraries and pools can open if they comply with public	health measures and ensure 1 metre physical distancing and record keeping. • Event facilities, including cinemas, stadiums, concert venues and casinos can have more than 100 people at a time, provided that there are no more than 100 in a defined space, and the groups do not mix. • Health and disability care services operate as normally as possible. • It is safe to send your children to schools, early learning services and tertiary education. There will be appropriate measures in place. • People at higher-risk of severe illness from COVID-19 (e.g. those with underlying medical conditions, especially if not well-controlled, and seniors) are encouraged to take additional precautions when leaving home. They may work, if they agree with their employer that they can do so safely. • Face coverings required on public transport and aircraft (but not inter-island ferries) – school buses and children under 12 are exempt along with passengers in taxis or ride share services and people with disabilities or mental health conditions.
Level 1 – Prepare The disease is contained in New Zealand	• COVID-19 is uncontrolled overseas. • Sporadic imported cases. • Isolated local transmission could be occurring in New Zealand.	• Border entry measures to minimise risk of importing COVID-19 cases. • Intensive testing for COVID-19. • Rapid contact tracing of any positive case. • Self-isolation and quarantine required. • Schools and workplaces open, and must operate safely. • No restrictions on personal movement but people are encouraged to maintain a record of where they have been. • No restrictions on gatherings but organisers encouraged to maintain records to enable contact tracing.	• Stay home if you're sick, report flu-like symptoms. • Wash and dry hands, cough into elbow, don't touch your face. • No restrictions on domestic transport – avoid public transport or travel if sick. • No restrictions on workplaces or services but they are encouraged to maintain records to enable contact tracing. • QR codes issued by the NZ Government must be displayed in workplaces and on public transport to enable use of the NZ COVID Tracer App for contact tracing.

Appendix B: Supplementary tables

Supplementary Table 1. Summary of studies examining the relationships between PA and MH and well-being (original research)

Authors	Country	Study design	Sample	Aims	Measurement (Instruments)	Outcomes
Armstrong & Oomen-Early, (2009)	United States	Cross sectional	• 227 full-time undergraduate students aged 18-24 years • Mean age of 19.87 ± 1.3 years	• To determine if there was a significant difference between collegiate athletes vs non-athletes and female vs male college students, in regard to self-esteem, social connectedness and depression • To determine if gender and athlete status interacted with other variables (e.g., exercise, sleep, self-esteem and social connectedness) and if these were predictors of depression	• Self-Reported PA Questionnaires • CSE-D • The Rosenberg Self-Esteem Scale • SCS- Revised	• High prevalence of depression among the college cohort in this study • 33.5% had clinically significant levels of depression • Athletes were found to have significantly lower levels of depression than non-athletes • Athlete status was not a significant predictor of depression when comparted to other variables such as gender, sleep and self-esteem • Female college students had higher levels of depression than males • Higher depression levels were associated with lower self-esteem and social connectedness
Balchin et al., (2016)	South Africa	Three-armed prospective randomised	• 30 moderately depressed males aged 18-42 years	• To identify the mechanisms behind improvements in	• MDI • HAM-D • MADRS	• High and moderate intensity exercise were associated with a positive

		control pilot study	• Mean age of 25.4 years • Randomly assigned into 3 groups: High (n = 9), moderate (n = 11) and control (n = 10) • Participated in a 6-week programme comprising of exercise 3 days/week for one hour. High group exercised at 70–75% of HR reserve, the moderate at 45–50% and control group kept HR below 120 bpm	depression as a result of exercise, related to the endorphin release of the PANIC system, in relation to high and moderate intensity exercise	• ANPS-2.4 • Suunto t6d watch with chest strap • Ergometer • Borg Rating of Perceived Exertion • PSPO • Blood samples before and after exercise	impact on moderate depression • Beta endorphin values did not increase significantly during exercise • The PANIC system was not confirmed as the mechanism underlying depression
Bixby et al., (2001)	United States	Cross sectional	• 27 healthy non-smokers (n =14 females) • Mean age of 23.1 ± 3.8 years	• To determine whether affective outcomes associated with low and high intensities of continuous steady-state exercise are achieved via differing temporal patterns of affective change	• EEG • EOG • ECG • VAMS • PANAS • Cycle ergometer to determine VO_{2max}	• The affective state following exercise improved with reference to baseline regardless of intensity • The path to the outcome of affective response during exercise varies with intensity • Low intensity is consistent with a maintenance type model where high-intensity is consistent with a rebound model.

Brown et al., (2000)	Australia	Longitudinal	• 14,502 young women (aged 18-23 years); 13,609 middle-age women; (45-50 years); 11,421 older women (ages 70-75 years). • Participants from all 3 groups were from the Australian Longitudinal Study on Women's Health	• To establish a healthy level of PA for young, middle-age and older women by exploring cross-sectional relationships between PA score with mental health, well-being, selected symptoms (constipation, tiredness and backpain) and medical conditions	• Age-specific questionnaires, each with more than 250 items. Included questions on sociodemographic characteristics, employment status, education status, health behaviours, weight etc. • SF-36 • Self-reported PA to determine PA score	• Significant relationships between PA scores and SF-36 in all three groups. Higher levels of PA were associated with better health status measured by SF-36 • A curvilinear relationship between mental health, PA scores and vitality was apparent in all groups • A PA score of about 15 (approximates to moderate intensity PA on most days of the week) • Women in all groups who reported low to moderate PA had a lower OR for a variety of symptoms (tiredness, constipation and back pain) and conditions compared to sedentary women e.g. middle-age women and tiredness = 0.70 (0.63-0.78) • The likelihood of older women having osteoporosis and hypertension was lower in women who reported moderate to high PA

						• No threshold of PA at which health benefits increased. • Findings suggest low to moderate levels of PA are associated with a range of health benefits for women of all ages
Chang et al., (2019)	China	Population based cohort study	• Data for the present study was obtained from the Chinese Leisure Study conducted in February and March 2014 through multistage stratified random sampling • 663 Chinese citizens aged 15 years and older • This study only included participants from the following cities: Beijing, Shanghai, Dalian, Guangzhou, Changsha, Chengdu and Xi'an	• To examine the positive effects of leisure settings on leisure satisfaction • To examine how leisure satisfaction serves as a mediating factor in the relationship between leisure settings (indoor or outdoor leisure), SWB and depression symptoms in Chinese residents	• Self-reported leisure activities questionnaire • A six-item scale that encompassed the 6 aspects of perceived leisure satisfaction (social, psychological, physical, relaxation, educational and aesthetic) was used to measure leisure satisfaction. • Diener's five item SWB scale • CES-D	• Outdoor recreation, leisure in nature and SWB are link to leisure satisfaction. Engaging in outdoor recreation and leisure in nature is suggested to improve SWB • Leisure in nature was the only setting that was positively associated with SWB and depression • Individuals with higher levels of leisure satisfaction reported fewer depressive symptoms and greater SWB • Results highlight the advantages of urban green spaces
Cox et al., (2004)	United States	Cross sectional	• 24 active women aged 18-45 years	• To study the effect of an acute bout of aerobic exercise on state anxiety	• Spielbergers STAI	• A decline in state anxiety from baseline to 5 min postexercise was

				of women while controlling for iron deficiency	• Borg Rating of Perceived Exertion • Submaximal exercise testing using a motorised treadmill • HR measured via monitors • Blood samples	observed for the control and the 60% VO_2 max conditions but not for the 80%VO_{2max} condition • A relatively high level of exercise intensity yields the best result in terms of reducing state anxiety
Daley & Welch (2004)	United Kingdom	Cross sectional	• 23 active students (n = 11 females) • Mean age of 22.4 ± 1.3 years • Participated in two cycle ergometer exercise conditions: 15 minutes and 30 minutes	• Compare the effects of the standard health recommended exercise duration of 30 minutes with a shorter 15-minute bout of exercise on affect scores during and after exercise	• Subjective Exercise Experience Scale • HR measured via monitors • Borg Rating of Perceived Exertion	• No significant differences between the 15-minute and 30-minute exercise bouts • Participants experienced a positive affective response after short bouts of acute exercise • As positive well-being scores increased, psychological distress and fatigue decreased simultaneously • 15-30 minutes of exercise are sufficient to produce increases in subjective experience scores in a recreationally fit population

Dishman et al., (2010)	United States	Randomised control trial	• 36 healthy male and female college students aged 18-35 years	• To determine if acute sessions of exercise repeated during 6 weeks of training would result in transient changes in vigour and fatigue.	• Aerobic testing via an incremental exercise test on a cycle ergometer to obtain VO_2 peak • POMS-SF	• Transient increases in the feelings of vigour and decreases in feelings of fatigue after each session of low or moderate intensity exercise • Chronic exercise training leads to improvements of feelings vigour and fatigue during preceding week • Reduced fatigue was only found following low intensity exercise, and only during the second and third session • Vigour is more sensitive to the effects of acute exercise than the feelings of fatigue among young people who report persistent fatigue
Farmer et al., (1988)	United states	Prospective longitudinal 8 year follow up to the first National Health and Nutrition Examination Survey	• 1497 adults aged 25-77 years	• To identify the relationship between self-reported PA and depressive symptoms	• CES-D • Self-reported PA	• The likelihood of developing depression in women who engaged in little or no recreational PA was twofold when compared to those who engaged in ‘moderate or ‘much’ activity • Recreational PA is an independent predictor of depressive symptoms at 8 year follow up

						• Physical inactivity may be a risk factor for depressive symptoms
Hamer et al., (2010)	United Kingdom	Longitudinal	• 3,920 adults • Mean age of • 51.0 ± 15.8 years • Participants are from the 2003 Scottish Health Survey	• To examine the association between recreational sedentary behaviour and mental health	• Self-reported TV time, PA and physical function • General Health Questionnaire • MCS-12	• Sedentary behaviour in leisure time is independently associated with poorer mental health scores
Hansen et al., (2001)	United States	Cross sectional	• 21 college students aged 20-26 years	• To examine the effect of a single bout of moderate exercise of increasing duration on mood states	• PAR-Q • Health and exercise history questionnaire • POMS • MC–SDS • Standardised physical fitness evaluation using the YMCA protocol to estimate VO_2 max	• 30 minutes of daily moderate PA accumulated in short bouts is sufficient to experience positive fitness and health benefits
Holstila et al., (2017)	Finland	Longitudinal	• 8960 participants aged 40-60 years (80% female)	• To examine the current and expected associations between changes in LTPA and the levels of physical and MH functioning	• SF-36	• Increased leisure time PA was associated with higher levels of physical functioning • Changes in PA were associated with MH functioning only to some extent • Vigorous PA is good for the maintenance of physical functioning, less

						so for mental health functioning
Kamimura et al., (2014)	United States	Longitudinal	• 299 females • Mean age of 42.9 years	• To examine the relationship between body esteem, motivation for exercise, depression and social support	• EMI-2 • BESAA- weight subscale • PHQ-9 • MOS-SS	• Gender specific interventions to promote PA and body image should be used in female free clinics • A myriad of PA motives should be used to increase the likelihood clients will adopt, sustain and enjoy exercise in their lifestyle
Lee & Robbins, (1998)	United States	Longitudinal	• 185 females aged 18-50 years in study 1 • Mean age of 24.2 years • 44 females from study 1 participated in study 2	• To add to existing literature on social connectedness and the feelings of anxiety and self-esteem.	Study 1: • SCS • SSQ-SF • CSES • STAI-AD Study 2: • GAS • STAI-AD • SSES • SIPI	Study 1: • Social Connectedness accounts for 16% of total variance in trait anxiety • Women with high levels of connectedness are less prone to anxiety in daily life. Whereas women with low connectedness are more likely to perceive life as more anxiety provoking Study 2: • Women with higher levels of social connectedness report higher levels of social identity. They also reported higher levels of social self-esteem

Martinsen et al., (1985)	Norway	Blocked randomised control trial	• 43 participants aged 17-60 years • Mean age of 40 years	• To assess the anti-depressive effects of systematic aerobic exercise in psychiatric patients in hospital	• BDI • CPRS • (depression subscale) • VO_{2max} using astrand indirect calorimetry	• BDI scores significantly higher in training group • Mean oxygen uptake significantly increased in the training group • Mean reductions in CPRS were larger in the training group • Patients with a small increase in VO_{2max} (<15%) in the training group demonstrated a similar anti-depressive effect to the control group • Patients with a moderate (15-30%) or large increase (>30%) in VO_{2max} uptake demonstrated larger anti-depressive effects • An aerobic training programme over 9 weeks has a substantial anti-depressive effect in hospitalised psychiatric patients up to 60 years of age
McMahon et al., (2017)	Europe	Cross sectional	• 11,072, adolescents (59% females) • Mean age 14.8 ± 0.84 years	• To examine physical activity, sport participation and	• WHO-5 • BDI-II • SAS • PACE +	• Moderate frequency of activity was positively correlated with well-being and negatively

				associations with well-being		correlated with anxiety and depressive symptoms • Regular PA and participation in sport independently contributed to greater well-being and lower levels of anxiety and depressive symptoms
Pietilä et al., (2015)	Finland	Cross sectional	• A random sample of 8000 Finns aged 15-74 years was drawn from the national population • register. • Of these, 3108 individuals participated	• To investigate the relationship between exposure to green spaces and self-perceived health in urban areas in Finland • To improve knowledge regarding the relationship between green spaces, PA and self-perceived health	• Measures of self-perceived health using 1-5 scale (1= poor, 5 = good) • Measures of PA using outdoor recreation visits within the past year (volume), estimating an annual frequency • Measure of green space via distance in kilometres from home to nearest park/forest and largest forest area	• Exposure to green areas is associated with self-perceived health. This relationship is most likely indirect
Rejeski et al., (1995)	United States	Empirical study	• 80 moderately fit females recruited from health and fitness classes at Wake Forest University • Mean age of 18.3 years	• To provide data on the moderating effects of dose of exercise on feeling states • To examine the influence of baseline psychological status and capture responses in	• Estimated VO_{2max} using Astrand Rhyming Bicycle Ergometer Test • PANAS • EFI • FS • RPE	• Mental health consequences of exercise in women are mediated by feeling states that occur during the activity. • No evidence for a dose-response between single bouts of aerobic exercise

				relation to an exercise stimulus		and feeling states 20 minutes later • Females who were more positive during exercise had the largest revitalisation scores after exercise • An individual's feelings toward exercise are important in understanding how PA influences psychological well-being
Södergren et al., (2008)	Sweden	Population based cohort study	• 3756 participants (1876 women) aged 25–64 years • Mean age 43.7 ± 11.3 years • A random sample of the adult Swedish population in 1999 were interviewed in a survey performed by Statistics Sweden. • Only participants from 1999 survey were included as that was the only year where 2 different questions regarding PA were assessed (exercise and total PA in all domains)	• To identify the most inactive individuals by assessing two dimensions of PA (exercise and total PA) • To investigate the correlation between exercise and total PA • To investigate the relationship between exercise, total PA and self-rated health.	• Self-reported PA questionnaire • Self-reported LTPA	• Exercise and total PA were independently associated with good self-rated health. • Individuals who exercised regularly and/or had a total PA of ≥ 6 hours/week had the highest odds of good self-rated health. • The correlation between exercise and total PA was low (gamma = 0.4, p = 0.02) • There was a significant relationship between higher levels of exercise, total PA and good self-rated health after adjusting confounding

						variables (gender, smoking and BMI)
Woo et al., (2009)	United States	Cross sectional	• 17 healthy female graduate students who were not aerobically trained • Mean age of 21 years	• To examine the impact of several different durations of steady-state exercise based on a theoretical multi-level measurement sensitive to valence and arousal of the affective state	• VO_{2max} via Bruce treadmill protocol. • POMS • TMD • EEG	• Psychological vigor and frontal EEG following 30 minutes of exercise were elevated compared to that following other exercise durations (15 and 45 minutes) and rest. • Findings support a dose-response relationship between exercise duration and affect (inverted 'U' relationship)

Abbreviations: ANPS-2.4 (Affective Neuroscience Personality Scales, version 2.4); BDI (Becks Depression Inventory); BDI-II (Becks Depression Inventory-second edition); BESAA (Body Esteem Scale for Adolescents and Adults-weight subscale); bpm (beats per minute); CES-D (The Center for Epidemiological Studies Depression Scale); CPRS (Comprehensive Psychopathological Rating Scale); CSES (Collective Self-Esteem Scale); ECG (electrocardiogram); EEG (electroencephalogram); EFI (Exercise Induced Feeling Inventory); EMI-2 (The Exercise Motivation Inventory); EOG (electro-oculogram); FS (Feeling Scale); GAS (Group Attitude Scale); HAM-D (Hamilton Rating Scale of Depression); HRQOL (Health-related quality of life); LTPA (leisure-time physical activity); MADRS (Montgomery-Asberg Depression Rating Scale); MC–SDS (Marlowe–Crowne Social Desirability Scale); MCS-12 (Mental Health Component Scale-12 item short form); MDI (Major Depression Inventory); MOS-SS (Medical Outcomes Study Social Support Survey); OR (odds ratio); PA (physical activity); PACE + (Patient-Centred Assessment and Counselling for Exercise Plus Nutrition); PANAS (Positive and Negative Affect Schedule); PAR-Q (The Physical Activity Readiness Questionnaire); PHQ-9 (Patient Health Questionnaire-9); POMS-SF (Profile of Mood States-Short Form); PSPO (Peak Sustained Power Output test); RPE (Rating of Perceived Exertion); SAS (Self-Rating Anxiety Scale); SCS (The social connectedness Scale); SF-36 (RAND 36-Item Health Survey Short form); SIPI (Social and Personal Identities Scale); SSES (State Self-Esteem Scale); SSQ-SF (Social Support Questionnaire – Short form); STAI (State-Trait Anxiety Inventory); STAI-AD (State Trait Anxiety Inventory- Adults); SWB (subjective well-being); TMD (Total Mood Disturbance); VAMS (Visual Analog Mood Scale); VO_{2max} (maximum volume of oxygen consumption); WHO-5 (World Health Organization Five Well-being Index).

Supplementary Table 2. Summary of studies examining the relationships between PA and MH and well-being (reviews and analyses)

Authors	Country	Study design	Sample	Aims	Measurement (Instruments)	Outcomes
Barton & Pretty, (2010)	United Kingdom	Multi study analysis	• 1252 participants recruited via 10 studies undertaken by the University of Essex (in the past 6 years)	• To assess the impact of green exercise on self-esteem and mood • To determine the most effective regime(s) for a dose of acute green exercise	• The Rosenberg Self-Esteem Scale	• Acute short-term exposures to facilitated green exercise improves both self-esteem and mood regardless of external factors such as age, gender, duration and intensity • Self-esteem and mood showed greatest changes for least duration (5 minutes). • Exposure to nature via green exercise can be considered a therapy with no obvious side effects • Those individuals that are currently physically inactive, sedentary or in poor mental health would gain health benefits if they were able to participate in regular short duration PA in green spaces.
Bize et al., (2007)	International	Systematic review	• Systematically searched Medline, Embase, CINAHL,	• To examine the relationship between PA levels and HRQL in	• HRQOL-4 • Telephone based PA questionnaire	• Cross sectional studies found that higher PA levels were regularly

			and PsycINFO databases for studies exploring HRQL in relation with PA. • A total of 14 studies were used for data analysis; 7 cross sectional; 2 cohort; 4 randomised controlled trials; 1 combination of cross sectional and longitudinal design • 230,649 healthy adults aged 15-65 years who have participated in studies related to PA	healthy adults from the general population under 65 years of age	• Paffenbarger PA questionnaire • SF-36 • Maximal treadmill exercise test • Self-reported LTPA • 3-day activity diaries • MAQ • WHOQOL-BREF • PWC bike ergometer test	associated with better HRQL scores • Higher PA levels were also associated with better physical functioning and vitality • Randomised control trials and cohort studies assessing the relationship between PA and HRQL found differences in HRQL scores dependent on PA levels, however this association was weak as studies lacked instrument validation and used inadequate randomisation procedures
Chan et al., (2018	International	Systematic review	• 2,241 adults across 38 original research articles • Studies were included if they had adult participants, one component of mood was recorded before and after exercising and if objective measures of exercise intensity were used	• To review the effects of exercise (intensity, duration, and modality) on mood improvements in adults • To provide a review of psychological and neurophysiological theories	• Various exercise modalities such as cycling, running, jogging, treadmill running, aerobic and anaerobic exercise, Tai-Chi, yoga, resistance training, strength training, low and moderate intensity walking and endurance training.	• Moderate intensity anaerobic exercise is associated with greater mood improvements. • Sessions of between 10 to 30 minutes are sufficient to improve mood • Anaerobic exercise is superior for mood improvements, whereas the relationship between aerobic exercise and

						mood needs further examination • The mechanisms underlying the positive effects of exercise on mood are not well understood
De Rezende et al., (2014)	International	Review	• Searched Medline, Embase), PsycINFO and Web of Science using keywords related to (sedentary behaviour and sitting time. • 893 articles • To be included articles had to be systematic review with/without meta-analysis that examined the relationship between sedentary behaviour and health outcomes	• To combine and synthesise the current evidence of the relationship between sedentary behaviour and health outcomes	N/A	• The evidence between sedentary behaviour and health outcomes is complex depending on the type of sedentary behaviour and age group • In children there is a strong relationship between TV viewing, screen time and obesity • Moderate evidence for blood pressure, total cholesterol, self-esteem, social behaviour problems, physical fitness and academic achievement (based on TV and screen time) • In adults, there was a strong relationship between sedentary behaviour and all-cause mortality and fatal and non-fatal CVD as well as metabolic syndrome based on TV viewing,

						screen time and sitting time • There was a strong relationship between sedentary behaviour and T2DM based on TV viewing • Inconclusive evidence for certain health outcomes in adults, adolescents and children
Janssen & LeBlanc, (2010)	International	Systematic review	• Searched Medline Embase, CINAHL PsycINFO, all evidence-based medicine reviews and SPORT-Discus • 86 studies • School aged children and youth aged 5-17 years with the following key indicators: • High blood cholesterol and blood pressure • Markers of the metabolic syndrome as a measure of cardiometabolic risk • Overweight/obesity as a measure of adiposity	• To perform a review of evidence in relation to PA and health in 5-17 year olds • To make recommendations on the appropriate intensity, volume and type of PA for minimum and optimum benefits in school aged children and youth	N/A	• PA is associated with many health benefits in school aged children and youth • There is a dose-response relationship between PA and health i.e. the more PA the greater the benefit • To achieve substantial health benefits, the PA should be at least moderate intensity with vigorous associated with even greater benefits. • Aerobic based activities have the greatest health benefit (aside from bone health)

			• Low bone density as a measure of skeletal health • Depression as a measure of mental health • Injuries as a negative health outcome of physical activity			
O'Connor et al., (2010)	International	Review	• Searched PubMed, Google Scholar and reference lists of identified review and data-based articles using the following phrases: strength training, resistance training and weight training combined with depression, anxiety, self-esteem, fatigue symptoms, sleep, chronic pain and cognition • 44 studies (n=3493; 2119 females) • Only included randomised controlled trials that investigated the effects of strength training alone. • Excluded quasi experimental designs	• To summarise evidence from randomised controlled trials • To examine whether strength training influences depression, anxiety, self-esteem, fatigue symptoms, sleep, chronic pain and cognition	• Strength training programmes	• Strength training was associated with reductions in anxiety symptoms (5 trials); depression symptoms in individuals diagnosed with depression (4 trials); fatigue symptoms (10 trials); pain intensity in patients with low back pain (5 trials); osteoarthritis (8 trials) and fibromyalgia (4 trials). • Strength training was also associated with improved cognition in older adults (7 trials); sleep quality in depressed older adults (2 trials) and self-esteem (6 trials) • Larger randomised controlled trials with a variety of participant

						samples are needed to better determine the consistency of the relationship between strength training and depression, anxiety, self-esteem, fatigue symptoms, sleep, chronic pain and cognition
Paluska, & Schwenk, (2000)	International	Review	• Medline search to locate articles on PA, exercise, depression and anxiety including human studies, meta-analyses and review articles. • Selected articles were grouped by age, disease type and therapeutic mechanism.	• To critically review current literature on the effects, mechanisms and potential benefits of using PA as a component in the treatment of depression and anxiety	N/A	• Aerobic and strength training are both effective for treating anxiety and depressive symptoms • PA is as effective as psychotherapy for treating mild to moderate depressive symptoms • Increased PA in individuals with severe depression symptoms demonstrated the greatest improvement in mood • State anxiety improves with acute exercise, whereas the response of trait anxiety to chronic exercise remains unclear

Peluso & Andrade, (2005)	International	Review	• Medline search for studies that evaluated the association between physical activity and mental health between 1990 and 2002. • 87 studies	• To review research focused on the relationship between physical activity and mental health and the association between exercise and mood	N/A	• PA has beneficial effects for the treatment of psychiatric diseases such as depressive and anxiety disorders • PA can also be harmful when performed inappropriately or intensely • Moderate exercise improves mood and helps maintain this at high levels • Vigorous exercise causes a deterioration in mood • Unable to define the cause effect relationship between PA and mental health /mood
Petruzzello et al., (1991)	International	Meta-analysis	• 3048 participants from 104 studies • Mean age of 34.16 ± 13.95 years	• To quantitatively review the exercise anxiety literature for state and trait anxiety and psychophysiological correlates of anxiety	• Various exercise modalities such as aerobic and anaerobic exercise and training • STAI • POMS • MAACL (anxiety subscale)	• Exercise is associated with reductions in anxiety, but only for aerobic exercise. Independent of age and health status • Training programs needed to exceed 10 weeks before significant changes in trait anxiety can occur • Exercise of at least 21 minutes seemed necessary to achieve

						reductions in state and trait anxiety • It remains to be seen what the minimum duration is necessary for anxiety reduction
Schuch et al., (2018)	International	Meta-analysis	• Prospective studies that evaluated incident depression were searched on PubMed, PsycINFO, Embase, and SPORT-Discus • Clinical, PA and depression data were extracted • A total of 49 prospective studies • 266,939 participants • Median proportion of females across studies was 53%. • Participants were of all ages, free of depression or depressive symptoms at baseline	• To examine the prospective relationship between physical activity and incident depression and potential moderators.	• IPAQ • Objective PA measures (e.g. accelerometers) • BDI • DSM-12D • ICD • CES-D • GDS-15/30 • SMFQ • WHO • ZSDS • PHQ-9 • PASE • GHQ • HADS-D • MHI-5 • MDI	• Individuals with high levels of PA had lower odds of developing depression (adjusted OR = 0.83,95% CI=0.79,0.88) in comparison to those with lower PA levels. • PA had a protective effect against the incidence of depression in young adults (adjusted OR = 0.90, 95% CI = 0.83, 0.98), adults (adjusted OR = 0.78, 95% CI = 0.70, 0.87) and in the elderly (adjusted OR = 0.79, 95% CI = 0.72, 0.86). • Protective effects of PA against depression were also seen across the geographical regions Asia, Europe, North America, and Oceania (with adjusted OR

						ranging from 0.65 to 0.84) • No moderators were identified.
Southwick et al., (2005)	International	Review	N/A	• To highlight factors that differentiate individuals who tolerate or benefit from highly stressful situations and what differentiates them from those who become symptomatic.	N/A	• Several brain regions, neurotransmitter systems, genetic factors and developmental influences are involved in stress resilience and stress-induced alterations in mood and anxiety
Teychenne et al., (2008)	International	Review	• 218,100 adults aged 10-89 years	• To examine the association between PA and depression.	• CES-D • GHQ • BDI • POMS • Physical Activity Index	• Inverse association between PA and the likelihood of depression in adults • Even low PA may have a protective effect against the likelihood of depression • There are several major gaps in the research area of PA and depression limiting the recommendations for an optimal dose
Teychenne et al., (2020)	N/A	Review	N/A	• To examine the current global physical activity recommendations for	N/A	• The 'optimal dose' of PA is uncertain

				adults and its relation to mental health, with a key focus on depression • To determine whether there is a need to extend the focus of existing guidelines to ensure they are mental health informed		• PA and mental health relationship is apparent even at low doses but is domain specific • Authors recommended the following based on the conclusions: - Do some PA during leisure time or in active travel - Prioritise activities you enjoy or personally choose to undertake - Some physical activity is better than none for both physical and mental health. - Guideline messages that encourage individuals to “move more” may increase PA but, may not lead to improved mental health or reduced mental ill-health (e.g. depression). - Therefore, encouraging individuals to participate in small amounts of enjoyable PA, ideally during leisure-time may increase mental health benefits alongside physical benefits.

Wiese et al., (2018)	International	Meta-analysis	• Searched PsycINFO, Business Source Premier, Medline, Hospitality and Tourism Complete, PsycArticles and Hospitality and Tourism Index. • Studies that contained a measure of both SWB and LTPA were included. • Excluded any studies that consisted of non-working adults, minors or retired participants. Only included working adults. • 12 articles were included in the meta-analysis • 4081 participants	• To examines to which extent LTPA is related to SWB in working adults.	N/A	• Engaging in more LTPA was significantly associated with two components of SWB, positive affect (r = 0.21) and life satisfaction (r = 0.12). The relationship between LTPA and positive affect was stronger than that for life satisfaction. • The relationship between LTPA and negative affect was not significant (r = −0.05). • The results contribute to the evidence for the importance of engaging in LTPA as a way of promoting SWB.

Abbreviations: BDI (Becks Depression Inventory); CES-D (The Center for Epidemiological Studies Depression Scale); BDI (Becks Depression Inventory); DSM-12D (12-item scale for DSM depression); GDS-15/30 (Geriatric Depression Scale); GHQ (General Health Questionnaire); HADS-D (Hospital Anxiety and Depression Scale); HAM-D (Hamilton Rating Scale of Depression); HRQL (Health-related quality of life); HRQOL-4 (Health-Related Quality of Life); ICD (International Classification of Diseases); LTPA (leisure-time physical activity); MAACL (Multiple Affect Adjective Check List); MAQ (Modifiable Activity Questionnaire); MDI (Major Depression Inventory); MHI-5 (Mental Health Index–5);OR (odds ratio); PA (physical activity); PASE (Physical Activity Scale for the Elderly); PHQ-9 (Patient Health Questionnaire–9); POMS (Profile of Mood States-Short Form); PWC (physical working capacity); SF-36 (RAND 36-Item Health Survey Short form); SMFQ (Short Mood and Feelings Questionnaire); STAI (State-Trait Anxiety Inventory); SWB (subjective well-being); WHO(World Health Organization); WHOQOL-BREF (World Health Organization Quality-of-Life Scale); ZSDS (Zung Self-Rating Depression Scale).

Appendix C: Participant Information Sheet

Effect of Coronavirus Restrictions on Physical Activity and Wellbeing Study

You are invited to take part in a study exploring the effect of Coronavirus (COVID-19) on physical activity participation and wellbeing. The choice to complete this survey is yours. If you do not want to take part, you do not have to give a reason. If you do want to take part now, but change your mind later, you can leave the survey at any time.

This study is part of a wider project initiated at the University of Winchester, England and is being run in several other countries, including the United Kingdom, Australia and Ireland. The New Zealand arm of the study is a collaboration between researchers at Massey, Lincoln and Canterbury Universities.

Why are we doing the study?

COVID-19 is an infectious disease caused by a newly discovered coronavirus. Most people infected with the COVID-19 virus will experience mild to moderate respiratory illness, however, some older people and those with underlying medical problems are more likely to develop serious illness.

On 26 March 2020, the New Zealand Government imposed a nation-wide alert level of 4 in response to the COVID-19 pandemic. Significant restrictions with regards to how we move and interact with other people and our community were implemented. These restrictions were put in place for at least four weeks to reduce the spread of COVID-19, with the goal of eliminating the disease within New Zealand. The current restrictions include leaving home only to: access essential services, like groceries, banks or pharmacies; go for a walk, or exercise and enjoy nature in the local area; go to work as an essential worker; and there is a recommendation to maintain a 2-metre distance from all other people when not at home.

The purpose of this study is to understand the population effect of COVID-19 on people's physical activity and wellbeing at different alert levels and stages of the New Zealand Government's strategy to counteract this pandemic. This information may help us to be better prepared to support people in achieving and maintaining optimal health and wellbeing in general terms, and if we were to encounter such events in the future.

What is involved?

If you would like to take part in the study, we ask that you give your consent on the following page and then complete a series of short online questionnaires about your physical activity patterns and wellbeing. These questionnaires should take about 10 minutes in total. Once you have completed the questionnaires, and if you are happy to be involved at future assessment points when the Alert Level changes (for example: from the current Level 4 to Level 3), we would like you to provide further consent for us to contact you at a later date. We would anticipate that you may be invited to complete the survey on four occasions over the course of the next 18 months. Further participation remains voluntary, and you may choose to participate in all, some or none of the follow up assessments.

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