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PHYSICAL ACTIVITY AND HEALTH DURING THE SARS-COV-2 PANDEMIC: THE EFFECTIVENESS OF AN ONLINE PHYSICAL ACTIVITY INTERVENTION

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DECLARATION

I, Adelle Kemlall Bhundoo, hereby certify that the work presented in this thesis is my own in its entirety, and where the work of others has been used, the appropriate citations have been included. This thesis has not been previously submitted to any institution, and is being submitted to the Durban University of Technology, in fulfilment of the requirements for the Doctor of Philosophy in Health Sciences degree.

_____ 01/02/2025

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ABSTRACT

Background

Regular physical activity (PA) is known to have several benefits in terms of physical and mental wellbeing. Researchers in the field of public health have investigated these benefits for several years with the general consensus that regular PA has immense potential to maintain health, prevent the development of non-communicable diseases and to contribute toward overall well-being. The last years have seen the emergence of online PA programmes as an option for increasing PA and this continues to increase with the evolution of technology and development of resources. The overall concept of online PA has been shown to provide PA opportunities for individuals who may not be able to, or may not desire to, access traditional PA establishments such as gyms, sports centres and clubs, among many others. It also provides an additional option for the accumulation of PA.

In March 2020, South Africa became integrated in the fight against the SARS-CoV-2 pandemic. The pandemic was an unpredictable time for the global population, with this highly contagious virus creating a state of disaster around the world. SARS-CoV-2, otherwise known as COVID-19, left the health sector in a state of turmoil. The high mortality and hospitalisation rates associated with the virus rapidly depleted healthcare resources. Government officials around the world were forced to impose lockdown restrictions in an attempt to control the spread of the virus, decrease mortality and hospitalisation rates and conserve healthcare resources. The lockdown restrictions were implemented according to WHO guidelines and allowed for individuals to move around only when considered essential. These restrictions may have assisted in managing the pandemic, however, the isolation created an underlying concern with regards to PA, particularly as a result of the closure of most public spaces, including sport establishments. Consequently, this necessitated a dire need for online PA programmes to become a more focused mechanism for promoting the accumulation of PA and minimising the impact of the reduced conventional PA opportunities, during the pandemic.

Aims & Objectives

This study aims to interrogate existing online PA programmes and their effects on physical and mental outcome measures and to evaluate the effectiveness of an online physical activity intervention programme during the SARS-CoV-2 pandemic.

Objective 1

To conduct a PROSPERO registered systematic review and meta-analysis pertaining to online PA interventions and its effectiveness in healthy individuals with regard to physical and mental outcome measures.

Objective 2

To conduct a re-focused analysis of and report on the South African data from an international online population-based survey.

Objective 3

To lead the South African cohort of a multicentred, two-armed, randomised-controlled trial and specifically re-analyse and report on the South African specific data obtained from this trial.

Objective 4

To provide guidelines and recommendations for future online PA programmes based on the research findings.

Methods

Systematic Review and Meta-analysis

A literature search was conducted on PubMed, Cochrane and Google Scholar. RCTs that were 4-weeks or longer in duration which investigated the effectiveness of online exercise (OE) versus no exercise (NEX) controls or face-to-face (FFE) exercise in healthy adults were included. A quality rating of each study included was conducted using the PEDro scale. Relevant data from each study were then extracted for a meta-analysis. The effect sizes were pooled using robust variance estimation.

South African Survey

A focused analysis of the SA statistics from the global Activity and health during the SARS-CoV-2 Pandemic (ASAP) study was conducted. This descriptive study consisted of an online cross-sectional questionnaire that was administered from 3 April 2020 to 9 May 2020. The questionnaire used the Nordic Physical Activity Questionnaire-short (NPAQ-short), and a five-point Likert scale to quantify changes in PA levels and WHO PA guideline compliance respectively. The data were analysed according to age and gender categories. Logistic regression was performed to identify significant themes emerging from the data.

South African Analysis of a Global Randomised Controlled Trial

A multicentred RCT was conducted to assess the effects of an 8-week trial (4-weeks of active intervention and 4-weeks of recorded sessions), with live-streaming exercise sessions provided by professionals in the field of sports and exercise medicine. Measures of physical and mental wellbeing were evaluated by means of weekly digital surveys. These measures included the NPAQ-short for PA levels, Generalised Anxiety Disorder Scale-7 (GAD-7) for anxiety, WHO-5 for mental wellbeing, Medical Outcome Study Sleep Scale (MOS sleep scale) for sleep, Chronic Pain Grade Scale (CPGS) for pain and disability and Self-Concordance Scale (SKK) for exercise motivation. The thesis includes a focused analysis of SA data from the global study, to assess SA-specific changes in PA levels and exercise motivation during the initial 4 weeks (live-streaming sessions) of the intervention.

Guidelines for Future Online Physical Activity Interventions

Specific recommendations for future online PA programs, have been formulated based on the findings of the various parts of this thesis.

Findings

Systematic Review and Meta-analysis

A total of 18 moderate to high methodological quality studies (PEDro scale) were included. OE improved more than NEX in measures of strength (Standard Mean Difference (SMD) =0.61), balance (SMD=0.52), endurance (SMD=0.85), PA (SMD=0.46), depression (SMD=1.08), mood/emotion (SMD=0.47), mental wellbeing (SMD=0.79), and self-efficacy (SMD=1.1). OE was less effective than FFE in all outcomes. GRADE classification revealed a low-moderate evidence certainty.

South African Survey

The analysis of 456 adult participants questionnaire responses revealed that, moderate (MPA) and vigorous (VPA) PA were reported to have reduced by 53.5% and 58%, respectively. The SA reductions in PA were higher than the those noted in the overall global study where reductions were reported as 41% in MPA and 42.2% in VPA. Approximately one third (30%) of the SA sample recorded a reduction in WHO PA guideline compliance during lockdown restrictions.

South African Analysis of a Global Randomised Controlled Trial

The analysis of the data from 105 participants (65 intervention; 40 control), that completed the initial 4-weeks active phase of the RCT showed a reduction in MPA in both the intervention group (IG) and control group (CG) of 32.6% and 16.1% respectively. VPA also reduced in the IG (42.1%), however, increased in the CG. Scores for exercise motivation increased by 13.1% and 16.9% IG and CG, respectively.

Conclusion

The systematic review and meta-analysis conducted in this thesis, indicates that there is a moderate level of evidence to support the use of online PA, when attempting to improve markers of physical and mental health. The SARS-CoV-2 pandemic, placed further emphasis on the need for effective online PA protocols, that allow for an increase in PA engagement as shown by the results of the survey analysed in this thesis. This need is exaggerated in instances when individuals are unable to access face-to-face PA facilities, especially since literature analysis indicated there is merit to online PA programs. However, the RCT analysis revealed that, in order for specific populations like South Africans, to benefit fully from such programs, there needs to be a level of customisation in the program planning. This customisation should carefully consider the context, strengths and limitations that are population specific.

Notwithstanding this, there is great potential in the field of online PA intervention research, particularly considering that existing online PA interventions have been reported as effective in not only improving PA levels but also towards supporting overall wellbeing. Future online PA interventions should therefore consider the identified key focus aspects during the development and implementation, to maximise uptake outcomes and overall impact of such programmes.

Keywords: online physical activity, digital exercise, SARS-CoV-2, WHO physical activity guidelines

DEDICATION

I dedicate my work to my husband, Omkar and my son, Shivansh, for being the reasons that I never gave up and for inspiring me to achieve more than I ever believed I could.

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LIST OF ABBREVIATIONS

ASAP	Activity and health during the SARS-CoV-2 Pandemic
CACE	Complier Average Causal Effect
CG	Control Group
CI	Confidence Interval
CON	Control
CPGS	Chronic Pain Grade Scale
DHE	Digital Home Exercise
FFE	Face-to-Face Exercise
GAD-7	Generalized Anxiety Disorder Scale-7
IG	Intervention Group
ITT	Intention-to-treat
MD	Mean Difference
min	Minutes
MOS	Medical Outcome Study
MPA	Moderate Physical Activity
NEX	No-Exercise Group
NPAQ-short	Nordic Physical Activity Questionnaire-short
OE	Online Exercise Group
PA	Physical Activity
PAR-Q	Physical Activity Readiness Questionnaire

RCT	Randomised Controlled Trial
RoM	Ratio of Means
SD	Standard Deviation
SKK	Self-Concordance Scale
VPA	Vigorous Physical Activity
WHO	World Health Organisation

LIST OF PUBLICATIONS

Published Manuscripts:

- *Physical activity levels during SARS-CoV2- pandemic: a focus on South African data from the 'Activity and health during the SARS-CoV-2 Pandemic' (ASAP) study*

  Adelle Kemlall Bhundoo, Jan Wilke and Julian David Pillay

  African Journal of Inter/Multidisciplinary Studies

- *The effectiveness of the 'Move ASAP' online exercise intervention during the SARS-CoV-2 pandemic: a focus on South African data from the multi-centre randomised controlled trial*

  Adelle Kemlall Bhundoo, Jan Wilke and Julian David Pillay

  African Journal for Physical Activity and Health Sciences

Manuscripts Under Review:

- *The effectiveness of online exercise on physical activity, motor function and mental health: A systematic review with meta-analysis*

  Adelle Kemlall Bhundoo, Julian David Pillay and Jan Wilke

  Journal of Medical Internet Research

CHAPTER ONE

INTRODUCTION

1.1. Background

Physical activity (PA) and its benefits, to both physical and mental health and well-being, is well documented. The literature clearly stipulates the immense benefits associated with regular physical activity (Madigan *et al.,* 2021; Herbet *et al.,* 2020). Many studies have noted marked improvement in physical indicators such as strength, endurance, flexibility and balance, when patients engage in any form of regular exercise (Miko *et al* 2020), with just as significant an amount of research highlighting the positive implications of PA on mental outcome measures such as depression, anxiety, fear, memory and loneliness (Herbet *et al.,* 2020; An *et al.,* 2020). A vast number of investigations conducted over the years have also shown a positive correlation between physical activity and the management of systemic conditions such as diabetes, hypertension and hyperlipidaemia (Isath *et al.,* 2023). These benefits are not limited to the cardiovascular system, exercise has been reported to assist practitioners in the management of psychological, reproductive, neurological, digestive and muscular disorders as well (Dimitri *et al.,* 2020).

Online PA programs have become increasingly more popular and more intricate as time has progressed, showing significant improvement in health and health related outcomes (Zangger *et al.,* 2023). With the advancements in technological devices as well as the increasing knowledge of how to use these advancements to their maximal potential, the arena of online PA has become abundant with emerging techniques (Ambrens *et al.,* 2023). The area of online PA ranges from simple activity tracking software, to pedometer logs, to interactive forums and support groups, to structured exercise sessions with qualified trainers (Daly *et al.,* 2021). These platforms can include video instructions or virtual interactions, and some have even been developed to include motivational and behavioural strategies which aim to provide patients with the psychological tools required to turn once off exercise attempts into lifelong healthy physical activity habits (Yang and Koenigstorfer, 2020). Hence, well developed online PA measures have the potential to provide access to beneficial PA opportunities which can be advantageous, especially in populations with an increased necessity for remote PA. An example of such a population is the old and ageing. Recent reports indicate that there is an emerging demographic change which will drastically increase the number of older individuals in the general population as the years progress (United Nations, 2023). It has been indicated that with an increase in age individuals become less mobile, and less independent (Cunningham *et al.,* 2020), thus, decreasing their access to facilities such as gyms. This can be exacerbated by decreased or insufficient income, lack of robust support structures and changes in living

arrangements (Wilson *et al.,* 2021). Furthermore, studies suggest a trend of decreasing PA in association with increasing age (Kwasniewska *et al.,* 2016) this coupled with the demographic change projections and the decreased concerns relating to decreased facility access, places focus on the need for effective and easily accessible online PA interventions to assist in maintaining and improving PA levels.

The need for online PA intervention was further highlighted in 2020, during the emergence of the SARS-CoV-2 global pandemic which left the world in a state of distress and uncertainty (Ng *et al.,* 2020). Political leaders around the world, directed by the regulations set out by the World Health Organisation (WHO) (World Health Organisation, 2020), were required to impose firm restrictions related to the movement of individuals in an attempt to stop person to person contact, thus curbing the spread of the virus (Cowling and Aiello, 2020). In South Africa, a complete lockdown was implemented which forced non-essential individuals to be completely housebound (Nyabadza *et al.,* 2020), and limited the movement of the general population within and out of the country (Moonasar *et al.,* 2021). These measures were adopted from 26 March 2020 to 1 October 2021.

The lockdown was implemented in stages, beginning with extremely strict regulations in the initial level 5 lockdown (South African Government, 2020) and less extreme restrictions in level 1 lockdown. Level 5 lockdown allowed for the operation of only essential services. The general population were required to remain housebound without any exposure to people living outside their households (South African National Department of Health, 2020). A work from home policy was implemented by a vast majority of the companies and organisations, and where work from home was not possible, many were left not working at all (South African Government, 2020; Naidoo and Naidoo, 2022). The levels of lockdown were constantly being adapted and adjusted ranging from most strict, level 5 to the most flexible, level 1 during the 18 months of restrictions. These adjustments were made based on the number of active SARS-COV-2 cases and mortality rates, the availability of medical resources, and later on the availability vaccines and acquisition of herd immunity (Donga *et al.,* 2021).

During the more stringent levels of lockdown measures, one of the regular activities that was negatively impacted on was PA. The restrictions stipulated that exercise establishments were prohibited from operating and group gatherings were banned (Stiegler and Bouchard, 2020). The justification for this regulation was that the respiratory droplets known to spread SARS-COV-2 could easily spread from person to person when exercising without a mask, and from

sharing common exercise equipment and surfaces (South African National Department of Health, 2020).

These lockdown restrictions increased the need for online PA protocols to combat the sedentary lifestyle that had been adopted by a large amount of the population, and to aid in terms of coping with reducing the severely increased amounts of stress and anxiety faced by individuals on a daily basis (Lewis *et al.,* 2022). This thesis investigates existing online PA interventions, examines the effectiveness of a new online PA intervention and provides guidelines and recommendations for future online PA protocols.

1.2. Research Problem

The SARS-CoV-2 pandemic and its related restrictions, has highlighted a need for effective, accessible online PA protocols that have the potential to positively impact physical well-being. This study hypothesises that individuals that have access to and participate in online PA interventions show improved physical well-being and physical activity outcomes when compared to those who do not participate in any PA interventions.

1.3. Aims & Objectives

Aims

This study aims to interrogate existing online PA programmes and their effects on physical outcome measures and to evaluate the effectiveness of an online physical activity intervention programme during the SARS-CoV-2 pandemic.

Objective 1

To conduct a PROSPERO registered systemic review and meta-analysis pertaining to online PA interventions and its effectiveness in healthy individuals with regard to physical and mental outcome measures.

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Objective 3

To lead the South African cohort of a multicentred, two-armed, randomised-controlled trial and specifically re-analyse and report on the South African specific data obtained from this trial.

Objective 4

To provide guidelines and recommendations for future online PA programmes based on the research findings.

1.4. Structure of the Thesis

This dissertation is structured in a publication format, accompanied by an introduction, including aims and objectives as Chapter One, a literature review as Chapter Two and a discussion, guidelines, recommendations and a conclusion as Chapter Six.

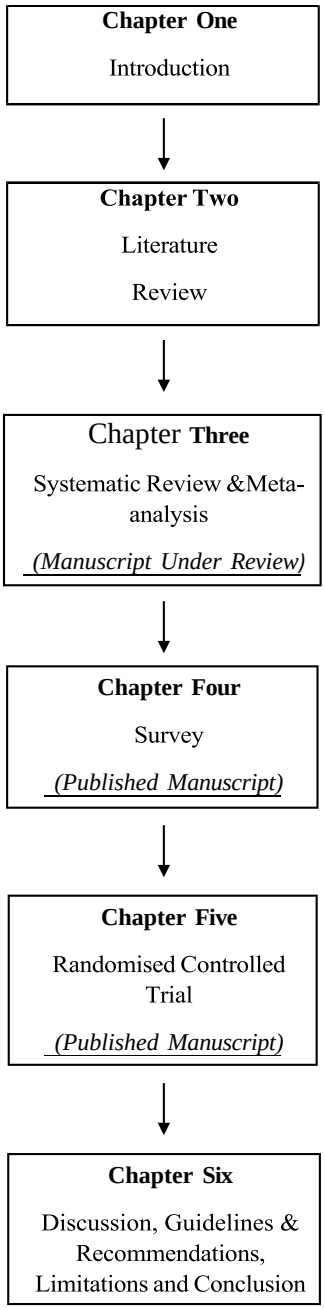

Figure 1. Structure of Thesis

Chapter 1:

Introduction

Chapter 2:

Literature Review

Chapter 3:

Manuscript 1: "*The effectiveness of online PA interventions on physical and mental wellbeing: A systematic review and meta-analysis".*

Chapter 4:

Manuscript 2: "*Physical activity levels during SARS-CoV2- pandemic: a focus on South African data from the 'Activity and health during the SARS-CoV-2 Pandemic' (ASAP) study".*

Chapter 5:

Manuscript 3: *"The effectiveness of the 'Move ASAP' online exercise intervention during the SARS-CoV-2 pandemic: a focus on South African data from the multi-centre randomised controlled trial".*

Chapter 6:

Discussion, guidelines and recommendations, limitations and conclusion

1.5. References

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CHAPTER TWO

LITERATURE REVIEW

Physical activity (PA) is generally defined as the movement of the human body resulting in the use of stored energy (Piggin, 2020). This movement can be intentional, such as engaging in sports or exercising or incidental where movement occurs as a part of daily functions, such as occupational or household tasks (Thivel *et al.,* 2018 and Malm *et al.,* 2019). Over the years PA has been acknowledged as a key component in the development and maintenance of physical and mental health and well-being (Rhodes *et al.,* 2017). The research emphasising the benefits of PA is extensive and has been reported in a large variety of studies across many different research populations and fields (Daskalopoulou *et al.,* 2017). This literature review presents an overview on the evidence for face-to-face PA, online PA, SARS-Cov2 and its effects on PA.

2.1. Benefits of Physical Activity

2.1.1. Physical Benefits

Physical inactivity has been shown to be a contributing factor in the development and progression of many physical pathological processes (Anderson and Durstine, 2019). The prescribed PA recommendations by the World Health Organisation (WHO), are that an adult should engage in a minimum of 150 minutes of moderate PA or 75 minutes of vigorous PA each week (Bull *et al.,* 2020). Studies show that inactive individuals are at a higher of developing chronic conditions that affect quality of life and mortality rates (González *et al.,* 2017). These conditions include; cardiovascular disease, diabetes, osteoarthritis and osteoporosis (Ng *et al.,* 2020b).

A) Cardiovascular Health

Numerous researchers in the field have conducted studies that concluded that engaging in the prescribed volume of PA can benefit individuals by decreasing the risk of development of chronic illness. A study conducted by Kraus *et al.,* (2019), concluded that increased PA has the potential to decrease the incidence of and the mortality rates relating to ischemic cardiovascular diseases, such as myocardial infarctions and cerebrovascular accidents. Another study conducted among adults across various ages and income groups revealed that PA and specifically vigorous PA can decrease the risks of developing cardiovascular disease and can also improve prognoses in individuals who have pre-existing cardiovascular illness (Winzer *et al.,* 2018). Blond *et al.,* (2020), conducted a study to investigate whether not PA levels that

were significantly higher than the recommended levels could possibly be harmful and increase mortality in the older population. However, this study concluded that the relationship between mortality and PA was an inversely proportionate one, where with increase PA levels, there was decreased mortality (Blond *et al.,* 2020). Additionally, regular intentional PA engagement in the forms of aerobic and resistance training has been shown to have positive effects on blood pressure and reducing cardiovascular risks in hypertensive patients (Boeno *et al.,* 2020). Barone *et al* (2021), concluded that in addition to its positive effects on blood pressure, PA further benefits cardiovascular health by regulating blood cholesterol levels. In general research over the years has consistently shown that PA forms an important component in the management and prevention of cardiovascular disease (Elagizi *et al.,* 2020).

B) Metabolic Health

Studies have indicated that developing healthy PA levels can reduce the risk of metabolic disease as well as assist in the management of existing metabolic disease in patients across age groups (Al Zaki *et al.,* 2023). Metabolic dysfunction inadvertently further increases risks for cardiovascular disease. Improved PA improves metabolic function which decreased additional cardiovascular risks (Wu *et al.,* 2024). In the field of diabetes research, a large number of studies concur that regular patient specific PA can assist in the regulation of blood glucose levels and the overall health and wellbeing of patients with prediabetes and diabetes (Colberg *et al.,* 2016). Chang *et al.,* (2021), supported the findings of previous studies by indicating that moderate PA can have a significant impact on glucose levels in patients living with type II diabetes. By balancing blood glucose levels, PA engagement in accordance with PA guidelines is beneficial in preventing and decreasing the risks of diabetic complications (Wake, 2020).

Furthermore, obesity is one of the leading causes of death globally and significantly increases an individual's risks of developing physical and mental health ailments (Gonze *et al.,* 2021). Several studies indicate that engagement in regular PA can assist in weight management by improving the balance between energy intake and energy expenditure (Stankovic *et al.,* 2021 and Lorensia *et al.,* 2024). Further PA benefits have been noted in studies measuring quality of life and its correlation with physical activity, which concluded that regular PA has the potential to significantly improve quality of life in adult populations (Marquez *et al.,* 2020).

C) Musculoskeletal Health

Brooke-Wavell *et al.,* (2022), indicated that patients with osteoporosis can benefit from specific strength and balance related PA to assist in slowing down the progression of the condition and improving bone health. PA in individuals with osteoporosis can improve balance, thus reducing the risk of falling its resultant injuries (McMillan *et al.,* 2017). These patients can significantly benefit of leisure time PA that involves a variety of movement types and intensities (Pinheiro *et al.,* 2020). As such another study revealed and PA in the form of weight bearing training can have a significant positive effect on osteoporosis prevention and management (Aibar-Almazán *et al.,* 2022).

Osteoarthritis is an additional musculoskeletal condition that benefits from PA engagement Regular PA has been further linked to the improved mobility and decreased pain in patients with osteoarthritis (White *et al.,* 2013). Daste *et al.,* (2021), stated that adapted PA has the potential to be more beneficial than pharmaceutical therapy in terms of improving the symptoms associated with osteoarthritis. Aydemir *et al.,* (2022) further indicated that a fear for PA engagement associated with osteoarthritis pain can increase the risk for decreased PA participation, which can worsen the trajectory of the condition.

Additional physical benefits have been noted in studies that showed an improvement in muscle and bone health, translating into improved mobility especially in the elderly, previously injured and post-operative patients (Brach *et al.,* 2023, Edouard *et al.,* 2023 and Parry *et al.,* 2017). Reasonable amounts of PA in alignment with WHO guidelines can reduce musculoskeletal pain (Rhim *et al.,* 2022). This decreased pain and dysfunction can improve workplace productivity (Ribas *et al.,* 2021).

2.1.2. Mental benefits

Mental health is another arena where the benefits of regular PA comes into focus. With the rise in mental health issues in society today there has been an increasing amount of studies that show the positive impact that regular PA has on preventing and improving conditions such as depression, anxiety and mood disorders (Mikkelsen *et al.,* 2017). Belcher *et al.,* (2021) indicated that PA during adolescence has the potential to contribute towards healthy brain development, which is associated with improved mental health, as well as, a decreased risk for the development of mental health conditions. Whereas, Huang *et al.,* (2024) concluded that

there was a definite enhancement of mental health in their study that investigated the effects of PA on the mental health of undergraduate students.

A) Depression and Anxiety

A recent review also advocated for the positive effects that PA have on depression, anxiety and distress (Singh *et al.,* 2023). A different review study conducted by Pearce *et al.,* (2022), revealed and even low volumes of regular PA can significantly improve mental health outcomes and reduce the risk of mental health illness. Some studies recommend the integration of PA into the management regimens for depression (Schuch and Stubbs, 2019), anxiety (Kandola *et al.,* 2018) and mood disorders (Chan *et al.,* 2019). PA works by stimulating the release of endorphins which have the potential to stabilise and improve moods and decrease symptoms of depression and anxiety (Mahindru *et al.,* 2023). Hallgren *et al.,* (2020), suggested that further to improving existing symptoms of depression and anxiety, PA has the potential to decrease the risk of the development of these mental health conditions. A similar result was reported in terms of the improvement of non-clinical anxiety relief with the potential to improve clinical symptoms as well in the cases of children and young adults (Carter *et al.,* 2021).

B) Cognitive Function

Some studies have linked PA to improved cognitive function which can improve thinking, learning, judgement and memory (Erickson *et al.,* 2019). This can be especially beneficial in cases of dementia and other conditions that result in a decrease in cognitive functioning (Najar *et al.,* 2019). In these cases, it has been indicated that PA improves cognitive functioning and decreases the progression of symptoms in dementia causing conditions such as Alzheimer's disease (Kouloutbani *et al.,* 2019). Treyer *et al.,* (2021), indicated that beta-amyloid deposition in the cerebrum is a natural progression of aging, which affects cognitive functioning. PA participation has the potential to decrease the volume of beta-amyloid deposition which consequently improves cognitive function in older adults (Treyer *et al.,* 2021). PA especially PA that involves a level of cognitive involvement has been shown to create positive effects in individuals previously diagnosed with mild cognitive impairment (Biazus-Sehn *et al.,* 2020). In a study conducted by Fassier *et al.,* (2022), it was stated that females that possess the apolipoprotein E (APOE) e4 allele gene have an increased risk of cognitive impairment. This

study concluded that participation in vigorous PA earlier in life has the potential to decreases these females' risk for cognitive deficits associated with aging (Fassier, *et al.,* 2022).

C) Other Psychiatric Benefits

The mental health benefits of regular PA extend even further into other psychiatric conditions. Vancampfort *et al.,* (2017) stated that patients with bipolar disorder, schizophrenia and major depressive disorder are more likely to be physically inactive and noncompliant with global PA recommendations. A study revealed that regular healthy levels of PA may possibly reduce the risk for psychotic conditions such as schizophrenia (Brokmeier *et al.,* 2020). Ryu *et al.,* (2020), concluded that intentional PA in the form of outdoor cycling, stabilised schizophrenia related symptoms of psychosis and cognitive dysfunction. Another study supported PA for the prevention of bipolar disorder, especially in those with a predisposition for the development of this condition (Sun *et al.,* 2020). Further to this Rantala *et al.,* (2021), encouraged the inclusion of PA in the management and risk profiling for bipolar disorder.

Regular PA has been noted to further improve self-esteem in children, adolescents (Gilani and Dashipour, 2017) and adults (Zamani Sani *et al.,* 2016). Toros *et al.,* 2023, indicated similar positive PA effects in individuals over the age of 65 years. The positive effects of PA on self-esteem has been attributed to an improved body image, as well as stress reduction (Pop, 2016). Researchers have conducted studies that showed a reduction in stress levels in individuals who engaged in regular PA versus those who do not due to decreased cortisol levels associated with PA (Wood *et al.,* 2018).

2.1.3. Other Health Benefits

The positive effect elicited by PA on cortisol levels further improves inflammation recovery and healing, along with decreasing the risk of chronic disease development (Chaplin *et al.,* 2021). A study conducted by McPhee *et al.,* (2016), concluded that regular PA can improve the overall health of older individuals, whilst concurrently reducing the risks of development of further chronic health complications. Another study conducted by Andrieieva *et al.,* (2019), reported that age-specific PA can decrease the rate of aging. Studies conducted on the effects on pre-operative PA on post-operative recovery have noted a marked improvement in post-

operative recovery when individuals engage in a regime of PA pre-operatively (Nilsson *et al.,* 2016 and Fong *et al.,* 2023).

Further to this a regulation of cortisol levels has been associated with an improvement in sleep patterns and establishing good sleep habits (De Nys *et al.,* 2022). Ghrouz *et al.,* (2019), concluded that there is a positive correlation between increased PA interaction and quality of sleep. It has been further noted that a regular, healthy volume of PA is vital in ensuring good sleep quality and sleep duration in children (Tremblay *et al.,* 2016). Healthy sleep patterns have a direct positive effect on the general wellbeing of an individual, allowing for optimisation of several physiological processes (Chaput *et al.,* 2020).

Similarly, studies have shown a positive relationship between PA and the prevention and management of various types of cancer (McTiernan *et al.,* 2019 and Moore *et al.,* 2016). It has been indicated that PA engagement has the potential to improve patient outcomes and quality of life following a cancer diagnosis (Misiąg *et al.,* 2022). Ligibel *et al.,* (2019), suggested that regular PA assists in weight management, which directly affects the levels of adipose tissue present in females. This can reduce the risk for the development of breast cancer. Another study investigating the effects of PA on colorectal cancer sufferers, stated that PA can improve outcomes in patients who undergo surgical treatment of colorectal cancer (Lee *et al.,* 2021). Additionally, PA has been noted to improve cancer related fatigue in individuals undergoing cancer therapy (Dun *et al.,* 2020). Friedenreich *et al.,* (2016), indicated that the is a positive relationship between PA and its inclusion in the cancer therapy, however, there is a need for more research on the matter.

2.2. Online Physical Activity

The concept of online PA immerged many years ago and has grown exponentially with the advancements in technology seen on a regular basis (Zangger *et al.,* 2023). Online PA essentially refers to any PA activity or routine that occurs through, is recorded on or is aided by resources on a digital platform, (Ambrens *et al.,* 2023). This differs from the traditional face-to-face interactions have been the historic method for PA, which involved the use of gyms, parks, trails, and other PA facilities (Hall *et al.,* 2021). Online PA is a broad banner under which a variety of PA tools and methods can be accessed by individuals to enhance fitness levels and to improve PA volume (Alley *et al.,* 2018).

2.2.1. Types of Online Physical Activity

There exists as assortment of online PA interventions that range from simple exercise tracking, to motivational messaging and group interactions to interactive PA interfaces that allow users to engage with resources to improve their PA and fitness levels (Daly *et al.,* 2021 and Hammami *et al.,* 2022). These types of online PA include:

A) Streaming Programs

These platforms involve live streaming of videos and regimens that individuals can access in order to engage with PA without having needing to use traditional PA facilities (Yu and Song, 2024). Some programs have trained instructors who interact with participants via video calling to instruct them on best practices and proper techniques when engaging with various types of exercise to improve PA levels (Chatzipanagioti *et al.,* 2024). To this effect, a study conducted by Chang *et al.,* (2021) revealed that use of a Facebook guided-live streaming program had the potential to increase PA engagement in older adults. A study conducted with adolescent participants also indicated an increase in PA levels, when investigating the effectiveness of live-streaming programs on PA (Parker *et al.,* 2021). A different study conducted during the SARS-CoV-2 pandemic revealed that live-streaming was more effective than pre-recorded videos in improving PA engagement (Cardinali *et al.,* 2022). Guo and Fussell (2022), suggested that there is merit to streaming exercise groups, however, highlighted the need for real-time feedback and more advanced tracking equipment. Tian *et al.,* (2022), concluded that the overall perception of the use live-streaming PA programs was positive, in a study conducted in China, during the SARS-CoV-2 pandemic

B) Pre-recorded PA programs

Although, Cardinali *et al.,* (2022), stated that streaming PA programs were more effective than pre-recorded videos, they did further indicate that pre-recorded videos were still effective in increasing PA in certain facets of training. Another study conducted by Granet *et al.,* (2023), indicated that using pre-recorded PA sessions in combination with streaming sessions, has the potential to increase PA engagement, thus, maximising the benefits. A study conducted on older adults during the SARS-CoV-2 pandemic, concluded that even after the pandemic and its related movement restrictions, online PA programs that include pre-recorded sessions, can introduce a means of increasing PA among this at-risk population (Mehrabi *et al.,* 2023). Further to this, a different study yielded similar findings, in a younger population. Indicating

that there is benefit in using pre-recorded videos to encourage increased leisure time PA (McDonough *et al.,* 2022). Fucarino *et al.,* (2024), stated that in individuals who are motivated to increase PA engagement, pre-recorded videos are preferred as this did not require them to stick to strict schedule as may be required by live-streaming sessions. Roberts *et al.,* (2017), encouraged the use of pre-recorded videos in the promotions of PA among older individuals, with limited access to other face-to-face PA opportunities.

C) Fitness Applications

Fitness applications can assist improve PA (Schoeppe *et al.,* 2016), by tracking PA engagement, accessing sedentary time, providing motivational prompts and messages to remind users to engage in PA (Lewis *et al.,* 2017). Smartphone applications in particular provide a means by which healthcare providers can encourage patients to engage with and track PA levels as well as other health related patterns (Higgins, 2016). These applications can also be used to track energy intake and expenditure, sleep patterns and basic vitals. For example, blood pressure, oxygen saturation and heart rate (Liu *et al.,* 2022). Fitness applications vary in their offerings, and a study conducted by Wang and Collins (2021), showed that applications with multiple functions are more effective in positive PA related changes and in application use. Mobile applications that integrate tracking and PA programs have been showed to be effective in increasing certain measures of PA (Zhou *et al.,* 2018). These fitness applications have the potential to improve cardiorespiratory fitness by encouraging increased levels of PA engagement (Berglind *et al.,* 2020). Fitness applications are also used by individuals to assist in training or preparing for specific PA goals such as participation in events, races etc (Coughlin *et al.,* 2016).

D) Virtual Reality and Video Games

An interesting and growing type of online PA is active gaming (Althoff *et al.,* 2016). These are platforms that were originally aimed at video games but have evolved to include an active portion that increases the user's body movement and energy expenditure, thus improving PA volume (LeBlanc and Chaput, 2017). Gaming applications that encourage movement, have been reported to elicit positive effects not only on PA but also on other well-being markers (Halbrook *et al.,* 2019). A study conducted by Stanmore *et al.,* (2017) stated that there are cognitive benefits associated with the use of exergaming to improve and maintain cognitive

function. Ahn *et al* (2019), showed that there including rewards-based technologies into gaming applications can further enhance PA engagement especially among children. Xbox gaming PA interventions have been indicated as a valuable resource which can play a role increasing general PA (Golden and Getchell, 2017). As such as study conducted by Naugle *et al* (2019), that investigated the effects of Nintendo and Xbox Kinect on healthy adult participants, concluded that the energy expenditure from these gaming programs was similar to that of regular mild PA engagement. A different study investigating the effects of a dance Xbox Kinect class, concluded that although the gaming class was not as effective in increasing energy expenditure as a face-to-face class, it did significantly increase heart rates and energy expenditure, which are vital components of increased PA fitness (Eason *et al.*, 2016).

E) Social Fitness Platforms

Social fitness platforms are online interfaces that use combinations of PA tracking, social and virtual group interactions, to motivate users to increase PA, with the goal of increasing physical fitness and well-being (Van de Pol, 2023). These platforms have the potential to use the development of social connections to enhance PA and support, by using the concept of human connection to encourage healthy PA behaviour (Reiner *et al.*, 2023). Additionally, the concept of social fitness platforms elicits a sense of community, which can enhance the previously discussed virtual reality applications leading to an amplification of the benefits of these online PA engagements (Sarupuri *et al.*, 2024). The use of social fitness integrations in digital applications and PA devices, can further enhance PA participation by creating a sense of competition and validation when individuals share their PA goals and achievements, on social networking sites, such as Facebook (Zhu *et al.*, 2017). Stragier *et al* (2018) conducted a study that measured PA level with running as an outcome measure. This study indicated that individuals who possess and "achievement based", mindset appreciate the ability to interact with likeminded individuals on digital PA platforms that offer a social function (Stragier *et al.*, 2018).

2.2.2. Additional Benefits and Limitations of Online Physical Activity

Benefits

Online PA yields similar physical and mental health benefits as those noted in face-to-face PA engagement (Kikuchi *et al.*, 2022), however, there are some additional benefits that arise with the use of online PA. These specific benefits are:

A) Accessibility

Online PA allows access to PA tools and resources irrespective of the availability of face-to-face fitness facilities (Hu *et al.,* 2021), this presents a more cost-effective approach in certain communities (Alley *et al.,* 2016). This enables individuals to make use of PA promotion platforms from the locations of comfort, whilst still delivering sufficient opportunity to remain physically active (Broekhuizen *et al.*, 2016). Additionally, this can be useful in individuals with work and study schedules that do not comply with conventional hours (Blake *et al.,* 2017). A different study indicated that patients with debilitating conditions such as multiple sclerosis have decreased access to PA facilities, which impacts their PA engagement. Such individuals could benefit from online PA programs due to their ease of access (Marziniak *et al.,* 2018). Online PA interventions have the potential to deliver large scale PA opportunities to various populations thus, increasing PA accessibility (Jahangiry *et al.*, 2017)

B) Flexibility

With the increasing pace of daily activities, increased work hours and the inevitable juggling of leisure time that has become a norm in modern day living (Pega *et al.*, 2021), even when individuals do have access to face-to-face facilities, limitations exist with finding the available time to make use of such facilities (Füzéki *et al.,* 2021). A study conducted investigating the barriers of PA in adult diabetic individuals revealed that PA a lack of flexibility in terms of time schedules was one of the reasons for decreased PA interactions (Lidegaard *et al.,* 2016). Blake *et al* (2017), suggested that the lack of available free time during normal daily function time frames, decreases the motivation to exercise among those working unconventional hours, this leaves room for the use of online PA programs, which allow for time-flexible engagement. Online PA programs allow an individual the opportunity access PA resources at any time and from any location (Silva-Jose *et al.*, 2022 and Senbekov *et al.*, 2020).

C) Interaction and Engagement

Online platforms that have group interactions built into the structure of the platform can present the opportunity for social interactions (Galway *et al.,* 2023), especially those living in remote areas or those with limited access to group interactions to engage with others on a similar PA journey (Heinrich *et al.,* 2022). This adds a social aspect to the benefits on online PA (Füzéki *et al.,* 2021). The use of social integrations in online PA programs, allows for individuals with

similar backgrounds and similar PA targets to interact (Reiner *et al.,* 2023), thus, increasing motivation and desire to remain consistent with PA engagement (Van de Pol, 2023). Furthermore, applications that include tailoring allow for individual specific customisation which can improve PA motivation (Alley *et al.,* 2016)

These benefits specific to the use of online PA platforms have been shown to be especially important in instances where traditional PA facilities cannot be accessed, the most recent widespread example of this was the SARS-CoV2 pandemic.

Limitations

Online PA, while offering convenience and accessibility among other benefits, does present limitations that impact its effectiveness (Kikuchi *et al.,* 2022).

A) Quality of Instruction and Feedback

An important limitation regarding the use of online PA programs related to the decrease in interaction between instructors and participants, in comparison to face-to-face PA protocols. This can decrease the reduced quality of instruction and feedback, which can negatively impact participant technique and motivation (Peterlin *et al.,* 2024*).* A study conducted by da Silva *et al*., (2022), showed that participants reported difficulties in adapting to proper PA techniques when using online PA platforms. These difficulties were attributed to a lack of real-time instructor feedback which plays a crucial role in the PA execution, which directly impacts PA adherence and could lead to injury (da Silva *et al*., 2022).

B) Lack of Personalisation

Online PA platforms especially those that do not include live instructor feedback, are designed in a generalised format, which suits the estimated PA needs of a specific population group (Kemel *et al.,* 2024). This generalised approach has a negative impact on PA engagement as it does not address the specific individual participant needs required to effectively change PA behaviour (Kang and Kim, 2017). The lack of personalisation prevalent in online PA programs has the potential to decrease PA levels, due to participants feeling either overwhelmed or under-challenged when engaging with the online PA content (Kemel *et al*., 2024). This can lead to a decrease participants motivation thus, negatively affecting the adherence to online PA interventions (Behzadnia *et al.,* 2018).

C) Increased Sedentary Behaviour and Decreased Social Interaction

Studies have indicated that excessive reliance on internet-based platforms can inadvertently

reduce overall PA levels due to increased levels of screen exposure (Ji *et al*., 2024). Screen exposure has been associated with increased sedentary behaviour. As such, the use of online PA programs can encourage screen exposure, thus, influencing sedentary behaviour and decreasing social interaction (Almeheyawi *et al*., 2024). This lack of social interaction negatively impacts the sense of community and accountability that traditional group settings provide. Thus, diminishing mental and social well-being despite some improvements in physical health (Kemel *et al*., 2024). These limitations underscore the need for hybrid approaches that combine the accessibility of online programs with the benefits of in-person engagement.

2.2.3. Increased Popularity of Online Physical Activity

As the years have progressed and the dynamics of everyday life evolved, many circumstances have brought to light the need for online PA protocols:

A) Increased levels of Inactivity

Recently conducted studies have indicated that a significant percentage of the global population can be classified as inactive (Hall *et al.,* 2021). Individuals across all age, race and sex categories have be reported as non-compliant with the WHO PA recommendations (Woessner *et al.,* 2021). Based on the benefits of regular PA, this lack of PA engagement has the potential to have detrimental effects on the physical and mental health of the general population (Amini *et al.,* 2021). Hence, there is a distinct need for the development and implementation of innovative and convenient PA strategies. The use of online PA can deliver PA opportunity in populations where inactivity is rife (Silva *et al.,* 2021). Mclaughlin *et al.,* (2021), suggested that online PA programs have the potential to have a positive impact on overall PA levels, which can combat high levels of physical inactivity. A study conducted by Damen *et al.,* (2020), showed that digital PA programs can be integrated into workplace interfaces to address inactivity that occurs during work hours.

B) Technology Progression

As the world progresses towards further integration of internet use in daily functioning, and with the advancements in technology that occur on a regular basis, it is imperative that the PA sector advances as well (Woessner *et al.,* 2021). The increased use of internet and digital platforms allows for an opportunity to increase PA awareness and PA engagement among a variety of populations throughout the world (Bull *et al.,* 2020). The constant technological

advances and their relevance to the field of PA, consistently increase the accessibility, usability, and effectiveness, of online PA interventions especially in remote settings (Skjæret *et al.,* 2016). These technologies allow for better PA tracking, PA related social interactions and PA motivation techniques, to reach individuals from different socioeconomic levels (Katz and Marshal, 2018). Sullivan and Lachman (2017), indicated that the evolution of PA related technology in accordance with behavioural strategies has a greater benefit with regards to improve overall PA participation. The growth and development of technology, has made tremendously progression over the years and future developments have the potential to further facilitate and enhance improved PA and other positive health behaviours (Lupton, 2020).

C) Vulnerable/marginalised groups

There are certain populations who have a greater disadvantage with regards to access to PA facilities. Older adults are an example of such a population (da Silva *et al.,* 2022). Research suggests that the age and physical activity are inversely proportionate, in that an increase in age tends to result in decreased levels of PA (Kwasniewska *et al.,* 2016). This has been attributed to several factors, decreased physical capability, socioeconomic barriers and a lack of social support (Cunningham *et al.,* 2020). For this particular population, the use of online PA can potentially increase engagement as individuals could access programs remotely (Wilson *et al.,* 2021). Considering the benefits of PA and the increased risk for chronic illness with age, this avenue needs to be explored especially considering the changes in demographics, which shows a projected increase in the size of the older population in the coming years (United Nations, 2023).

Another population that could benefit from access to online PA programs is those who live in remote locations (Sallis *et al.,* 2016). In these instances, the distance between residential dwellings and traditional PA establishments is too large for individuals to travel (McCormack *et al.,* 2023). Hence, online PA programs especially in light of growing internet accessibility throughout the world, could offer the benefits of PA without the need for increased traveling (Barnett *et al.,* 2017).

Those with chronic debilitating diseases such multiple sclerosis can also benefit from online PA interventions to assist in increasing movement, whilst taking into considerations the limitations that exist with regards to accessing regular PA facilities (Kaur *et al.,* 2024). Online app-based protocols have also been shown to be more effective in improving at home PA in patients with musculoskeletal conditions (Lambert *et al.,* 2017).

D) Adaptability to Periods of Crisis

There are specific scenarios when access to traditional face-to-face PA establishments may be compromised by external factors such as natural disasters, political disturbances, and states of emergency (Bertrand *et al.,* 2021). In these situations, PA engagement and its benefits should not be neglected, and can be encouraged through online PA platforms. The most recent and relevant example of such a scenario was the SARS-CoV-2 pandemic (Slater *et al.,* 2020) where individuals could not access PA facilities due to restrictions on mobility of the general population (Hammami *et al.,* 2022). A study investigating the adaptability of digital during crises indicated that these platforms have the ability to increase PA and control weight gain during instances where regular PA cannot be accessed (Dor-Haim *et al.,* 2021). Another study indicated that the use on online PA tools can assist in improving PA thus eliciting physical and mental health benefits, during the SARS-CoV-2 pandemic and any future pandemics of similar nature (Hermassi *et al.,* 2021). This adaptability provides the basis for the inclusion of online PA engagement in the protocols and planning for future pandemics and pandemic like crises (Dor-Haim *et al.,* 2021).

2.3. Key Theoretical Constructs in Physical Activity Interventions

The efficacy of online physical activity programs requires the development of such programs to be based on firm theoretical foundations. Several theoretical models have been applied to understand and influence physical activity behaviour in age of digital fitness.

2.3.1. Social Cognitive Theory (SCT)

A) Self-Efficacy

Self- efficacy is a component of SCT that is based on an individual's belief in their ability to perform goal orientated behaviours (Schunk and DiBenedetto, 2020). Researchers have concluded that increased levels of self-efficacy are directly associated with increased physical activity participation (Lewis *et al.,* 2016). A study found that including self-efficacy related SCT factors in the constructs of PA interventions, resulted in improved PA engagement and positive dietary changes in patients with Type 2 Diabetes. This highlighted the positive role played by self-efficacy in changing PA behaviour (Sebastian *et al.,* 2021).

Romeo et al (2021), conducted a study that examined the use of self-efficacy principles in the smartphone delivered PA interventions, by including aspects of goal setting. This study

concluded that there is a directly proportional relationship between SCT application and increasing PA participation. A different study indicated that increasing self-efficacy leads to increased program enjoyment which enhances PA program participation (Jönsson *et al.,* 2018).

B) Social Support

The availability of social support structures has been known to have a remarkable impact on the thought processes and behavioural patterns across various aspects of physical and mental health (Harandi, *et al.,* 2017). Increased social support has been associated with increased motivation to perform PA and PA related tasks. (Lindsay Smith *et al.,* 2017). Research in the field of behavioural changes in relation to online PA interaction, has shown that there is a strong link between increased social support and increased PA levels (Beauchamp *et al* 2019).

Kelly et al (2017), concluded that social support can improve PA which can lead to improved cognitive function in older individuals and recommended that future studies include the use of social support constructs in an attempt to understand these relationships more thoroughly. Aspects of social support can be included in online PA interventions by means of chat groups, social media sharing and online group sessions, which create a sense of community and increase the motivation to participate (Pope *et al.,* 2019). Hence, it can be concluded that online PA interventions that include factors encouraging social support have increased intervention interactions (Beauchamp *et al.,* 2019).

C) Outcome Expectations

The concept of outcome expectations, addresses the natural process of an individual relating specific consequences to their behavioural changes (Lent *et al.,* 2017). With regards to PA, these expectations can directly affect the individual's motivation to be physical active and to maintain recommended PA levels. The literature states that by associating positive outcome expectations with PA engagement, researchers may increase the participation in PA programs thus positively impacting PA levels (Rhodes *et al.,* 2019).

Online PA programs that aim to improve participants' outcome expectations as a means by which to enhance PA participation have been effective in increasing markers of physical well-being, in patients with Type 2 Diabetes (Sze *et al.,* 2023). Ku and Leung (2024), stated that the use of aspects of SCT such as outcome expectation measurements within online PA programs can increase the effectiveness of such programs.

2.3.2. Self-Determination Theory (SDT)

A) Intrinsic Motivation

Intrinsic motivation makes references to the physiological motivational factors that affect one's behaviour based on the enjoyment, and benefits that directly affect the individual well-being (Hosseini *et al.,* 2020). In a study that investigated the concepts autonomy, competence and relatedness, in relation to PA participation, indicated that addressing these crucial elements when designing PA intervention can increase the intrinsic motivation to engage with PA (Behzadnia *et al.,* 2018).

A different study investigating the effects of intrinsic motivation on PA, revealed that interventions encouraging intrinsic activity as a basis for improving PA behaviours, show enhanced PA participation (Knittle *et al.,* 2018). Additionally, a study investigating the role of autonomy to enhance intrinsic motivation, indicate that the relationship between autonomy and intrinsic motivation has a positive impact on the PA interactions and can initiate the development of long-standing PA behaviour changes (Kalajas-Tilga *et al.,* 2020).

B) Extrinsic Motivation

Extrinsic motivation refers to the external factors that motivate changes in individual behaviours, incorporating aspects such as ego and rewards (Hosseini *et al.,* 2020). A systematic review and meta-analysis conducted on the use of SDT considerations in the development of PA interventions can positively impact factors of extrinsic motivation to improve PA behavioural changes (Manninen *et al.,* 2022). A study investigating the effects of social media on extrinsic motivation for PA behaviour change, concluded that there is a potential positive relationship between increasing motivation using social media and increasing PA engagement and PA program adherence (Al-Eisa *et al.,* 2016).

The incorporation of extrinsic motivation aspects such as PA level tracking on public platforms, motivational interviews and community-based PA engagement, into online PA interventions, impacts long-term motivation for PA participation (Nuss *et al.,* 2021). Pope and Pelletier (2021), concluded that the inclusion of extrinsic motivational messaging in the design of PA interventions can improve program participation and retention.

2.3.3. Transtheoretical Model (TTM)

The transtheoretical model of behavioural change, stipulates that changes in behaviour are

premediated concepts that occur in association with a process of thought-provoking choices (Liu *et al.,* 2018). Zare *et al* (2016), conducted a study investigating the stages of change and its association with PA behaviour changes. This study concluded that the use of stage of change mechanisms in PA interventions can significantly improve PA participation by impacting the thoughts relating to perceived benefits of PA engagement (Zare *et al.,* 2016). A study conducted by Han *et al* (2017) to gauge the effects of TTM aspects on decreasing sedentary behaviour and increasing PA interactions, showed that individuals in the early stages of sedentary behaviour were less inclined change their PA behaviour than those in the late stages.

Jiménez-Zazo et al (2020), indicated that TTM strategies are useful in the development of PA interventions for older participants, and if applied sufficiently these strategies have the ability to change PA behaviour in the older population. In a different age group, targeting university students Kang and Kim (2017), stated that TTM constructs can adjust thought processes that positively impact PA behavioural decision making. The benefits and barriers associated with PA behavioural change linked to TTM constructs are individual specific as they relate to the PA stage of change that each individual belongs to. Hence, individualisation within TTM based PA interventions can lend to effectiveness and program adherence.

2.4. SARS-CoV-2

The SARS-CoV-2 pandemic emerged in the December 2019, in Wuhan, China (Hsu *et al.,* 2020). The virus which was similar to previously identified coronaviruses, and began to spread rapidly throughout the world and was declared a global pandemic by WHO in March 2020 (Adil *et al.,* 2021). SARS-CoV-2 was declared a highly contagious virus that replicated within the upper airways (Lamers and Haagmans, 2022) and spread via respiratory droplets and aerosol (Harrison and Wang, 2020). Symptomatic individuals presented with a range of symptoms from fever, fatigue, muscle aches, loss of taste and smell (Çalıca Utku *et al.,* 2020) and coughing to more severe such as pneumonia, respiratory distress and death (Madabhavi *et al.,* 2020). The severity of the illness varied from patient to patient. The trajectory of the infection was unpredictable with a large number of people requiring hospitalisation, intubation and ventilation (Tsai *et al.,* 2021). The reported global death toll from SARS-CoV-2 infections between January 2020 and December 2021 was approximately, 5.94 million (Msemburi, *et al.,* 2023). However, WHO reports indicate that due to underreporting of SARS-CoV-2 related deaths, the estimate death toll may be as high as 14.9 million globally (Taylor, 2022). Due to the highly infectious nature of the virus and the serious complications especially for those who

were immunocompromised (Hsu *et al.,* 2020), government authorities around the world implemented a series of lockdowns, which aimed to limit person to person contact, and decrease the infection and mortality rates (Pradhan *et al.,* 2020).

2.4.1. SARS-CoV-2 lockdown

Governments around the world employed strategies to curb the spread of the virus and to salvage incomes and livelihoods (Papadopoulos *et al.,* 2020). By April 2020, many countries had adopted customised versions of lockdown policies which mandated social distancing and mask wearing as well as prohibited international and national traveling (Koh, 2020). WHO, recommended that these lockdown measures should be applied to all non-essential groups of the population and that schools, businesses and any other non-essential public areas should be closed (Al Zobbi *et al.,* 2020). Gatherings even at private residences were limited, and the use of public facilities was prohibited (Xu and Li, 2020). Studies show that lockdowns were effective in reduces infection and mortality rates and some research concluded that strict lockdown measures implemented earlier in the country's SARS-CoV-2 timeline had a direct positive impact on the overall trajectory of the pandemic (Kharroubi, and Saleh, 2020 and Meo *et al.,* 2020). It was this rationale that formed the foundation of South Africa's response when the virus first immerged (Kavanagh and Singh, 2020).

2.4.2. SARS-CoV-2 in South Africa

In March 2020 South Africa (SA) saw its first case of SARS-CoV-2, which was a citizen who had returned from Italy following a vacation (Stiegler and Bouchard, 2020). As more positive cases were brought to light following this initial infection, the president and his task team decided that it would be best implement strict lockdown restrictions which began on 27 March 2020 (Carlitz and Makhura, 2020).

The lockdown strategy for South African consisted of five-levels, with varying restrictions. These levels were labelled numerically the level five being the strictest and level one being the closest to normal pre-pandemic daily functioning (Olivier *et al.,* 2020). Each level had a specific set of regulations attached to it and throughout the course of the pandemic, government officials decided on the evolution and timeframes for each level (Haider *et al.,* 2020).

Level Five

This lockdown level was initially implemented on 27 March 2020 and entailed completed

confinement of all non-essential work, services, movement, travel and gatherings. The consumption of alcohol, tobacco and tobacco like substances were banned (Greyling *et al.*, 2021) and any individual found in possession of or retailing these substances was considered in breach of law. Law enforcement personnel were instructed to ensure strict compliance with these regulations (South African Government, 2020). Essential workers such as health care providers, food retailers and essential municipal workers were allowed to travel from work to their place of residence, however, these workers needed to produce proof of their work status if so requested by a law enforcement officer (South African National Department of Health, 2020). The general public was allowed to travel only for essential functions, such as grocery shopping or to visit a health care practitioner and were also requested to provide proof of their reason for travel to any law enforces officer that they may have encountered (Naidoo and Naidoo 2022). All non-compliant individuals faced legal consequences that ranged from fines, to being taken into police custody (South African Government, 2020).

Level Four

Level Four lockdown was introduced in May 2020, following the initial surge of infections (South African National Department of Health, 2020). This level allowed for limited return of economic activity, where selective businesses were permitted to commence operations, provide they adhered to strict sanitisation and social distancing protocols (Donga *et al.*, 2021). Individuals were allowed to move around in public spaces within a specific radius from their homes, provided they maintained social distancing and remained masked at all times (Naidoo and Naidoo, 2022). Curfews for public road access were introduced in this level and any person found traveling beyond set curfews was required to produce legitimate proof of the essential reason for their movement (Moonasar *et al.*, 2021). Social gatherings and alcohol consumption were still banned in this level (South African Government, 2020).

Level Three

Level Three was implemented in June 2020, one month after level 4 was introduced (South African National Department of Health, 2020). This level saw further reductions in restrictions, where more businesses were allowed to return to daily operations, under the condition that social distancing, wearing of masks and proper sanitisation policies were employed (Greyling *et al.*, 2021). The ban on the sale and consumption of alcohol was adjusted to allow for sale with government specified timeframes and for consumption to occur purely on an individual's residence (Donga *et al.*, 2021). Essential travel between provinces was allowed during level

three. Social gatherings, restaurants, hotels and other tourism related facilities that allowed for groups of people to be in a single confined space were still prohibited (South African Government, 2020).

Level Two

Level Two allowed for further leniency with regards to the movement and interactions of the general population. This level was implemented in August 2020, two months following the introduction of level three (Carlitz and Makhura, 2021). During level two, there was a return to pre-pandemic retail operations, under the condition of strict mask wearing and sanitisation policies to be implemented by all business owners and to be adhered to by all patrons (Pillai *et al.,* 2020). The tourism sector was allowed additional leeway in the services it offered. Hotels and other accommodation facilities were allowed to offer their services to individuals traveling for business, whilst leisure travel accommodation remained prohibited (South African Government, 2020). The ban on social gatherings was adjusted to allow for certain gatherings to occur, under very specified conditions related to social distancing, mask wearing and sanitisation processes (Siedner *et al.,* 2020).

Level One

In September 2020, the country transitioned into level one lockdown, which allowed for the closest return to pre-pandemic functioning (Pillai *et al.,* 2020). Public facilities such as gyms, parks, beaches etc were reopened with strict SARS-CoV-2 health protocols remaining in place (South African National Department of Health, 2020). Level one was in effect until the emergence of new SARS-CoV-2 variants and their related surges in infections, hospitalisations and deaths, when there were transient returns to stricter levels of lockdown (Carlitz and Makhura, 2021).

2.4.3. Challenges faced by South Africa During SARS-CoV-2

A) Socioeconomic Challenges

Poverty and Inequality

A large portion of the South African population lives in poverty on a daily basis. The SARS-CoV-2 pandemic and the lockdown restrictions that were necessary to contain the spread of the virus, impacted the poor most severely (Mubangizi, 2021). The government made attempts to assist those most in need, however, these provisions did not alleviate the pressure felt by

individuals living in dire straits (Francis *et al.,* 2020). The poorer communities struggled with food insecurities (Hart *et al.,* 2022). Further to this, there are several communities within SA that are overcrowded and lack access to the basic facilities such as adequate water and sanitation (Scheba and Millington, 2018). These facilities were necessary for compliance with the government's recommended precautionary measures (De Groot and Lemanski, 2021).

The inequality in the education sector was placed under the limelight when, had to abruptly shift to alternative learning which placed underequipped schools and universities at a great disadvantage, thus compromising the quality of education occurring during the pandemic (Maree, 2022). This was further highlighted by a lack of technological skills in both educators and students at various study levels due to the inequality of technological resources and infrastructure (Adu *et al.,* 2022). Which was presented very prominent challenge was the unavailability of stable internet connections in certain parts of the country. This affected education, health and employment as most regular activities has shifted to digital platforms (Dube, 2020).

Economic Disruption

The rapid and strict restrictions imposed at the commencement of the SARS-CoV-2 pandemic in SA placed a strained economy under additional strain (De Villiers *et al.,* 2020). The strain on the economy coupled with employment instabilities began to plague individuals across many socioeconomic categories (Stiegler and Bouchard, 2020). Ikwegbue *et al* (2021), indicated that the small businesses of SA suffered the most as they remained out of operation for the longest period of time during the more stringent lockdown levels. This was exacerbated by the increases rates of unemployment due to the pressure placed on larger companies (Hamadziripi and Chitimira, 2021). Many sectors suffered, with tourism, transport, construction and textile being among the most affected (Mbandlwa, 2020).

Furthermore, the challenges experienced by SA's citizens and its economy was exacerbated by load-shedding due to limited electricity resources (Andrade *et al.,* 2020). These deficits enhanced the distress felt by South Africans during the SARS-CoV-2 pandemic, leading to an increase in social and political tension, which created the opportunity for politically driven acts such as the incidents of unrest, looting and violent protesting in July 2021 (Bhattacharya and Rach, 2021). These economic disruptions, were not limited to the immediate futures associated with lockdown restrictions, instead, they have rippled in the lives and livelihoods of individuals long after the pandemic restrictions ended (Schotte and Zizzamia *et al.,* 2023).

Supply Chain Disruptions

The supply chains and their relevant systems were not equipped for the rapid and drastic changes they were required to undergo. This placed additional burden on the supply chains which impacted the availability of the already limited resources need by the country to overcome this period of crisis (Pretorius *et al.,* 2022). Due to the increases demand and the decreased freedom of imports and exports during the SARS-CoV-2 pandemic, there was a disruption in the supply of much need pharmaceuticals at a time when the healthcare system was already overburdened and under immense pressure (Takawira and Pooe, 2024). Despite initial challenges at the onset of the pandemic, the food sector managed to cope better with the shift in the supply and demand ratio. The disruptions in this area were owing more to an imbalance between panic buying and a lack of buying ability due to the socioeconomic strains placed on individuals (Njomane and Telukdarie, 2022).

The supply chain lessons learnt from the disruptions during the SARS-CoV-2 pandemic are vital and need to be considered in the planning and frameworks used for policies in future instances of national and international crisis. (Nel, 2021)

B) Health System Challenges

Overburdened Healthcare System and Healthcare Inequities

The major challenges seen in SA especially during the stricter lockdown levels was a lack of resources (Mbunge, 2020). Even prior to the emergence of the SARS-CoV-2 pandemic the public health sector lacked the resources to cope with the needs of those who could not afford private healthcare (Abrahams *et al.,* 2022). The health sector found itself under additional pressure during the pandemic, which began presenting as inefficient laboratory and testing facilities (Dheda *et al.,* 2020).

Hospitals and other health care facilities were severely under-resourced, which led to further strain on the country's basic functions (Mbunge, 2020). An additional challenge identified was a reduction in the availability of ambulance and emergency medical care services during the pandemic. This stemmed from a lack of funding in the public sector, with private services being unaffordable for those who fell into a lower income demographic (Rapanyane, 2022).

The inequalities of the healthcare facilities were further highlighted due to the difficulty experienced in the communities with co-morbidities such as tuberculosis and HIV. These conditions are highly prevalent in SA and increased the risk of complications with SARS-CoV-2 infections. Due to the lack of sufficient healthcare systems these individuals could not access

their relevant therapies as easily, which increased their risks for disease progression and complications (Schlueter *et al.,* 2021). Nwosu and Oyenubi (2021), indicated that it is imperative for the inequalities in the health sector to be investigated and addressed in the planning for future states of crisis, like the SARS-CoV-2 pandemic.

Healthcare Worker Shortages

The SARS-CoV-2 pandemic brought healthcare worker shortages into the limelight and emphasised the need for the health sector workforce to be increased (Matseke, 2023). The shortage of healthcare staff coupled with the loss of large volumes of healthcare workers who succumbed to SARS-CoV-2 infections, resulted in the decreased capacity within healthcare facilities to provide basic services such as chronic condition check-ups and medication dispensing (Lalla-Edward *et al.,* 2022). The rural and disadvantaged communities suffered the most as there was a shortage of available healthcare workers to allow sufficient operations of outlying clinics and healthcare facilities (Mbunge, 2020).

Government decision makers need to consider the difficulties encountered by healthcare personnel during the pandemic to during policy formulations and implementations in the event of states of disaster in the future (Lalla-Edward *et al.,* 2022). There needs to be emphasis on preventing resignations of current healthcare workers and encouraging employment of new healthcare workers to ensure the health sector can function optimally (Matseke, 2023).

C) Public Health Challenges

Community Transmission and Adherence to Public Health Measures

A study investigating infection rates in SA indicated that there was a high SARS-CoV-2 infection rate in homes and areas where individuals lived in close proximity of each other, this was noted to be especially significant in the rural communities and informal settlements (Cohen *et al.,* 2022). A large portion of the country's population resides in the areas that are densely populated, which resulted in poor maintenance of significant social distancing during the pandemic proved to be difficult. This inadvertently increased the transmission of the viruses leading to increased infection and mortality rates related to SARS-CoV-2 (Smith *et al.,* 2024). Overcrowding in rural and peri-urban areas throughout SA increased the rates of transmission and also contributed to a decreased adherence to public health measures (David and Mash, 2020).

In a survey conducted by Majam *et al* (2021), during the initial lockdown restrictions adopted

by SA it was indicated that there was insufficient adherence to mask wearing, social distancing and isolation measure by the general public. Another study revealed that although there was good initial compliance with the public health measures, there was an inversely proportionate relationship between the length of the lockdown and the compliance with safety measures (Dukhi *et al.,* 2021). Coetzee and Kagee (2020), raised a valid and important concern in stating that although the compliance with measures was inconsistent and insufficient for many individuals this was due to a lack of basic support and infrastructure which was beyond the individual's control.

Vaccine Hesitancy

The introduction of SARS-CoV-2 vaccine availability was met with contrasting reactions from the public. There was a significant part of the population who were averse to accepting vaccinations for social and political reasons (Cooper *et al.,* 2021). Many individuals had concerns regarding the effectiveness and the side effects associated with the vaccine, with some worrying that these vaccines the benefits of vaccination did not outweigh the possible risks (Katoto *et al.,* 2022). There were some that that lacked literacy regarding vaccines and their mechanisms of action, which created room for the development of misconceptions regarding the actual function of a vaccination (Groenewald, 2022).

Wiysonge *et al* (2022), stated that the vaccination encouragement campaigns added to the vaccine hesitancy as it did not incorporate strategies that addressed community behavioural and social impact on individual decision making. Additionally, there were portions of the population that did not see the necessity of vaccinations due to their misinformation regarding the seriousness of the SARS-CoV-2 infection and its resultant complications (Engelbrecht *et al.,* 2022). Tiwana and Smith (2024), further included the discussion of the religious components to vaccine hesitancy, where some individuals believed that vaccinations direct opposed their religious beliefs, hence, were not willing to be vaccinated. Generally, the concerns that resulting in vaccine hesitancy were and still are multifaceted, and need to be addressed, sensitively so as not to further discourage those who are hesitant (Katoto *et al.,* 2022 and Wiysonge *et al.,* 2022).

D) Ethical Challenges

Balancing Public Health and Individual Rights

The lack of resources in the healthcare sector placed healthcare workers pressure to make

ethical decisions that they would not have to make under normal circumstances (Singh and Moodley, 2020). The allocation of resources and the basis of treatment had to be based on the patient's chances of survival, which placed SA along with the rest of the world in a state of ethical conundrum (Behrens, 2020). Additionally, as the lockdown restrictions continued to evolve, the inequalities highlighted earlier became more obvious, which resulted in the doubt as to whether or not the lockdown was more harmful than it was helpful to the country's most disadvantaged populations (Labuschaigne, 2020). Furthermore, the healthcare workers quickly reached a stage of working to save others, without sufficient protection for themselves due to a lack of protective resources such as masks and gloves, this created an ethical challenge as it was viewed to infringe upon the basic human right of the healthcare workers (Mavis Mulaudzi *et al.,* 2021).

When vaccines became available SA, faced an entirely new set of challenges that required ethical consideration. Despite the vast differences in the private and public healthcare sectors (Ayenigbara *et al.,* 2021). In accordance with the global plans, SA decided that the most ethical route to take would be a risk-based vaccination process (Forman *et al.,* 2021). This meant that those with the highest risk of infection, i.e. healthcare workers across all facets of healthcare were vaccinated first. This was followed by those in high-risk essential occupations, then the general population at higher risk of complications from SARS-CoV-2 infection (60 and older or those with existing co-morbidities) and finally all adults (Moodley *et al.,* 2021)

Prioritizing Access to Care

In SA there exists an imbalance in the healthcare facility access among disadvantaged populations (Rapanyane, 2022). During the SARS-CoV-2 pandemic this imbalance became more apparent due to the decreased access to other facilities such as public transport. Resultantly, these disadvantaged groups were further disadvantaged with a greater lack of access to care (McKinney *et al.,* 2021). Furthermore, those that could access facilities were deterred from doing so due to fear of contracting SARS-CoV-2 (Pillay *et al.,* 2021)

Healthcare practitioners working in the SARS-CoV-2 hospitals during the pandemic were placed in the position to make ethical decisions for patient care and access to treatment options based on patient risk profiles (Behrens, 2020). In a non-pandemic setting the access to such treatment options would not be limited to this extent, which meant that there was a huge ethical burden placed in the hands of clinicians (Naidoo and Naidoo, 2021).

Patients who could not afford private healthcare, had to utilise the public healthcare facilities

which was previously under resourced and could not cope with the additional burden of the pandemic (Moodley *et al.,* 2021). The government did attempt to remedy this by proposing private and public sector collaboration and by procuring additional resources, however, there were global shortages and even the private sector was struggling (Naidoo and Naidoo, 2021).

2.5. Physical Activity During the SARS-CoV-2 pandemic

2.5.1. Impact of SARS-CoV-2-Related Restrictions on Physical Activity Levels

A) Reduced opportunities for physical activity

The SARS-CoV-2 pandemic forced the world into a state of emergency, individuals from every facet of life were driven into survival mode where activities that were previously considered an integral part of normal daily living were paused indefinitely (Hsu *et al.,* 2020). PA engagement was one of the daily activities that suffered from the restrictions during the pandemic and this highlighted the need for the promotion of effective online PA interventions (Oliveira *et al.,* 2022). Researchers in the field conducted studies measuring the effects of the pandemic lockdown measures on PA levels (Violant-Holz *et al.,* 2020). These studies showed a marked decrease in PA engagement during the lockdown periods around the world (Robinson *et al.,* 2021 and López-Valenciano *et al.,* 2021).

Despite the benefits associated with regular PA, and the potential benefits PA engagement may have had on the risk of infection for and recovery from the SARS-CoV-2 virus, PA was not a priority during the initial responses to the pandemic (Hasson *et al.,* 2022). Hence, studies conducted during the lockdowns, consistently recommended an encouragement of regular PA, in order to ensure that individuals could still access some of the benefits associated with PA (Füzéki *et al.,* 2020 and Polero *et al.,* 2020).

B) Increased sedentary behaviour

A systematic review conducted by Stockwell et al (2021), concluded that there was a significant decrease in PA participation during the SARS-CoV-2 pandemic, which was accompanied by a significant increase in sedentary behaviours. The increase in sedentary behaviour noted during the SARS-CoV-2 lockdown periods were documented across a variety of populations throughout the world (Amini *et al.,* 2021). A study conducted by Werneck *et al* (2021), showed that these changes in PA opportunities led to increased screen time, which potentially affected mental health markers in the general adult population.

Romero-Blanco et al (2020), studied the changes in the PA engagement among university students during the lockdown and indicated that there was a significant increase in sedentary behaviour due to decreased social interaction leading to reduced motivation to move around.

Additionally, a different study conducted by Cheval *et al* (2021), stated that the increase sedentary time and the decrease in PA during the SARS-CoV-2 pandemic, contributed to a reduction in efficient stress management. Thus, indicating that increased PA may assist in stress management during crises such as pandemics (Cheval *et al.,* 2021)

C) Disruption of regular exercise routines

The SARS-CoV-2 pandemic and resultant movement restrictions, placed the world in a state of stasis (Shahidi *et al.,* 2020). Furman et al (2023a), conducted a study that investigated the context of intentional PA engagement during the SARS-CoV-2 pandemic and concluded that there was a substantial negative shift is PA during the pandemic was owing partly to the changes in the previously established exercise routines. A different study highlighted the manner in which the disruption in leisure time PA patterns negatively impacted PA engagement motivation, which inadvertently decreased the levels of leisure time PA during the pandemic (Furman *et al.,* 2023b).

These findings were supported by a study conducted by Ray *et al* (2023), that showed that the changes in daily routines, affected the PA routines which had the potential to increase weight gain and other health indicators such as blood glucose levels. The reduced PA levels and the increase sedentary time, together with the disruptions in exercise routines noted during the pandemic, have created the awareness for the development of mechanisms using technology to improve PA during periods of crisis (Newbold *et al.,* 2021).

2.5.2. Mental Health Benefits of Physical Activity During the SARS-CoV-2 Pandemic

A) Reduced anxiety and depression

The isolation and uncertainty experienced during the SARS-CoV-2 pandemic and its associated lockdown restrictions, increased the prevalence of depression and anxiety during this time (Ai *et al.,* 2021). Hence, the effects of PA on depression and anxiety as discussed earlier in this literature review, became an area of focus in pandemic related research. Maugeri *et al* (2020), showed that there was a significant decline in psychological well-being markers in relation to decreased PA levels during the pandemic. Another study indicated that engagement in light PA

during the pandemic lockdown restrictions, decreased markers of depression and anxiety caused by the isolation (Callow *et al.,* 2020).

Due to these potential benefits it was recommended that research in PA during the pandemic, aims to develop mechanisms that can deliver the mental health benefits of PA whilst maintaining the necessary public health measures (Dwyer *et al.,* 2020). Marconcin *et al* (2022), concluded that a positive link exists between increasing PA engagement during SAR-CoV-2 pandemic and improving depression and anxiety assessments. Another study, highlighted that the increased anxiety during the pandemic could act as a barrier to PA participation and encouraged further projects to aim at increasing PA motivation to overcome anxiety and increase PA levels (Marashi *et al.,* 2021).

B) Improved sleep quality

The increased levels of stress and the associated anxiety during the SARS-CoV-2 pandemic, had a negative impact on sleep quality (Martínez-de-Quel *et al.,* 2021). PA participation has been shown to improve sleep quality as already highlighted in this literature review (De Nys *et al.,* 2022). Hence, researchers indicated that the public health measure during the pandemic, created room for decreased PA opportunity thus, decreasing the quality of sleep during in the adult population during the pandemic (Martínez-de-Quel *et al.,* 2021). A study conducted by Igram *et al* (2020), revealed reductions in both sleep quality and PA during the lockdown restrictions and eluded that an increase PA may be beneficial in combating the reduction in quality of sleep.

Further to this there was an increase in screen exposure in students during the pandemic which had additional negative effects on sleep quality. Hence, the encouragement of PA during this time had the potential to improve sleep directly and indirectly by decreasing the amount of sedentary screen time (Guo *et al.,* 2021). The general recommendations from research investigating the benefits of PA on sleep, conclude that an increased PA engagement during SARS-CoV-2 had positive effects on sleep, hence increasing PA should be incorporated into the planning and frameworks for future periods of crisis (Chouchou *et al.,* 2021).

C) Enhanced cognitive function

In addition to depression, anxiety and sleep, the isolation and lack of interaction and movement during the SARS-CoV-2 pandemic affected the cognitive functioning of individuals, across

various ages (Ingram *et al.*, 2021). Chambonnière et al (2021), investigated the effects of isolation on the cognitive functioning of children and reported a noticeable reduction among the participants. This led to the recommendation for improved PA interaction to improve cognitive functions in children.

Studies that involved older participants during the pandemic to investigate the effectiveness of PA on cognitive decline, concluded that aerobic activities had the potential to improve cognitive function the older population (Wang *et al.*, 2023). Miyazaki *et al* (2022), supported these findings with a study they conducted on healthy older individuals, which yielded similar improvements in cognitive function, following an aerobic program aimed at increasing PA levels.

The increased physical inactivity during the pandemic, had an inversely relationship with cognitive function in healthy and previously impaired individuals (Chen *et al.*, 2021). Thus, most studies in this area, concluded that increasing PA during the pandemic had a positive effect on cognitive function, thus, increasing the need for PA encouragement to be included in the protocols for pandemics and other periods of isolation (Ingram *et al.*, 2021).

2.5.3. Online and Remote Physical Activity Interventions During SARS-CoV-2

A) Effectiveness of virtual fitness programs

In the setting of the pandemic and its resultant restrictions on non-essential movement, there was a significant decrease in the PA interactions. Several studies were conducted to investigate the effectiveness of digital fitness programs on PA levels. Liu *et al.,* found that there were improved PA levels in the general adult population in a study using fitness applications. Another study conducted on healthy elderly participants, concluded that live-streaming online PA programs have the potential to improve markers of physical well-being (Aksay, 2021). Furthermore, a study conducted by Moreira *et al* (2022), showed an improved quality of life in individuals who participated in an online workplace PA intervention. Vandoni *et al* (2022) conducted a study investigating the effects of supervised online PA, on the physical health markers of obese children. This study indicated a positive association between online PA and the body mass index (BMI), physical fitness and PA levels. A different study concluded that online PA programs can assist in the management of children with Type 1 Diabetes during isolation, thus, decreasing the risk of related complications (Calcaterra *et al.,* 2021).

Additionally, a study investigating the effects of online PA on the blood pressure (BP) of

pregnant females, indicated that regular PA participation via an online platform during the pandemic stabilised BP, thus, improving overall health outcomes (Silva-Jose *et al.,* 2021). Further to this, Pinto et al (2022) concluded that patients using online cardiovascular rehabilitation during the lockdowns showed significant improvements in cardiovascular functioning.

B) Challenges and barriers to online physical activity

The research on online PA during the SARS-CoV-2 pandemic yielded many beneficial results, however, there are some noteworthy challenges and barriers that need to be addressed in forthcoming studies. Ho and Merchant (2022), concluded that some older participants lacked technological skills that may be necessary for optimal online PA participation, whereas, others lacked the financial capacity to fully engage with online PA resources. The unavailability of sufficient internet access and digital technology infrastructures, was highlighted as an additional challenge especially in rural and outlying communities (Lai and Widmar, 2021).

A different study conducted by Gorzelitz *et al* (2022), indicated that a lack participant confidence and a concern for risks may present as barriers to effective online PA interactions. An additional barrier was presented by Richardson *et al* (2023), which stated that despite the benefits of online PA interventions, certain populations such as individuals that are visually impaired can struggle to access these programs, thus reducing access to PA benefits. Additionally, Ebert et al (2024), stated that the programs designed during the pandemic may require further investigations in order for their results to be applicable to future periods of crisis and isolation.

C) Innovative approaches to promote physical activity

The decrease in PA during the SARS-CoV-2 pandemic is well documented, and many recommendations have stemmed from studies investigating approaches that may be effective in promoting PA during periods of isolation. Rogers *et al* (2020), investigated the existing behaviours of adults with decreased PA, and concluded that there is a need to consider behavioural change techniques when formulating plans to encourage PA engagement.

A different study indicated that adults with co-morbidities were more likely to decrease PA, which placed them at further risk for the development of SARS-CoV-2 and other health complications. Hence, it was recommended that future techniques used to promote PA, focuses

on the element of participants' risk and behavioural change (Clemente-Suárez *et al.,* 2022). Further to this Marchant *et al* (2021), indicated that to increase the effectiveness of online PA programs, researchers must incorporate behavioural change techniques to assist in habit formation which can increase program engagement.

Some studies revealed that although the lockdown restrictions decreased regular PA, these restrictions also presented an opportunity for increased PA via other platforms such as online (Ng *et al.,* 2020). Parker et al (2021), showed that the use of online PA interventions can promote increases in PA during timeframes where conventional PA mechanisms are inaccessible.

2.5.4. Physical Activity and SARS-CoV-2 Recovery

A) The role of exercise in post-SARS-CoV-2 rehabilitation

Participation in intentional PA in the form of exercise and rehabilitation has been documented as beneficial in the recovery process following SARS-CoV-2 infection. In a study investigating the use of an online rehabilitation program for previously SARS-CoV-2 positive patients, it was concluded that patients responded well to online rehabilitation, with positive increases in physical functioning and other physical health markers (Estebanez-Pérez *et al.,* 2022). This was supported by a different study conducted by Estebanez-Pérez *et al* (2023), which showed significant improvement in the pulmonary, cardiovascular and overall health outcome measures in patients following SARS-CoV-2 infection. Salvador-Ruiz *et al* (2024) indicated that digital rehabilitation in patients with post-acute COVID syndrome, responded well to the digital program, thus improving their functioning and potentially improving their long-term complications. These findings were supported by those of Jimeno-Almazán *et al* (2021), which showed a reduction in post-acute COVID syndrome symptoms and improved recovery in patients who participated in an online rehabilitation program. Another study conducted by Kortianou *et al* (2022), that investigated the effects of customised virtual PA on the recovery of patients who had been hospitalised from severe SARS-CoV-2 infection, indicated a significant improvement in physical functioning in these individuals.

B) Physical Activity guidelines for SARS-CoV-2 survivors

Despite the many benefits associated with PA and physical health, due to the unpredictable long-term effects and recovery period associated with SARS-CoV-2 infection, research advises

that return to PA and related activities be done in a gradual fashion guided by exercise and healthcare professional (Halle *et al.,* 2021). A study conducted by Wittmer *et al* (2021), indicated that early, gradual mobilisation following a SARS-CoV-2 infection, can increase functionality and speed up recovery.

Cattadori *et al* (2022), added to these recommendations, by indicating that due to the uncertainty of long-COVID effects, before the commencement of PA, it may be beneficial for individuals to be assessed for cardiorespiratory functioning to prevent undesired side effects. A different study concluded that a well-rounded approach to rehabilitation that includes varying levels of individualised PA can improve the general well-being of patients, following SARS-CoV-2 infection (Jimeno-Almazán *et al.,* 2022). Whilst, another study indicated that even light PA engagement in combination with respiratory rehabilitations can enhance overall healing and improve outcomes in patients after testing positive for SARS-CoV-2 (Hekmatikar *et al.,* 2021).

2.6. Evidence-based Interventions

Evidence-based interventions (EBI) are tools used to inform evidence-based practice (EBP) in health and health related arenas (Wiltsey Stirman *et al.,* 2019). It is important that the interventions be based a thorough inspection of the literature, with identifications of gaps in the literature that could lead to the development of new knowledge or the growth of existing knowledge in a specific topic (Shelton *et al.,* 2018). EBIs leads to EBP, which considers the constantly changing landscapes of research, and contemplates the research pertaining to effectiveness, applicability, as well as, provider and participant perspectives, preferences and beliefs (Albarqouni *et al.,* 2018).

EBIs are interventions that have been meticulously tested and authenticated on the basis of scientific research. Typically, these interventions are based on experimental evidence indicating their efficacy in addressing specific health and health related issues (Rotheram-Borus, 2021). For an intervention to be classified as evidence-based, generally involves testing by randomised controlled trials (RCT), that present the evidence in a manner that can be applied and improved upon in future research and practice (Bhide *et al.,* 2018).

This process involves a series of steps that begin with inspecting the existing literature, identifying the area of need for improved EBIs, collating information specific to the involved population and performing RCT and other trials to ascertain the effectiveness of the interventions (Wiltsey Stirman *et al.,* 2019). The aim of this step-wise approach to creating

EBIs is to ensure that interventions are customised to suit specific populations in specific conditions (Alicia *et al.,* 2019).

Ultimately, these interventions need to add to the already established literature on a specific health related topic. EBIs are able to achieve this by creating the foundation for improved clinical practices that lead to improved health statuses (Wensing and Grol, 2019). Additionally, these interventions pave the way for future investigations by means of recommendations and guidelines emanating from their findings, thus building upon the literature supporting EBP (Nadalin Penno *et al.,* 2019). The results of EBIs assist in the development of frameworks and policies that aim to guide future practices based on effective and tested strategies (Kirchner *et al.,* 2020).

2.6.1. Designing Evidence-Based Interventions

The process of designing an EBI, requires researchers to take a systematic approach using various types of study methods. This includes:

Barrier Identification: Investigating and identifying the deficits present within the target population is the first crucial aspect of designing EBIs. This can be achieved by conducting studies such as participant interviews, focus group discussions and quantitative surveys (Croot *et al.,* 2019). These studies help the researcher gauge the views and opinions of participants whilst simultaneously identifying the gaps that exist in terms of intervention creation (Brown *et al.,* 2024).

Linking Barriers to Intervention Components: The gaps identified during barrier identification form the foundation upon which theoretical frameworks can be used to create intervention components that aim to address and mitigate the identified barriers (Colquhoun *et al.,* 2017). At this stage the use of behavioural change theories become paramount in the manner in which the intervention effectiveness is measured (Croot *et al.,* 2019).

User Engagement and Intervention Refinement: This stage builds on the theoretical frameworks by investigating the population involved to ensure that the intervention design has optimal acceptability and feasibility (Powell *et al.,* 2017). These investigations can lead to preliminary testing such as pilot studies and feasibility studies, which allow for feedback related adjustments to the final intervention (Powell *et al.,* 2019).

Intervention Implementation and Evaluation: The final stage involves implementing the intervention, analysing the findings, reporting the findings in relation to the existing literature

and identifying limitations and recommendations for future studies (Bhide *et al.,* 2018). This ensures that findings of the intervention irrespective of whether or not they support the hypothesis of the research will lead to future EBIs that are constantly evolving and improving EBP (Dunning *et al.,* 2019).

2.6.2. The Role of Systematic Reviews and Meta-Analysis in Informing Evidence-Based Interventions

Systematic reviews and meta-analyses play a vital role in the designing of EBIs and in guiding EBP. This study type allows for a structured aggregation and analysis of the existing literature in a particular research area (Chandler *et al.,* 2019). By providing a synthesis of evidence based on a particular topic, systematic reviews and meta-analyses, present the evidence in a single critically summarised document. This assists professionals in the clinical environment during decision and policy making processes (Garavito *et al.,* 2024). Systematic reviews and meta-analyses add to evidence-based interventions in a variety of ways.

Evidence Synthesis: These studies source and collate numerous relevant published articles according to a set of specified inclusion criteria, based on the relevant research question (Paez, 2017). This places researchers and clinicians in a position to fully understand the current evidence and effectiveness of the collated studies (Albarqouni *et al.,* 2018).

Guiding Future Research: In addition to sourcing and summarising the existing evidence, systematic reviews and meta-analyses allow for the identification of barriers and gaps as discussed earlier in the EBI design process. This adds to the literature by identifying areas where further investigations are necessary (Paez, 2017).

Quality Assessment: Systematic reviews and meta-analyses go beyond summarising and include the evaluation of study qualities which highlights the reliability and applicability of the results presented in the relevant individual studies. employ rigorous methodologies to assess the quality of included studies (Djulbegovic and Guyatt, 2017).

Policy Development: Systematic reviews and meta-analyses present a further benefit to the development of EBP, by creating a basis upon which existing challenges within a field can be addressed (Garavito *et al.,* 2024). These challenges and the presentation of the credibility of the literature within the field can inform decision making processes, which can directly impact on policy developments and implementations (Chandler *et al.,* 2019).

2.6.3. The Role of Surveys in informing Evidence-Based Interventions

Surveys play a vital role in contributing to EBIs, by allowing researchers to gauge target population specific details and perspectives. They enhance the process of data collection especially in large populations, whist maintaining a cost-effective approach (Shahmoradi *et al.,* 2017). The findings of surveys lead to collection of specified information on the needs for new intervention strategies, whilst allowing for the evaluation of the effectiveness of existing inventions. Practices (Albarqouni *et al.,* 2018).

Pilot tested surveys are tools that benefit researchers and clinicians in the identifying challenges, gaining insight on manners in which to remedy those challenges and assessing the effectiveness of the remedies implemented (Nayak and Narayan, 2019).

Surveys as Tools for Intervention Strategies: Surveys can be beneficial in several different settings and inform and enhance the implementation of improved EBP strategies (Avella, 2016). Surveys conducted at regular intervals can allow for longitudinal data collection and analysis which can contribute towards the development of policies within a specific field (Ball, 2019).

Including theoretical frameworks: The use of tailored questions within a survey based on the research questions, can assist researchers in introducing theoretical frameworks that shape desired behavioural changes required to elicit effectiveness of interventions (Atkins *et al.,* 2017). Hence, in additional to data collection, surveys can be utilised for producing changes in perceptions and behaviours (Hong *et al.,* 2017).

Enhancing Evidence-Based Decision Making: Surveys can further influence EBIs by assessing evidence-based decision-making strategies (De Marchi *et al.,* 2016). This can assist in the understanding the disparities in clinical decision making allowing for standardisation of healthcare approaches, which has the potential to improve EBP (Garavito *et al.,* 2024).

2.6.4. The Role of Randomised Controlled Trials in Informing Evidence-Based Interventions

A RCT is a type of study that is widely acknowledged as the gold-standard for clinically based research in various fields. RCTs are designed to ensure optimal credibility and to reduce bias in effectiveness studies (Webber and Prouse, 2018). These study types aim to investigate the cause-effect relationship to evaluate intervention effectiveness among randomly assigned participants into intervention and control groups (Spieth *et al.,* 2016). RCTs are commonly

associated with EBIs and EBP, and are known to produce scientifically sound results that can be used to address gaps and challenges identified in the literature (Bhide *et al.,* 2018).

Establishing Efficacy and Effectiveness: RCTs are the major study type utilised for investigating the effectiveness and applicability of interventions (Garattini *et al.,* 2016). Randomising participant group allocation limits bias and thus ensuring the documentation of more accurate intervention effects. These studies add significant knowledge to the available evidence within specific fields. Thus, making significant contributions to EBP (Zabor *et al.,* 2020).

Informing Policy and Practice: The findings from well-structured RCTs have the potential to influence clinical practice as well as lay the foundation for the development and improvement of healthcare policies, by applying results across similar populations and circumstances (Bhide *et al.,* 2018). Additionally, in instances where RCTs do not yield the expected results, the limitations from such RCTs can be used to guide future research in the related field (Deaton and Cartwright, 2018).

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CHAPTER THREE

SYSTEMATIC REVIEW

&

META-ANALYSIS

The effectiveness of online exercise on physical activity, motor function and mental health: A systematic review with meta-analysis

This chapter (Chapter Three) comprises a manuscript that is currently under by the Journal of Medical Internet Research. The manuscript is a systematic review and meta-analysis of the literature relating to online PA and the effectiveness of online PA interventions. By performing both a review and a meta-analysis the aim was to critically evaluate the current literature and provide a more quantitative approach to the assessment of the effectiveness of existing online PA interventions.

Manuscript Title: The effectiveness of online exercise on physical activity, motor function and mental health: A systematic review with meta-analysis

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The effectiveness of online exercise on physical activity, motor function and mental health: A systematic review with meta-analysis

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Abstract

Background: Regular engagement in exercise is associated with a multitude of physical and mental health benefits. In view of the technical progress, the ageing society and the recent public life restrictions during the COVID-19 pandemic, the delivery of interventions using digital devices has become highly popular. This systematic review with meta-analysis examined the effects of online exercise programs on physical activity (PA), motor performance, and mental health.

Objective: To conduct a PROSPERO registered systemic review and meta-analysis pertaining to online PA interventions and its effectiveness in healthy individuals with regard to physical and mental outcome measures.

Methods: A systematic literature search was performed using PubMed, Cochrane and Google Scholar. Randomized, controlled trials assessing the effects of online exercise (OE) vs. no exercise (NEX) or face-to-face exercise (FFE) in healthy adults were included. Effect sizes (standardized mean difference/SMD) were pooled using robust variance estimation and the certainty about the evidence was rated by means of the GRADE criteria.

Results: A total of 18 articles with moderate to high methodological quality (8/11 points on the PEDro scale) were identified. OE was superior to NEX regarding strength (SMD=0.61), balance (SMD=0.52), endurance (SMD=0.85), PA (SMD=0.46), depression (SMD=1.08), mood/emotion (SMD=0.47), mental wellbeing (SMD=0.79), and self-efficacy (SMD=1.1). Compared to FFE, OE was non-inferior for all tested outcomes. The certainty about the evidence was low to moderate.

Conclusion: OE represents an effective strategy to improve PA, physical function and mental health in healthy adults. However, in view of the partly limited certainty about the evidence, additional well-designed studies are warranted to further delineate the value of OE.

PROSPERO registration number: CRD42022338871

Keywords: Online physical activity, motor performance, mental health.

Introduction

Physical Activity (PA) has been demonstrated to represent a significant contributor to health[1]. Irrespective of the type of PA, its advantages are unanimously agreed upon as regular movement has been shown to decrease morbidity and improve prognoses in relation to a wide variety of pathologies[2,3]. Regular PA is, furthermore, linked to improved psychological wellbeing[4,5] and a lower incidence of mental disorders[6]. In recent years, however, the increasing time demands placed on the average individual have posed a definite threat to the ability to achieve the recommended levels of PA[7]. This is of utmost importance because sedentary lifestyle habits are a risk factor of major non-communicable diseases, such as diabetes, obesity, and hypertension[8-10] as well as of mental health conditions such as, depression and anxiety[11].

In view of the pivotal role of PA, the availability of exercise offers (e.g. gyms, sports clubs, public exercise facilities) is central to maintain public health. Yet, as the hallmark of the demographic change, the number of older people is expected to more than double within the next 25 years[12], meaning that more and more seniors with co-morbidities will require attention, supervision, and treatment. Of note, PA decreases with increasing age, which reflects a pressing need for novel and easily accessible PA platforms[13]. Further to this, there has been a shift towards individualisation in both, the society and healthcare[14,15]. All these issues highlight that exercise interventions be tailored according to the preferences of the indivual[15,16].

The onset of the SARS CoV-2 pandemic has been another accelerator to the development of digital exercise offers. The global population was denied access to exercise establishments in an attempt to curb the spread of the virus[17], which inadvertently forced otherwise physically active people into a state of inactivity[18,19]. This created a large demand for online programs, that were user-friendly, effective and, most importantly, allowed individuals from various fitness backgrounds to remain physically active without increasing the risk for contracting SARS CoV-2[20]. Online exercise programs have included simple pedometer tracking software, PA support forums, home exercise guidelines, PA reporting logs, structured virtual exercise platforms, and live-streamed workouts[21]. Alike programs have remained popular even though pandemic-related restrictions have been lifted. As vaccinations have formed a foundation for infection control, the virus continues to mutate, leaving room for future outbreaks that cannot be controlled without adjustments to the current vaccines, which may still require the need for social distancing in the future[22,23]. Hence the necessity for efficient online exercise programs remains relevant.

Two previous systematic reviews[21,24] found beneficial effects of online PA programs on a variety of outcomes. However, more than 10 years have passed since their publication. Furthermore, these articles either did not include a meta-analysis[21], combined healthy and diseased individuals[21,24], or did not report on possible changes in mental health[21,24]. This systematic review aimed to provide an up-to-date insight into the collective effectiveness of structured online exercise programs on PA, motor function and mental health.

Methods

We performed a systematic review with meta-analysis summarizing the effects of digital online exercise (OE) vs. no exercise (NEX) or conventional face-to-face exercise (FFE). Outcomes included markers of PA, physical function and mental health. The review protocol was prospectively registered in the PROSPERO database (CRD42022338871).

Date Sources and Source Strategy

Two independent investigators performed a systematic literature search using PubMed, Cochrane library, and Google Scholar. The search term was: "(exercise OR "PA") AND (internet* OR online* OR web* OR e-health OR digital OR tele* OR virtual) AND home*". Searches were limited to articles published from 1 January 2000 to December 2022. This range was chosen due the lack of suitable online technologies prior to 2000. In addition to database searches, the reference lists of all included studies were checked to identify further potentially eligible articles[25]. Article titles were screened manually using a Microsoft Excel spreadsheet, and duplicates were identified by arranging the spreadsheet in alphabetical order.

Eligibility Criteria

Studies were considered eligible for inclusion based on the following criteria; (1) randomized, controlled trial (RCT) design; (2) OE intervention with a duration of at least 4 weeks, (3) recruitment of healthy adults, (4) measurement of PA, motor performance and/or mental health surrogates; (5) publication in English language.

Study Quality, Risk of Bias and Certainty about the Evidence

Study quality was evaluated by means of the PEDro scale[26,27]. Two examiners independently rated each study and in case of disagreement, meetings were held to achieve consensus[28]. For the identification of a potential reporting bias, we used visual inspection of funnel plots. To classify the certainty about the evidence as very low, low, moderate, or high, the criteria of the GRADE working group were applied[29]. Briefly, the evaluation starts with the assumption of a

high certainty about the evidence due to the RCT design. The GRADE framework then suggests adjusting the certainty as follows: in case of risk of bias, imprecision, inconsistency of results, indirectness of the evidence, or publication bias, one point is subtracted for each weakness. In contrast, a large-magnitude of the effect or a dose-response gradient lead to an upgrade of the certainty rating[29].

Data Extraction

We extracted the following data: sample size, participant characteristics, interventions, measurements, and results (pre–post changes plus standard deviations of each intervention arm). The primary outcomes of the meta-analysis were PA, motor function (strength, endurance, balance, flexibility, gait, body composition) and mental health (depression, anxiety, mood/emotion, psychological well-being, sleep, self-efficacy). If a study performed more than one test assessing the same outcome, all effect sizes (ES) were obtained.

Data Processing and Statistical Analysis

For each trial arm, we extracted the mean baseline and postintervention values, pre-post changes, and the related standard deviations (SD). In case of incomplete reporting (i.e., missing SDs of the changes from baseline), the corresponding authors of the trials were contacted. If no values could be obtained, missing data were determined from figures or imputed according to Cochrane recommendations: $SD_{change} = \sqrt{(SD^2_{baseline} + SD^2_{postintervention}) - (2 \times Corr \times SD_{baseline} \times SD_{postintervention})}$, where Corr = 0.7. The value chosen for Corr represents a conservative estimate of the correlation between the baseline and post-treatment SDs[30].

Robust variance estimation random[31] was used to pool the standardized mean differences (SMD) and 95% confidence intervals for OE vs. NEX as well as OE vs. FFE. Dependency of ES was considered by nesting the term ‘study’ as a random factor in the model. The between-study variance component was determined by means of Tau^2, using the method-of-moments estimate; for within-study variance (more than one dependent effect size), ω^2 was calculated[32]. We interpreted resulting ES as follows: small (SMD = 0.2), medium (SMD = 0.5) or large (SMD = 0.8) [40]. The employed software was R (R Foundation for Statistical Computing, Vienna, Austria), packages meta (G Schwarzer) and robumeta (version 2.0)[33].

Results

The initial database searches yielded a total of n=6335 articles (Figure 1). After removal of duplicates and application of inclusion criteria, n=18 studies were included.

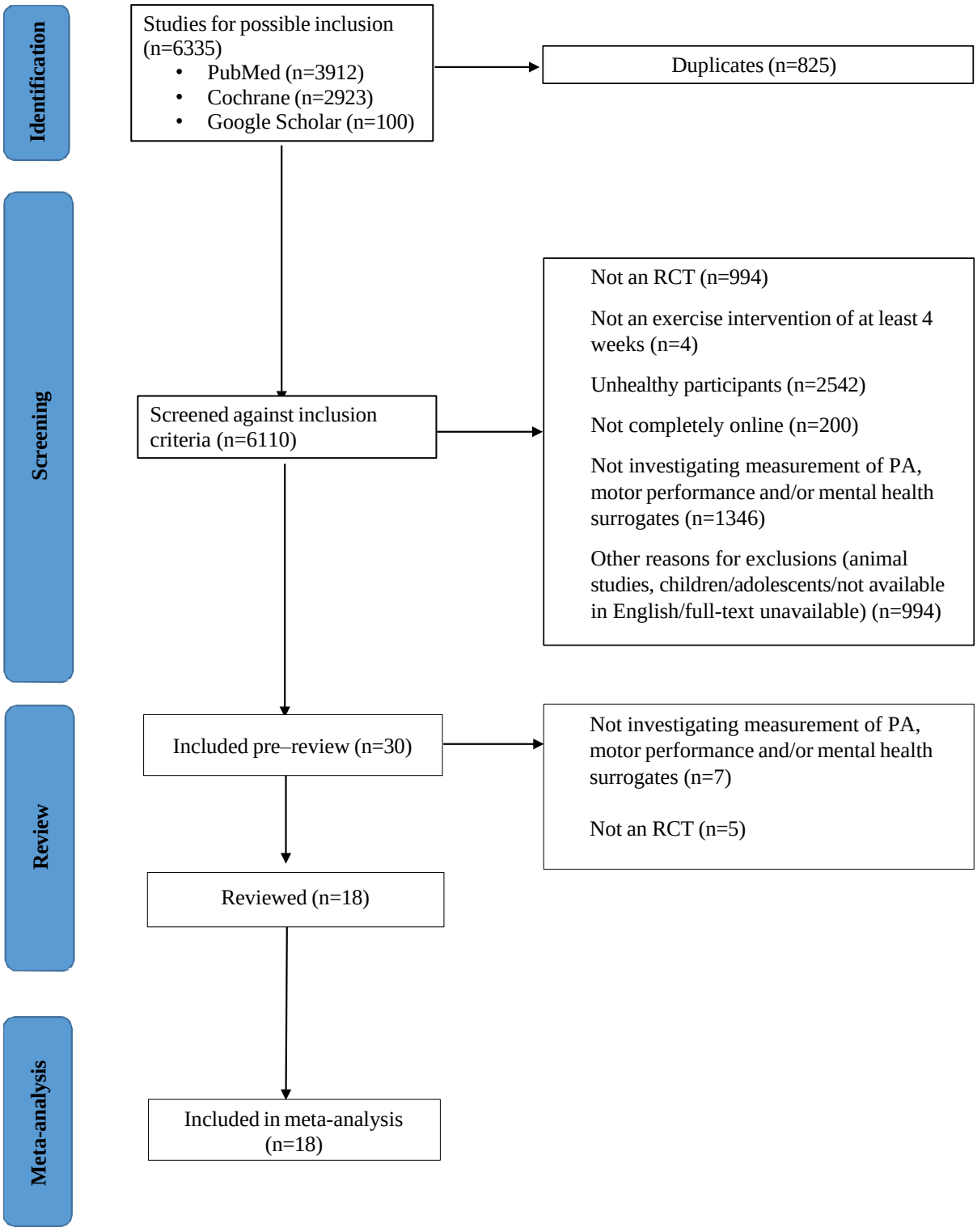

Figure 1: PRISMA Flow of the literature search

Study Characteristics

The characteristics of the 18 included studies, which included a total of n=3531 cumulative participants, are displayed in Table 1. Half (n=9) of the studies had participants that were older than 65 years, the remaining half (n=9) examined young or middle-aged adults. Five studies compared OE to FFE, while 12 investigated OE vs. NEX, and one compared OE to both FFE and NEX. Motor performance outcomes were assessed in 11 studies, PA was measured in 5 studies, and mental health was examined in 8 studies. The mean (SD) duration of the OE interventions was 12.5 (10.34) weeks and the mean (SD) training frequency was 2.7 (1.94) sessions per week.

Table 1. Study Characteristics of Included Studies

Study	*Sample*	*Intervention*	*Outcomes (Measurement Tools)*
Baez *et al* [2017]	n= 37 (27 W, 9 M) 71±6 years	Group 1: online personalised program with social environment for group exercising, messaging and persuasion features, 2x30-40min/week, 8 weeks. Group 2: home-based program, no social or individual persuasion features, 2x30-40min/week, 8 weeks.	Strength (*Leg Muscle Strength Score),* Gait Speed *(Time measured for normal gait)*
Beauchamp *et al* [2021]	n=241 (187 W, 54 M) 73± 5 years	Group 1: live-streaming, group sessions with a trainer, social breakout groups, 50-60min/session for at least 3xweekly, 12 weeks Group 2: live-streaming, individual sessions with a trainer, 50-60min/session for at least 3xweekly, 12 weeks Group 3: no exercise for 12 weeks, access to program at the end of 12 weeks	Depression (*CES-D*), Mental Wellness *(8-item measure on a 7-point Likert Scale)*
Chang *et al* [2022]	n=73 (56 W, 17 M) 70 ± 5 years	Group 1: live-streaming exercise, 70-90min/session, 8 weeks	Strength *(Chair Stand Test),* Endurance *(2-min Step Test),* Balance *(8-foot-up-and-go),*

		Group 2: no exercise for 8 weeks	Flexibility *(Back Scratch Test and Chair Sit & Reach Test)*
Dekker-van Weering *et al* [2017]	n= 36 (INT=12 W, 9 M) 71±4 years (CON=10 W, 5 M) 69±4 years	Group 1: live-streaming exercise, 3x30min/week, 12 weeks Group 2: no exercise for 12 weeks	Mental Wellness (*EQ-5D-3L)*
Hartman *et al* [2017]	n=205 (INT=104 W) 39±11 years (CON=101 W) 40±10 years	Group 1: accelerometer tracks PA, combined with goal setting, motivational messaging, 6 months Group 2: received general health tips such diet etc, no PA advice, 6 months	Physical Activity *(7-Day PA Recall)*
Jennings *et al* [2020]	n=1048 (INT=247M, 31 W) 75±7 years (CON=700 M, 70 W) 74±7 years	Group 1: live-streaming therapist led exercise, 1-9 sessions/week, 5 weeks Group 2: no exercise for 5 weeks	Strength *(Arm Curls, Chair Stand Test)*, Gait Speed *(Time measured for normal gait)*
Kikuchi *et al* [2021]	n=34 (INT=12 M, 11 W) 45±16 years (CON=3M, 8 W) 39±10 years	Group 1: live-streaming, 2x60min/week, 8 weeks Group 2: face-to-face, 2x60min/week, 8 weeks	Strength *(Maximum Voluntary Contraction, Isokinetic Strength, Grip Strength, Chair Stand Test, Push Up Test)*, Blood Pressure *(Systolic and Diastolic)*

Langeard *et al* [2022]	n=41 (OE=10 W, 3 M) 73±4 years (FFE=9 W, 6M) 72±4 years (CON= 8 W, 5 M) 74±4 years	Group 1: live-streaming with trainer, 2x60min/week, 16 weeks Group 2: face-to-face with same trainer, 2x60min/week, 16 weeks Group 3: no exercise for 16 weeks	Strength (*Hand Grip Test, Trunk Extension Test, Knee Extension Test, Knee Flexion Test & Lower Limb Power Test*), Endurance (*VO2 max measurement*), Body Fat *(Fat mass %)*
Marcus *et al* [2007]	n=249 (OES=68 W, 14 M) 46±9 years (OET=66 W, 15 M) 45±9 years (FFE=72 W, 14 M) 45±10 years	Group 1: online PA material with PA logs only Group 2: online PA material with PA logs, goal setting, motivational messaging and personalised feedback Group 3: face-to-face PA material with PA logs, goal setting, motivational messaging and personalised feedback	Endurance *(VO2 Max Measurement)*
Marcus *et al* [2016]	n=205 (INT=104 W) 39±11 years (CON=101 W) 40±10 years	Group 1: online PA material, combined with goal setting, motivational messaging, 6 months Group 2: received general health tips such diet etc, no PA material, 6 months	Physical Activity (*7-Day PA Recall and accelerometers)*, Depression *(CES-D)*, Mood/Emotion *(PACES)*, Self-Efficacy (*5-item instrument designed by research team)*

Napolitano *et al* [2003]	n=65 (9 M, 56 W) 43±10 years	Group1: online PA material including weekly health and PA related tip sheets, 12 weeks Group 2: no exercise for 12 weeks	Physical Activity *(Self-monitoring PA logs)*
Pressler *et al* [2010]	n=105 (12 W, 93 M) median age 48 (range 25-60) years	Group 1: online structured exercise, 3x30-70min/week, 12 weeks Group 2: online unstructured exercise, no schedule, no specified sessions/week, 12 weeks	Endurance *(VO2 Peak measurement and PMAX measurement)*, Blood Pressure *(Systolic and Diastolic)*, Body Fat *(Bio-impedance-monitor)*
Tekin & Cetisli-Korkmaz [2022]	n=255 (INT=72 M, 60 W) 68±4 years (CON=66 M, 57 W) 70±5 years	Group 1: online recorded videos, 5days/week, participants recorded themselves doing exercise and forwarded to researchers, 4 weeks Group 2: no exercise for 4 weeks	Strength (*SPPB Chair Test*), Balance *(SPPB Balance Test)*, Gait Speed (*SPPB Gait Test)*, Depression *(GDS*), Self-Efficacy *(MFES)*
Waden & Cartwright [2022]	n=34 (INT=17 W) 43±11 years (CON=14 W, 3 M) 42±10 years	Group 1: live-streaming yoga program, 2-3x50min/week, 6 weeks Group 2: no exercise for 6 weeks, access to exercises post intervention	Depression (*DASS-21*), Anxiety *(DASS-21)*, Mood/Emotion *(PSS-14)*, Mental Wellness *(WEMWBS)*, Self-Efficacy *(CSES-26)*
Wilke *et al* [2022]	n=763 (237 M, 523 W, 2 D, 1 U) 33±13 years	Group 1: live-streaming synchronous exercise program, with trainer, according to schedule, 30-60 min/session, 5	Physical Activity (*Nordic Physical Activity*

		days/week, 4 weeks, recorded sessions 4 weeks post intervention Group 2: no exercise for 4 weeks, access to recorded sessions 4 weeks post intervention	*Questionnaire*), Anxiety *(GAD-7)*, Mood/Emotion (*Self-Concordance Scale*), Mental Wellness *(WHO-5)*, Sleep *(MOS Sleep Scale)*
Wu *et al* [2022]	n=80 (34 W, 46 M) 23±3 years	Group 1: live-streaming exercise, 3x30min/week, 4 weeks Group 2: no exercise for 4 weeks	Endurance (*Running*), Mood/Emotion *(5-item Brief Symptom Rating Scale score)*, Sleep *(CPSQI Score)*
Yi & Yim [2021]	n=70 (INT=8 M, 27 W) 76±6 years (CON=4 M, 31 W) 77±6 years	Group 1: live-streaming exercise, 2x40min/week, 8 weeks Group 2: no exercise for 8 weeks	Strength (*5-times-sit-to-stand Test & Grip strength Test*), Endurance (*Timed Up and Go*), Balance *(Eye Closed postural Sway Tests)*, Gait Speed *(Gait Speed and 10meter Walk Test*)
Zengin Alpozgen *et al* [2022]	n=30 (INT=10 W, 5 M) 67±4 years (CON=7 W, 8 M) 69±6 years	Group 1: live-streaming sessions with trainer, 3x40-45min/week, 6 weeks Group 2: no exercise for 6 weeks, access to program at the end of 6 weeks	Strength (*Biceps Curl Test & Chair Stand Test*), Endurance (*2-min Step Up Test*), Balance (*8-step-up-walk*), Flexibility (*Sit & Reach and Back*

			Scratch Tests), Physical Activity *(Nottingham Health Profile)*

INT=intervention, CON=control, M=men, W=women, D=diverse, U=unspecified, OE=online exercise, FFE=face-to-face exercise, OES=online exercise standard, OET=online exercise tailored

Study Quality and Risk of Reporting Bias

Ratings on the PEDro scale ranged from 3 to 11 with a mean of 8.1±2.3 out of 11 points (Table 2). All studies reported between group statistical analyses for at least one key outcome measure. Almost all (94%, n=17) articles provided clear eligibility criteria; had intervention and control groups that were similar at baseline with regards to key prognostic indicators; and reported point and variability measures for at least one key outcome measure. A clear majority (83%, n=15) used randomised groups allocation whilst, 78% (n=14) ensured concealed group allocations. A slightly smaller share (72%, n=13) reported all participants receiving the intended intervention and the use of intention to treat in cases where participants did not receive the intended interventions; and reported outcome measures for at least 85% of the initial group allocations. In terms of blinding, 61% (n=11) of the studies reported participant blinding, 44% (n=8) indicated assessor blinding, and only 17% (n=3) stipulated therapist blinding.

Visual inspection of funnel plots yielded indications for a reporting bias regarding strength measures in OE vs. FFE and for mood/emotion in OE vs. NEX.

Table 2. PEDro scores of the included studies

	Baez *et al* [2017]	Beauchamp *et al* [2021]	Chang *et al* [2022]	Dekker-van Weering *et al* [2017]	Hartman *et al* [2017]	Jennings *et al* [2020]	Kikuchi *et al* [2021]	Langeard *et al* [2022]	Marcus *et al* [2007]	Marcus *et al* [2016]	Napolitano *et al* [2003]	Pressler *et al* [2010]	Tekin & Cetisli-Korkmaz [2022]	Waden & Cartwright [2022]	Wilke *et al* [2022]	Wu *et al* [2022]	Yi & Yim [2021]	Zengin Alpozgen *et al* [2022]
Eligibility criteria specified	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1
Random group allocation	1	1	0	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1
Allocation concealed	1	1	0	1	1	0	0	1	1	1	1	1	1	0	1	1	1	1
Groups similar at baseline regarding most important prognostic indicators	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1
Participant blinding	1	1	1	0	1	0	0	1	1	1	1	1	1	0	1	0	0	0
Therapist blinding	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
Assessor blinding	1	1	0	0	1	0	0	1	0	1	0	0	1	0	1	0	0	1
Measures of at least one outcome obtained from >85% of participants	1	1	0	1	1	0	0	1	1	0	1	1	0	1	1	1	1	1
All participants received treatment or control as allocated or data for >1 outcome analysed intention to treat	1	1	1	1	1	0	0	1	1	1	1	0	1	0	1	1	0	1
Results of between-group comparisons reported for >1 outcome	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Point measures and measures of variability for >1 outcome	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1
TOTAL PEDro Score	10	11	6	8	10	3	3	11	9	10	8	8	9	6	10	8	7	9

1=Yes, 0=No

Meta-analysis

Compared to NEX (Table 3), OE had a beneficial effect on measures of strength (SMD=0.61, 95% CI=0.06 to 1.15, *p*=0.04, moderate certainty about the evidence), balance (SMD=0.52, 95% CI=0.06 to 0.99, *p*=0.04, moderate certainty), endurance (SMD=0.85, 95% CI=-0.01 to 1.70, *p*=0.05, low certainty) and physical activity (SMD=0.46, 95% CI=0.05 to 0.87, *p*=0.04, moderate certainty). No difference was found for gait speed (moderate certainty) and flexibility (low certainty).

Table 3. Effects of online exercise vs. inactive control on markers of motor performance and physical activity

Outcome	*Studies (ES)*	*SMD (95% CI)*	*p value*	*Tau^2/$Omega^2$*
Strength	5 (12)	0.61 (0.06 to 1.15)	0.04	0.14/0
Endurance	5 (6)	0.85 (-0.01 to 1.70)	0.05	0.32/0
Balance	4 (9)	0.52 (0.06 to 0.99)	0.04	0.13/0
Gait	2 (3)	0.26 (-2.23 to 2.75)	0.41	0.03/0
Flexibility	2 (4)	0.74 (-6.32 to 7.80)	0.41	0.53/0
Physical Activity	5 (7)	0.46 (0.05 to 0.87)	0.04	0.07/0

ES=effect sizes, SMD=standardised mean difference, CI=confidence interval

With regard to mental health outcomes (Table 4), OE was superior to NEX for depression (SMD=1.08, 95% CI -0.01 to 2.16, *p*=0.05, moderate certainty), mood/emotion (SMD=0.47, 95% CI=0.05 to 0.90, *p*=0.04, low certainty), mental wellbeing (SMD=0.79, 95% CI=0.06 to 1.52, *p*=0.05, moderate certainty), and self-efficacy (SMD=1.1, 95% CI=1.03 to 1.17, *p*=0.06, moderate certainty). No effect was found for anxiety and sleep (p>0.05, moderate certainty).

Table 4. Effects of online exercise vs. inactive control on markers of mental health

Outcome	*Studies (ES)*	*SMD (95% CI)*	*p value*	*Tau²/Omega²*
Depression	4 (5)	1.08 (-0.01 to 2.16)	0.05	0.07/0.4
Anxiety	2 (2)	0.20 (-3.19 to 3.59)	0.59	0.10/0
Mood/Emotion	5 (10)	0.47 (0.05 to 0.90)	0.04	0.08/0
Mental Wellbeing	4 (5)	0.79 (0.06 to 1.52)	0.04	0/1.4
Sleep	2 (3)	-0.26 (-2.57 to 2.06)	0.40	0.05/0
Self-Efficacy	3 (3)	1.1 (1.03 to 1.17)	0.06	0/0

ES=effect sizes, SMD=standardised mean difference, CI=confidence interval

Regarding OE vs. FFE (Table 5), no difference was found for most measures (strength: very low certainty, endurance: moderate certainty, body fat: low certainty). However, gait speed improved more in OE (SMD=0.25, 95% CI=0.24 to 0.26, *p*=0.002, moderate certainty).

Table 5. Effects of online exercise vs. face-to-face exercise on markers of motor performance and body composition

Outcome	*Studies (ES)*	*SMD (95% CI)*	*p value*	*Tau²/Omega²*
Strength	4 (14)	-0.20 (-0.84 to 0.45)	0.41	0.13/0
Endurance	3 (4)	-0.04 (-0.34 to 0.27)	0.66	0/0
Gait Speed	2 (2)	0.25 (0.24 to 0.26)	0.002	0/0
Body Fat	2 (2)	-0.07 (-4.87 to 4.73)	0.88	0.18/0

ES=effect sizes, SMD=standardised mean difference, CI=confidence interval

Discussion

The manifold benefits of exercise have been repeatedly presented in the literature[1,2]. Recently, there has been a shift towards the use of online platforms aiming to provide easily accessible exercise opportunities to the general population[21,24]. To the best of our knowledge, this article is the most comprehensive and up-to-date quantitative summary of the available evidence. We show that OE is non-inferior to FFE and superior to NEX in a variety of measures of physical function, mental health, and PA.

Regarding motor performance, OE induced moderate-to-large improvements in strength, endurance, and balance, which accords with data from older reviews[21,24] In contrast, gait speed and flexibility did not change. This may be related to a lack of power as both outcomes were investigated in only two studies. For mental health outcomes, the very large positive effects on depression (SMD: 1.08) and self-efficacy (SMD: 1.1) were striking. A beneficial impact, although of smaller magnitude, was also observed for mood/emotion and mental wellbeing. While the sizable effects of OE on most psychological outcomes are in line with studies examining face-to-face exercise[34,35], the lack of a change in anxiety is a bit surprising because anxiety had been reported to improve in response to conventional exercise[36]. Again, the non-significant effect size may be due to the small number of studies (n=2).

Our results have implications for clinical practice. It would be reasonable to assume that exercise performed face-to-face would be the most effective way to improve health and performance. Yet, as we demonstrated non-inferiority of OE, the selection of the exercise mode may be left to the individual preference. Half of the studies reviewed (n=9) utilised older participants (>65 years). This is noteworthy because the projected change in demographics leaves older individuals at a higher risk for decreased PA[13]. Online PA interventions have the potential to provide these elderly persons with a safe, effective and accessible PA opportunity. As much as there is the limitation of digital literacy[37], research suggests that this limitation is improving.[37], hence, as the years unfold, the use of online PA interventions may become more beneficial and used in the older population[39]. Online exercise may also be of particular interest in rural areas where public PA infrastructure (e.g., availability of sports clubs, or gyms) is limited[40]. As the share of users with internet access is increasing steadily around the globe[41], OE may be of help in the fight against the pandemic of inactivity. Finally, OE can also help to reduce the direct costs of exercise as streamed contents would theoretically be available to an

unlimited number of individuals rather than being limited to those who can afford memberships in face-to-face PA facilities[42].

However, some caveats also require consideration. A large benefit of FFE is that coaches have a 3D view on exercising individuals which allows for an easier correction and monitoring of movement execution. While this is less a concern for healthy individuals, it may become relevant for elderly or diseased persons[43,44]. Another issue relates to inter-personal factors as sports and exercise cannot be reduced to their direct physical effects. When exercising in a group, social interaction can increase motivation or build friendships that could be of value in other aspects of life[45,46].

A particular strength of our review is that we only included RCTs, as this study type is viewed to be the most valid in the assessment of intervention effectiveness[47]. In addition, the mean PEDro score of 8.1 indicates a good overall quality, which adds to the validity of the findings. Notwithstanding, in about one third of the outcomes, the certainty about the evidence was low which was probably due to the small number of studies resulting in large confidence intervals, reporting bias and heterogeneity. We therefore reinforce the need for additional studies to fully gauge the long-term effects of OE[48-50]. This particularly applies because some of the studies included in our review were conducted during the SARS-CoV-2 pandemic and it is unknown how the specific conditions affected the overall result of the meta-analysis. It is imperative that more studies are conducted in a less volatile period to observe unbiased effects in relation to the everyday lives of individuals[51]. Finally, to reduce heterogeneity, we limited inclusions to studies with healthy participants. Further investigations are required to report specifically on the effectiveness and safety of OE in unhealthy participants as well as studies that include sub-analyses based on the type of OE used in interventions.

Conclusion

There is mostly moderate certainty-evidence that OE improves PA, motor performance, and mental health when compared to NEX. In addition, OE seems non-inferior to FFE. However, additional studies including larger sample sizes, longer study durations and long-term follow-up measurements are warranted in order to better delineate the benefits of OE interventions.

Declarations

Competing Interests None

Contributors JW was responsible for study design. AKB and JW were responsible for data collection and data analysis. AKB created the initial manuscript, which was read, revised and approved for submission by JW and JDP.

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CHAPTER FOUR

SURVEY

Physical activity levels during SARS-CoV2- pandemic: a focus on South African data from the 'Activity and health during the SARS-CoV-2 Pandemic' (ASAP) study

Chapter Two highlighted the current literature indicating the benefits of regular PA, the growing necessity for effective online PA interventions and the effectiveness of current online PA interventions. The systematic review and meta-analysis presented in Chapter Three also introduced the increased need for online PA that emerged during the SARS-CoV-2 pandemic. This chapter (Chapter Four) is presented as a published manuscript that reports a focused analysis of the South African data from the global 'Activity and health during the SARS-CoV-2 Pandemic' (ASAP) study. The global survey was an online survey conducted over the course of the government-enforced lockdown restrictions during the SARS-CoV-2 pandemic. The survey aimed to establish the level of change in PA during the lockdown restrictions and to assess the extent to which these restrictions affected PA opportunities and PA engagement. The research question for this survey, was "Has lockdown restrictions decreased PA engagement in the general adult population?".

The results of this survey served as a basis upon which the randomised controlled trial (RCT) discussed in Chapter Four was designed. This manuscript describes the changes in PA specific to South Africa compared to the generalised global findings. It also presents more context-specific limitations and recommendations.

Manuscript Title: Physical activity levels during SARS-CoV2- pandemic: a focus on South African data from the 'Activity and health during the SARS-CoV-2 Pandemic' (ASAP) study

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RESEARCH ARTICLE:

Physical Activity Levels During SARS-Cov2- Pandemic: A Focus on South African Data from the 'Activity and Health During the SARS-Cov-2 Pandemic' (ASAP) Study

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Abstract

In March 2020, the SARS-CoV2 pandemic emerged in South Africa (SA). Due to the highly contagious nature of this virus, the government employed lockdown restrictions to decrease the rate of infections and deaths. These restrictions prohibited the use of shared exercise facilities, which inadvertently decreased opportunity for physical activity (PA). This article provides a sub-analysis of the SA dataset within the worldwide ASAP study, specifically focusing on physical activity and compliance with the guidelines of the World Health Organisation (WHO) in SA. The study utilised an online cross-sectional descriptive questionnaire administered from 3 April 2020 to 9 May 2020, that evaluated PA volume pre and during restrictions using the Nordic Physical Activity Questionnaire-short (NPAQ-short), and WHO PA guideline compliance using a five-point Likert scale. The results revealed a decrease in overall moderate to vigorous and vigorous PA by 53.5% and 58%, respectively; 30% of the sample reported decreased WHO PA guideline compliance during lockdown when compared to compliance before lockdown. The lockdown measures adopted during the pandemic aided in decreasing the spread of the virus but contributed significantly to the decrease in PA among the healthy population. This decrease may have impacted individuals' health and increased the risk for non-pandemic related health conditions. Hence, PA and the availability and access to remote PA resources need to be considered in planning for future pandemics and natural disasters.

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Introduction

The health risks, associated with being physically inactive, have been researched extensively in the fields of physical and mental wellness over the years (Falck *et al*., 2017: 800; Saunders *et al*., 2020: 197). A lack of sufficient exercise increases an individual's risk of developing a variety of physical and mental ailments (Biddle *et al.*, 2017: 134). There is evidence to suggest an association between a lack of physical activity and the prevalence of lifestyle diseases such as hypertension, diabetes mellitus, cerebrovascular accidents and mental health conditions such as anxiety and depression (Biddle *et al.*, 2017: 134; Lear *et al*., 2017: 2643; Paudel *et al*., 2023: 921; Alley *et al*., 2018: 1). As much as the common focus is usually placed on the cardiovascular benefits of regular physical activity (PA) (Lear *et al.,* 2017: 2643; Paudel *et al*., 2023: 921), the advantages result in improved physiological functioning which may contribute to better overall health outcomes (Alley *et al.,* 2018: 1; Heath *et al*., 2012: 272). For example, studies have shown that increased PA volumes not only improve physiological processes, but also aid in the prevention and control of pathological pathways (Ficarra *et al*., 2022: 402; Xie *et al*., 2020: 4). These benefits are not limited to physical wellness, but have a significant positive effect on mental wellness (De Nys *et al* 2022: 1; Vancampfort *et al*., 2017: 1) in those without mental conditions as well as individuals who have existing psychological ailments (Patel *et al*., 2013: 766; Herbert, 2022: 1). The World Health Organisation (WHO), recommends a minimum of 150 minutes (min) of moderate PA or 75 min of vigorous PA per week, however, with the high physical and mental demands placed on the average adult, this minimum requirement can be difficult to achieve (Bull *et al*., 2020: 1451).

In March 2020 the first reported positive case of SARS-CoV2 presented in SA (Taylor *et al*., 2021: 50). The country found itself joining several other countries in the fight against this rapidly spreading virus as the global pandemic emerged. This novel virus threatened lives and livelihoods across all walks of life (Taylor *et al*., 2021: 50). Medical resources were strained and in order to prevent further rapid spread of the virus and to decrease mortality rates, political leadership around the world began to implement drastic lockdown and isolation measures as recommended by the WHO guidelines (Haider *et al*., 2020: 1). SA implemented a complete lockdown, where only essential workers and essential service providers were permitted to leave their homes (South African National Department of Health). Law enforcement officers were instructed to ensure that any persons found traveling in public were to produce proof of valid permits for their movement for the stipulated work activities that were permitted during the lockdown period (South African National Department of Health, 2020; Stiegler and Bouchard, 2020: 695). This lockdown period

began on 26 March 2020 and allowed for a full return to normal activities on 1 October 2021 (South African National Department of Health, 2020; Stiegler and Bouchard, 2020: 695; Donga *et al.,* 2021: 1).

During this lockdown period, there were several adjustments to the restriction parameters. These changes were implemented as lockdown levels (Level 5 to Level 1) (South African National Department of Health, 2020; Stiegler and Bouchard, 2020: 695), with modifications being made based on the severity of infection rates and the level of mortality rates as well as the general preparedness of the health care systems in the country (Naidoo and Naidoo 2022: 01). As the infection risks and mortality rates lowered, the lockdown levels were altered from Level 5, most stringent restrictions to Level 1, a return to normal activities with minimal to no restrictions (South African National Department of Health, 2020; Donga *et al.,* 2021: 1; Naidoo and Naidoo, 2022: 01). Access to regular exercise facilities was severely restricted, particularly in the early stages of the more stringent lockdown enforcement (Levels 3 to 5), due to the ease with which the virus could spread from the use of shared exercise equipment and surfaces (South African Government, 2020). The fact that individuals could not comfortably wear masks whilst exercising coupled with an increase in laboured breathing during exercise, meant that they could easily transmit respiratory droplets to other users of exercise establishments and onto equipment and surfaces (South African Government, 2020; You *et al*., 123). The foundation of implementing lockdown measures focused on minimising the spread of SARS-CoV2, however, these measures also had the potential to significantly impact the overall physical and mental wellness of healthy individuals by decreasing PA opportunities (You *et al.,* 2022: 123).

The 'activity and health during the SARS-CoV-2 Pandemic' (ASAP) survey was designed to evaluate the effects on PA engagement during active lockdown periods in several countries (Ammar *et al*., 2020: 1). It aimed to gauge the effect of these lockdown measures on individuals' PA levels, whilst also comparing PA levels preceding SARS-CoV2 to those during the lockdown timeframes to WHO guideline compliance (Wilke *et al* 2021a: 1; Wilke *et al*., 2021b: 1; Wilke *et al*., 2020: 1). This manuscript presents a detailed reporting on the data collected in the South African cohort of the global study.

Methodology

The original study used an online cross-sectional survey (ASAP) (Wilke *et al*., 2021b: 1) to evaluate the volume and type of PA performed by participants during the SARS-CoV2 lockdowns, from 3 April to 9 May 2020. The participants were adults older than 18 years of age, living or working in SA during the implementation of lockdown measures in response to the SARS-CoV2 pandemic, and had limited access to public exercise facilities or group exercise interaction. A convenience sampling technique (Etikan *et al*., 2016: 1) was adopted where participants were recruited using DUT Pinboards as well as social media

avenues such as Facebook and WhatsApp. The South African sample made up 3.4% (n=456) of the total global sample (n=13503) (Wilke *et al*., 2021b: 1). The components of the survey were planned and compiled by the members of the global research team. These components comprised three sections. The first section was dedicated to; demographic and general characteristics such as age, sex, work mode (remote work, office work, both remote and office work, no work, unspecified), work categories (full-time, part-time, unspecified), the presence of cold and flu symptoms, and the SARS-CoV2 test status where cold and flu symptoms were present; PA type and PA levels; compliance with WHO PA guidelines about the implementation of lockdown measures. The second section was, the Nordic Physical Activity Questionnaire-short (NPAQ-short), which assessed the amount of physical activity in minutes that participants were engaging in during the course of the lockdown measures and about the amount of physical activity they were engaging in for the same period before the start of lockdown (Wilke *et al*., 2021b: 1).

The NPAQ-short was chosen as it has been reported as a reliable measure of PA with WHO recommendations (Danquah *et al*., 2018: 1). This section of the survey recorded the participants' involvement in moderate PA (MPA) and vigorous PA (VPA) in minutes per week (min/week), during leisure and work time. For the NPAQ-short, MPA is considered any activity resulting in an increased heart rate and increased respiratory rate. VPA is defined as an activity that causes a high increase in heart rate in addition to sweating and breathlessness. The third section of the survey was a five-point Likert scale to evaluate the degree of change in total PA between the pre- and post- lockdown timeframes, with 'pre-lockdown' indicating activity before the onset of lockdown restrictions and 'post-lockdown' relating to activity after the onset of lockdown/during the lockdown period. This scale provided participants with 5 options to quantify the change in PA that ranged from a large decrease to a large increase. Once the questions, ratings and sections were decided on, the survey underwent a focus group assessment. The focus group was made up of a combination of health and physical activity experts as well as members of the general population. The focus group aimed at ensuring that the survey was easily understood. Following the necessary changes, the survey was finalised and was disseminated. The surveys were available to participants in English for four (4) weeks via the SoSci Survey interface. Ethical approval was obtained by the institutional research ethics committee at the Durban University of Technology, Ethical Clearance number IREC 090/20. Participants provided consent via a digital informed consent submission before being included in the study.

The statistical analysis encompassed both descriptive and inferential approaches to assess PA levels and compliance with WHO guidelines. Descriptive statistics, including mean and standard deviation (SD) were used to summarise the data based on its normality, which was evaluated using the Shapiro-Wilk

test. The study also reported counts and percentages for categorical variables such as age groups and sex. Inferential statistics included the Chi-square test for categorical variables and the t-test for numerical variables to compare pre-lockdown and post-lockdown PA levels. Additionally, the study employed multinomial logistic regression to model the odds of WHO guideline compliance across four categories (pre- and post-lockdown, pre-lockdown only, post-lockdown only, neither pre- nor post-lockdown) based on the independent variables of sex and age, providing insights into differential impacts of these factors on PA outcomes. Multinomial logistic regression was employed to model the impact of sex and age individually, and combined sex and age on outcome probabilities across three guideline conditions: pre-lockdown only, post-lockdown only, and neither pre-nor post-lockdown.

Results

As presented in Table 1, a total of 456 adults participated in the South African part of the ASAP survey. The majority of participants (n=257; 56.4%) were female with a mean (standard deviation (SD)) age of 33.3 (13.7). Males accounted for 199 (43.6%) of the total group, the mean age of which was 32.06 (14.8). A small group (n=21; 4.6%) presented with flu-like symptoms. Of these, only one (4.8%) participant tested positive for SARS-CoV2.

Table 1: General characteristics (n=456)

Sex % (n)		
	Female	56.4 (257)
Male		43.6 (199)
Mean age (SD) years		
	Female	33.3 (13.7)
Male		32.1 (14.8)
Mean age categories (SD) years		
18-29		22.1 (3.0)
30-39		33.9 (2.9)
40-49		44.7 (2.6)
50-59		53.7 (2.7)
60-69		63.4 (2.6)
70-79		71.0 (1.2)
Work Mode % (n)		
Remote (Home office)		46.3 (211)
Office		3.7 (17)
No formal employment		44.3 (202)
Both remote and office		2.0 (9)
	Unspecified	3.7 (17)
Work category % (n)		
	Full-time	39.7 (181)
	Part-time	8.8 (40)
	Unspecified	1.5 (7)
	Did not answer	50 (228)

Most of the participants (n=211; 46.3%) reported working from home during lockdown restrictions; nearly half the participants (n=202; 44.3%) reported not working at all, whilst a small number (n=17;3.7%) reported working from an office or outside their home and 9 participants (2%) reported working from home and an office. A small group (n=17; 3.7%) did not provide a response regarding their workload. Half of the total participants (n=228; 50%) did not respond to the work category section of the survey. Of the

remaining half (n=181; 39.7%) were working full-time at the time, 40 (8.8%) participants were working part-time. Seven (1.5%) participants did not specify their work category.

The study utilised participants' self-reported MPA and VPA provided in minutes per week (min/week) as a tool for the determination of PA levels. These measures were documented separately as MPA and VPA levels during leisure and occupational time, respectively. Table 2 reflects a summary of the findings.

Table 2: Physical activity levels pre - and post-lockdown restrictions

	Leisure time PA		**Work time PA**		**Total**	
	MPA (min/week)	***VPA (min/week)***	***MPA (min/week)***	***VPA (min/week)***	***MPA (min/week)***	***VPA (min/week)***
Pre-lockdown	216.2 (415.3)	105.9 (248.6)	141.0 (404.1)	53.2 (130.6)	357.2 (639.8)	159.0 (325.6)
During lockdown	113.1 (289.9)	42.8 (125.4)	53.10 (134.2)	24.0 (87.8)	116.2 (349.4)	66.8 (190.1)
Difference (Pre-Post)	-103.1 (278.6) *	-63.1 (200.9) *	-87.9 (384.7) *	-29.2 (131.1) *	-191.0 (547.2) *	-92.3 (295.1) *
% change	47.7	59.6	62.3	54.9	53.5	58.0

Mean (SD). MPA = moderate physical activity, VPA = vigorous physical activity, min = minutes. *=p<0.05

As shown in Table 2, the mean in min/week (SD) values for MPA and VPA during participants' leisure-time PA were 216.2 (415.3) and 105.9 (248.6), respectively before lockdown was implemented. These values decreased by 47.7% for MPA and 59.6% for VPA during the implementation of SARS-CoV2 lockdown restrictions. PA during work time was recorded as 141.0 (404.1) for MPA and 53.2 (130.6) for VPA before lockdown. During the lockdown period, there was a 62.3% decrease in MPA and a 54.9% decrease in VPA. The results for total PA, indicated a 53.5% reduction for MPA, whereas VPA reduced by 58.0%. Overall, the largest decrease (62.3%) was seen in the MPA - work-time category. A significant change (p=<0.001) in PA was noted across all categories (leisure-time PA, work time PA, and total PA) in the comparison of MPA and VPA measurements before and during the implementation of lockdown restrictions.

Prior to the implementation of lockdown measures the highest volumes of total MPA and VPA were reported in males (409.6 min/week and 198.4 min/week, respectively) who made up 43.6% of the total sample size. Males reported reductions across all categories of PA levels during the various lockdown categories, with MPA decreasing by 54.9%, 65.6%, and 58.7% for the leisure time PA, work time PA, and

total PA categories, respectively. Leisure time and work time VPA in males showed a decrease of 66.2% and 65.1%, whereas, the total VPA in men decreased by 65.8%. A similar pattern was observed in females who made up 56.4% of the sample, however, the overall percentage changes reported in females were less than those reported in males., i.e. females recorded a 39.6%, 59.6% and 48.3% decrease in leisure time PA, work time PA and total MPA, respectively. In the VPA category, females reported reductions of 52.0% and 41.5% for leisure time and work time, respectively, and a decrease of 48.7% for total VPA. The levels for MPA and VPA were statistically significant, p=0.004 and p=<0.001 respectively, between sex categories before the introduction of lockdown measures. Figure 1 illustrates the total PA levels for both MPA and VPA categorised according to sex-age groups.

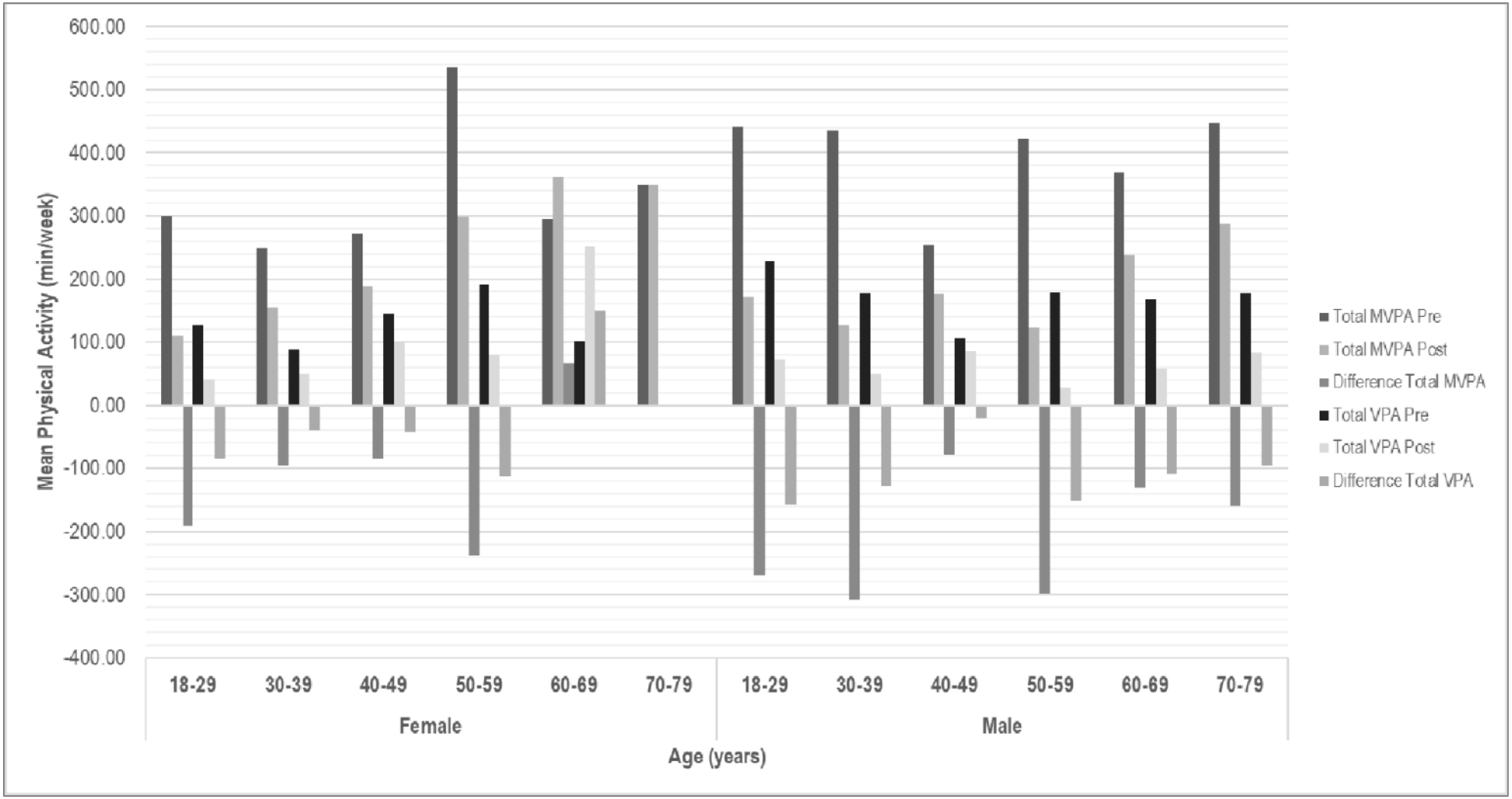

Figure 1: Total physical activity levels by sex-age groups

The findings comparing sex and age categories for total MPA and VPA volume revealed that females aged between 50-59 years had the highest MPA (536.0 min/week) and VPA (191.5 min/week) levels pre-lockdown, whereas females aged between 40-49 and 30-39 reported the lowest MPA (272.6 min/week) and VPA (88.3 min/week) levels pre-lockdown respectively. During lockdown, females reported decreases in total MPA and VPA levels in most age groups, with the greatest reduction being a 67.3% decrease in total VPA in females aged between 18-29 years. The smallest reduction was seen in total MPA levels in females aged between 60-69. Interestingly, the age group 60-69 (females) was the only category to more than double in total VPA volume during the lockdown period, showing an increase of 147.0%, whilst no change was noted in the 70-79 age group for neither MPA nor VPA. Males aged between 70-79 years reported the largest volume of MPA (447.5 min/week) prior to the onset of lockdown restrictions, whereas, the 18-29 age group reported the highest VPA levels (229.2 min/week). The lowest mean MPA and VPA values pre-lockdown in males were noted in the 40-49 age group, however, this age group also presented with the least percentage reductions in MPA (30.8%) and VPA (19.2%) during lockdown. Males aged 30-39 reported a 70.9% decrease in their total MPA levels, which was the greatest percentage shift noted for males in total MPA.

Statistical significance was noted as $p<0.001$ for MPA across all age categories. A pairwise comparison was then conducted using the Kruskal-Wallis Test to determine the between-group effects. The test showed statistical significance in only 4 comparisons: 18-29 – 60-69 ($p=0.047$); 18-29-50-59 ($p=<0.001$); 40-49-50-59 ($p=0.002$) and 30-39-50-59 ($p=0.008$).

Physical activity levels with WHO guidelines

The survey assessed compliance with WHO PA guidelines to gauge participants' level of PA engagement with what is prescribed to achieve and maintain healthy PA levels. The findings revealed that only approximately one-third (n=150; 32.9%) of 456 participants were compliant with WHO PA guidelines before and during lockdown implementation. Similarly, nearly one-third (n=137; 30%) met the WHO PA guidelines before SARS-CoV2 lockdown restrictions, however, were non-compliant during lockdown measures. There were 19 (4.2%) participants who were non-compliant before lockdown but became compliant during the lockdown. A total of 150 (32.9%) of the participants were non-compliant with WHO guidelines, before and during lockdown implementation. The overall comparison amongst the WHO compliance categories is statistically significant ($p=<0.001$), however, the significance lies in the comparison between the 'post' only group and the other 3 groups. When comparisons were conducted between the 'pre and post', 'pre-only', and 'neither pre- nor post' groups, insignificant p-values were obtained.

When categorised according to age, the results showed that the 18-29 age group was the most compliant with WHO guidelines among all the categories of lockdown measures. The 18-29 age group contributed to the guidelines categories as follows; pre and post: 63 (42%); pre-only: 75 (54.7%); post only: 9 (47.4%) and neither pre-nor post: 107 (71.3%). There was a general trend of decreasing adherence as age increased, with participants aged 70-79 showing the least adherence to guidelines in any category; pre and post: 3 (2%); pre-only: 1 (0.7%); post-only: 0 (0%) and neither pre-nor post: 1 (0.7%). A p-value of 0.001, suggests that the differences in adherence across age groups were statistically significant.

As shown in Figure 2, 82 (54.7%) and 73 (45.3%) of the participants who were compliant with WHO guidelines before and during lockdown were females and males, respectively.

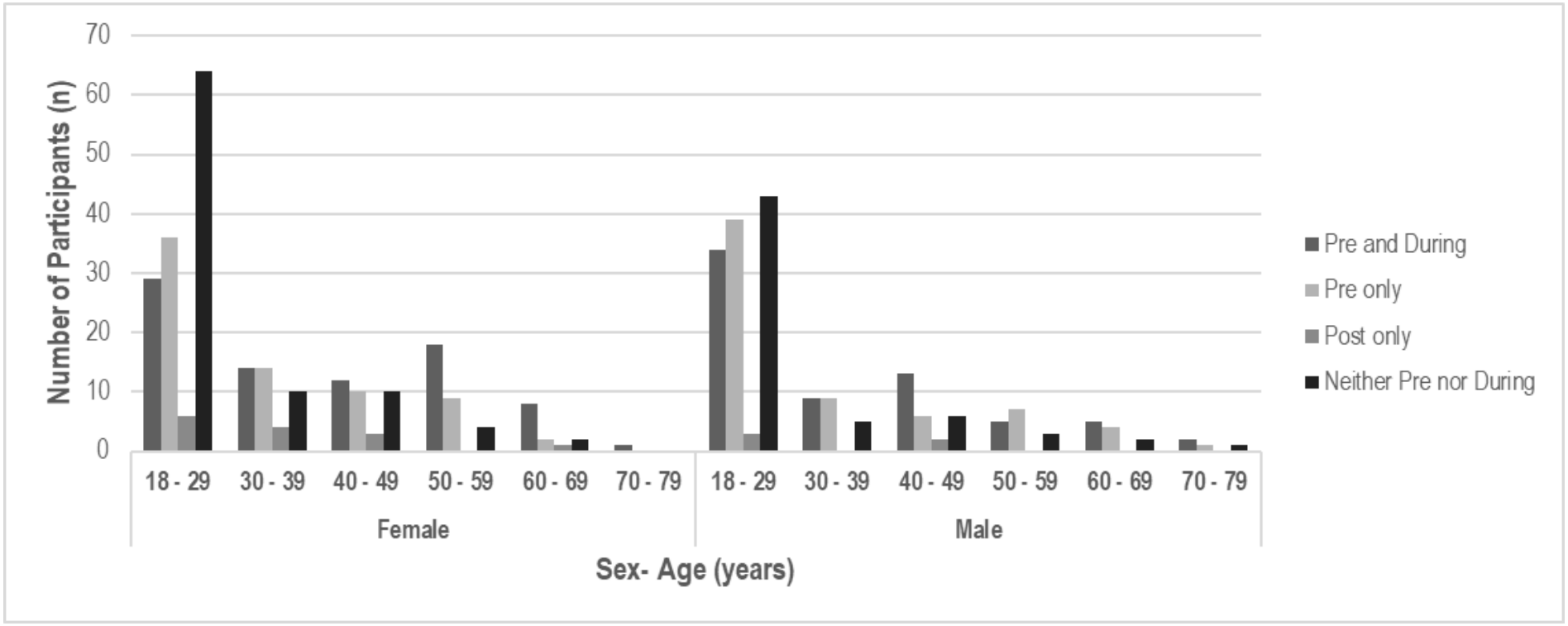

Figure 2: Compliance with WHO physical activity guidelines according to sex and age

Females appeared to be more likely than men to comply with guidelines across all age categories (p=0.002). A marked difference was noted between the number of females (n=14, 73.7%) and males (n=5, 26.3%) who were not compliant with WHO PA guidelines before lockdown, but became compliant during lockdown, although not statistically significant (p=0.217). Notably, the 18-29 category for both males (n=119, 59.8%) and females (n= 135, 52.5%) was the most compliant group in terms of meeting WHO guidelines across the comparison categories and the 70-79 category was the least compliant, with males reported as 4 (2%) and females as 1 (0.4%).

Logistic regression analysis

A logistic regression analysis (Table 3) examined the extent of interaction between sex, age and combined age and sex on the likelihood of participant compliance with WHO guidelines before and during lockdown restrictions. The reference category used for this analysis was the “pre and post” category as this would be most favourable in terms of adherence to WHO guidelines.

Table 3: Logistic Regression – sex, age, combined sex and age

Sex								
Guidelines Pre post[a]		B	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
							Lower Bound	Upper Bound
Pre only	[Sex=Female]	-0,114	0,232	1	0,630	0,892	0,561	1,419
Post only	[Sex=Female]	0,842	2,379	1	0,123	2,322	0,796	6,773
Neither Pre nor Post	[Sex=Female]	0,218	0,871	1	0,351	1,244	0,787	1,967
Age								
Pre only	Age	-0,020	5,760	1	0,016	0,981	0,965	0,996
Post only	Age	-0,017	1,024	1	0,311	0,983	0,951	1,016
Neither Pre nor Post	Age	-0,045	25,077	1	<0.001	0,956	0,939	0,973
Sex and Age								
Pre only	[Sex=Female] * Age	-0,023	6,677	1	0,010	0,978	0,961	0,995
	[Sex=Male] * Age	-0,016	3,417	1	0,065	0,984	0,967	1,001
Post only	[Sex=Female] * Age	-0,013	0,524	1	0,469	0,987	0,954	1,022
	[Sex=Male] * Age	-0,033	2,132	1	0,144	0,968	0,926	1,011
Neither Pre nor Post	[Sex=Female] * Age	-0,044	22,376	1	<0.001	0,956	0,939	0,974
	[Sex=Male] * Age	-0,047	21,477	1	<0.001	0,954	0,935	0,973

a. The reference category is: Pre and Post.

In the 'pre-only' category, the effect of age varied by sex. In females (sex=0.00) each additional year of age significantly reduced the odds of falling into this category by 2.2% (OR=0.98, p=0.010, CI:0.96–1.00), in other words, as age increased, the likelihood of meeting WHO guidelines pre-lockdown was reduced. In males (sex=1.00), each additional year of age also showed a trend towards reducing the odds of meeting WHO guidelines pre-lockdown by 1.6%, although this reduction was not statistically significant (OR=0.98, p=0.065, CI:0.97–1.00). In the 'post only' category, the changes in odds due to age also

varied by sex, but neither were statistically significant. Consequently, this implied that the likelihood of meeting WHO guidelines during lockdown was not affected by age or sex.

The 'neither pre-nor post' category showed a strong influence by age-sex interaction. For both females and males, each additional year (in terms of age) significantly reduced the odds of being categorised into this group, with females seeing a 4.4% decrease (OR=0.96, p<0.001, CI:0.94–0.97) and men a 4.6% decrease (OR=0.95, p<0.001, CI:0.94–0.97), i.e.as age increases, there is a decrease in the likelihood of not meeting guidelines pre-and-post-lockdown.

Discussion

Our re-analysis of the ASAP survey data (Wilke *et al*., 2020), focusing on the specific consequences of lockdown restrictions in SA, revealed that there was a distinct decrease in the amount of PA during lockdown when compared to levels before the implementation of lockdown restrictions. Our analysis showed that total MPA decreased by 53.5% and total VPA decreased by 58.0%. These changes in PA levels were higher than the percentage reported in the overall global ASAP survey results, which showed only a 41% reduction in MPA and 42.2% in VPA (Wilke *et al*., 2021b: 1). SA's reduction in total MPA and VPA was recorded as 1 of 4 countries with the largest reductions across the global study, the remaining three countries were Argentina, Brazil, and Chile. These four countries contributed to 21.4% of the combined global results (Wilke *et al*., 2021b: 1). Furthermore, among the countries that participated in the global ASAP survey, SA was one of the countries that reported the lowest pre-lockdown MPA and VPA volumes (Wilke *et al*., 2021b: 1).

The literature has shown that there are significant physical and mental health risks that are associated with decreased PA levels (Paudel *et al.,* 2023: 921), with the potential to exacerbate existing physical and mental health-related conditions, as well as increase the

risk for the development of pathologies in previously healthy individuals (Ficarra *et al*., 2022: 402; Xie *et al.,* 2020: 4; De Nys *et al*., 2022: 1). This, coupled with the overall increased mental load and uncertainty experienced throughout the world during the peaks of the pandemic, placed the general population at a higher risk of declining health. Studies investigating PA concerning its' benefits between males and females, have shown that despite the benefits associated with disease prevention and management, women do not engage in PA as readily as men do (Hugh-Jones *et al*., 2023: 1). This was reiterated in the significant differences in MPA ($p=0.004$) and VPA ($p<0.001$) between sexes, before the onset of lockdown, noted in our survey. Although there was no statistical significance generated between sexes during the lockdown stage of the survey (MPA p=0,461 and VPA p=0,163), the overall suggestion aligns with that of other studies which show that males are more likely to engage with PA than females are, thus potentially increasing the risk of health decline in females. (Vaccarezza *et al*., 2020: 1). When analysing age to PA changes, the survey results revealed significant statistical values among 4 paired age categories: 18-29 vs 60-69 ($p=0.047$), 18-29 vs 50-59 ($p<0.001$), 30-39 vs 50-59 ($p=0.008$) and 40-49 vs 50-59 ($p<0.002$). Studies have previously indicated a link between PA and aging, showing that increasing PA as an individual age has positive effects in preventing and managing the overall deterioration in mental and physical function (McPhee *et al.,* 2016: 567). Maher *et al.* (2015: 1407) suggest that as an individual becomes older their general well-being decreases and their predisposition to physical and mental conditions increases. However, regular PA practices have the potential to positively impact mental and physical well-being during the aging process (Marquet *et al*., 2020: 1). Hence, a decrease in PA during periods of lockdown may have a higher negative impact on older individuals.

The survey further assessed participant compliance with WHO PA guidelines and the compliance changes during the onset of lockdown restrictions. In accordance with the general decrease of PA during the restrictions 30.0% of the participants were WHO PA guidelines compliant before the implementation of SARS-CoV2 lockdown measures,

however, became non-compliant during the restrictions. The results further showed that 32.9% maintained PA levels according to WHO PA guidelines before and during SARS-CoV2 lockdown measures. A further 32.9% were non-compliant with WHO PA guidelines irrespective of SARS-CoV2 restrictions. A minor portion of the sample (4.2%) were compliant with WHO recommendations during the lockdown period but were non-compliant prior to the lockdown. Due to the effect that PA has on general well-being and the benefits associated with regular PA (Bowden-Davies *et al*., 2018: 1282; Stubbs *et al*., 2017: 545; Biddle *et al*., 2017: 134; Lear *et al*., 2017: 2643) the WHO has implemented guidelines for PA, these guidelines serve to inform good PA practices and encourage healthy levels of PA across sex and age groups, hence, non-compliance can increase the risks of developing mental and physical conditions.

The WHO PA guidelines compliance in this cohort across all categories was highest among males and females within the 18-29 age category, with a general decline in overall compliance noted as the age groups progressed. The least compliant group was 70-79 years, in both males and females across all compliance categories. Long-term decreases in PA are likely to affect the physical and mental well-being of individuals (Wilke *et al*., 2020: 1). There are significant amounts of literature that support the need for regular PA, and that document the adverse effects of insufficient PA or sedentary living (Garber *et al*., 2011: 1334). The findings of this survey suggested that sex alone cannot be linked to the likelihood of WHO guideline compliance. However, the statistics relating to age and sex, bring into focus a need for more tailored sex-age-specific guidelines to encourage compliance. These findings highlight the complexity of how sex and age together influence health outcomes in response to WHO guidelines, and compliance thereof. The significant effects in the "pre-only" and "neither pre-nor post " categories for both sexes suggest that age-specific and sex-specific strategies may be required to optimise guideline effectiveness. The consistent trend of age and sex impacting WHO PA guideline compliance underscores the need for further investigation into how these factors interact to

shape responses to health interventions, potentially guiding a more tailored approach to patient care.

The effects of insufficient PA levels extend but are not limited to the cardiovascular, neurological, endocrine, respiratory, and gastrointestinal systems (Chau *et al*., 2017: 617; Myers *et al*., 2019: 1; Vella *et al*., 2023: 132). The psychological impacts of PA and the lack thereof cannot be ignored either, as studies show a correlation between PA and conditions such as depression, anxiety, and mood disorders (Harridge and Lazarus, 2017: 152). SA is no exception, and local studies conducted have shown that there is a definite connection between insufficient PA and disease processes (Schuch and Vancampfort, 2021: 177; Micklesfield, 2021: 1), hence, the exaggerated decrease noted during the SARS-CoV2 lockdowns, raises the concern for further negative effects on physical and mental health conditions. Studies regarding SARS-CoV2 and how it's containment measures lead the way for protocol development for future pandemics, have concluded that social distancing and contact restrictions should be the basis for addressing any future pandemic emergence (Khanna *et al*., 2020: 702; Kolié, 2022: 1). Considering the obvious decline in PA noted in the global ASAP study (Wilke *et al*., 2021a: 1) and the specific South African results in this cohort, it is imperative to ensure that future global and local events requiring person to person contact restrictions do not impact the overall well-being of the general healthy population by impeding PA opportunities. The general findings of the South African data align with those of the overall global data, showing the need for effective PA resources for individuals who are not able to or simply do not want to participate in regular PA activities at regular PA establishments. This study and other studies like this have the potential to assist in the development of future frameworks and guidelines for PA during periods of isolation.

Our analysis adds to the global ASAP results by providing a deeper analysis of PA during the lockdown period in SA and, to the best of our knowledge, is the only study specifically

looking at this. Our analysis further provides likelihood ratios by way of a logistic regression with particular reference to sex and age concerning WHO PA guideline compliance.

Conclusion

The findings of the South African data align with those of the overall global data, showing the need for effective PA resources for individuals who are not able to or simply do not want to participate in regular PA activities at regular PA establishments. These results highlighted the need for improved PA mechanisms to ensure that individuals have access to viable PA options in the instances when regular PA activities may not be accessible or feasible. SARS-CoV2 and its resultant effects, have contributed to a foundation upon which the plans for any future health or environmental catastrophes will be developed. The basis for management during these future events rests largely on physical distancing and decreased interactions between individuals. This study highlights that, although physical distancing may prevent widespread disease progression, it may decrease well-being by impacting the accumulation of PA for individuals during lockdown periods. This study, and other studies like this, has the potential to assist in the development of future frameworks and guidelines for PA during periods of isolation. Hence the need for the development of tailored PA programs that may be accessed remotely. This would allow for the maintenance of WHO recommended PA levels and prevent the risks associated with sedentariness across age and sex during any future calamities requiring lockdown restrictions that limit individual movement.

As the South African cohort was part of a much larger international study, the results reflected an overall generic insight. This result could be improved by further PA and PA compliance studies targeting South Africans only, allowing for specific data collection and interpretation in the context of the country, its population, resources as well as social, cultural, and economic influences. A further limitation was that the survey did not fully consider the effect that the pandemic itself may have had on the participants' hesitance to engage in PA during lockdown, but instead focused more on PA opportunities during

lockdown restrictions. This limitation could be remedied in future studies by including participant-specific or open-ended questions around aspects such as hesitance. This report was not able to analyse the impact of 'remote' versus 'office' work on PA levels and WHO PA guideline compliance, particularly because a large percentage (44.3%) of the participants in this cohort were not working at all during the lockdown period. A further investigation and analysis of these variables could provide added insight into the changes reported in our findings.

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CHAPTER FIVE

RANDOMISED CONTROLLED TRIAL

The effectiveness of the 'Move ASAP' online exercise intervention during the SARS-CoV-2 pandemic: a focus on South African data from the multi-centre randomised controlled trial

The online survey ("ASAP" survey) presented as a published manuscript in Chapter Four highlighted a decrease in PA engagement during the lockdown periods of the SARS-CoV-2 pandemic. This highlighted the need for structured and effective online PA interventions.

The RCT ("Move ASAP") presented in this chapter (Chapter Five) was designed, based on the findings of the ASAP survey and aimed to answer the following research questions:

1. Will a structured online PA program increase PA engagement during the SARS-CoV-2 pandemic lockdown restrictions".
2. Will the South African cohort analysis yield similar results to those of the global 'Move ASAP' study?

The hypothesis for this RCT was that a structured online PA program will improve markers of PA and mental health indicators.

This chapter (Chapter Five) presents a manuscript (accepted for publication) that focuses specifically on the South African data from the Move ASAP study. It reports a re-focused analysis of the South African statistics in relation to the global report and provides South African-specific limitation and recommendations. The manuscript further presents drop out statistics, which aims to answer the research question: "What are the general characteristics of drop out participants in an online PA program?".

Manuscript Title: The effectiveness of the 'Move ASAP' online exercise intervention during the SARS-CoV-2 pandemic: a focus on South African data from the multi-centre randomised controlled trial

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The effectiveness of the 'Move ASAP' online exercise intervention during the SARS-CoV-2 pandemic: A focus on South African data from the multi-centre randomised controlled trial

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Abstract

The SARS-CoV-2 pandemic impacted health and well-being globally. South Africa, like other countries, had implemented movement restrictions starting from March 2020. These restrictions, as anticipated, decreased exercise uptake and consequently, physical activity (PA) levels. The 'Move ASAP' (Activity and health during the SARS-CoV-2 Pandemic) study was a global multicentred randomised controlled trial conducted during SARS-CoV-2 lockdown restrictions, that evaluated the effectiveness of an 8-week trial (4 weeks of active intervention and 4 weeks of recorded sessions), with virtual exercise sessions provided by a professional fitness trainer. This report focuses on the findings of the trial in a South African context, about PA and exercise motivation before and after the 4-

week active intervention. Moderate PA (MPA) and vigorous PA (VPA) were measured using the Nordic Physical Activity Questionnaire Short (NPAQ-Short) and the Self-Concordance Scale (SKK) was administered to determine exercise motivation. Results revealed decreases of 32.6% and 16.1% in MPA for the intervention (IG) and control (CG) groups, respectively. Between-group differences in MPA were not statistically significant (p=0.120). A 42.1% decrease in VPA in the IG and a threefold increase in VPA in the CG was noted (p=0.001). SKK scores increased by 13.1% (IG) and 16.9% (CG). Notably, a 52.1% dropout rate was recorded (IG: 55.3%; CG: 44.7%). Decreased PA levels in IG and CG may have been associated with the high dropout rates and the limited consideration of South African context-specific challenges. Online PA programmes need to be formulated with specific contexts and population nuances in mind. This is particularly relevant amid the backdrop of possible future pandemics or other emergencies.

Keywords: Online physical activity, digital exercise, SARS-CoV2, exercise motivation.

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Introduction

The benefits of remaining physically active, and the risks associated with a lack of physical activity (PA), have been the focus area of research for many years (Pojednic *et al*., 2022; Warburton & Bredin, 2017). Documented literature strongly advocates for the accumulation of regular PA in an effort to maintain a healthy lifestyle (Sylvia *et al*., 2022) and attain general well-being. Evidence also suggests that individuals maintaining PA levels within the prescribed recommendations by the World Health Organisation (WHO), may support a decreased progression of existing disease conditions as well as reduce the risk of the development of future physical and mental health ailments (Bull *et al*., 2020).

Online PA interventions have existed for many years; however, recent years have seen an increased use of online resources to support PA (McIntosh *et al.,* 2017). A number of studies have suggested that online PA has the potential to be as effective as face-to-face PA interventions (Lee *et al.,* 2023) and allows for the delivery of PA opportunities to larger samples at more affordable costs (Couper *et al.,* 2010; Lee *et al*., 2024). The purpose and anticipated outcomes of such programmes are multi-faceted, ranging from basic tracking of PA to more in-depth interactive experiences. In support of this perspective, a considerable amount of research has contributed to the development of applications and software that work to help individuals track PA (Yen *et al.,* 2022), in terms of mode, volume, intensity and frequency of engagement, thus affording individuals the opportunity to monitor and increase their regular PA (Yang *et al*., 2019). Some studies have focused on using online protocols to improve exercise behaviours by providing motivational support to individuals (Conroy *et al*., 2014). Other studies have focused on improving specific physical functioning in special population groups, for example, Collombon *et al.* (2023) and Cox *et al*. (2019) conducted investigations that focused on improving balance in the elderly to prevent falling.

Other online programmes focus on providing specified interactive exercises aimed at increasing and maintaining healthy PA levels (Peng *et al*., 2022). These various types of online PA interventions became a particular focus of PA research during the SARS-COV-2 pandemic – a period during which governments throughout the world set out to introduce restrictions aimed at curbing the spread of the virus and preventing the loss of lives (Sachs *et al.*, 2022).

South Africa's response, in accordance with the guidelines published by the World Health Organisation (WHO), was to implement lockdown measures that limited the movement of the general population within the country and beyond its borders (Moonasar *et al.*, 2021). These measures included five levels of lockdown which were implemented in stages based the rates of infection and mortality (South African Government 2020). Level Five was the strictest which restricted all non-essential movement of the general population and Level One was the most lenient which allowed for the closest return to regular daily activities (South African National Department of Health 2020). Consequently, one of the regular activities negatively impacted was PA. The SARS-COV-2 restrictions prohibited exercise establishments from operating as group gatherings were banned (Stiegler & Bouchard, 2020). Thus, a significant decrease in PA engagement was noted during lockdown.

The global 'Activity and Health during the SARS-CoV-2 Pandemic' (ASAP) survey (Wilke *et al.*, 2021a) and the South African results therein (Bhundoo *et al*., 2024), indicated a substantial decrease in participants' PA levels during the lockdown when compared to PA levels before the pandemic. There was also a significant negative effect on the general mental well-being of participants during the government enforced restrictions (Wilke *et al.*, 2021b). The survey brought into focus a need for a well-structured, virtual PA intervention that would allow

individuals to participate in guided online PA without having to use public exercise facilities or exercise groups (Wilke *et al.,* 2021a).

The aim of this study was to present the results of an analysis of the South African data collected in the active digital exercise phase of the 'Move ASAP' (Activity and Health during the SARS-CoV-2 Pandemic) study and to identify specific limitations associated with the South African segment of the global study. We hypothesise that the 4-week active PA intervention improves overall PA volume in minutes per week.

Methodology

Study design

The global study (Wilke *et al*., 2022) utilised a two-armed randomised controlled trial (RCT) design, where participants were randomly allocated to either the intervention group (IG) or control group (CG). The intervention was conducted during SARS-CoV-2 lockdown restrictions, over 4 weeks, during which participants in IG had access to live, virtual exercise sessions with a physiotherapist specialising in exercise and sports therapy present. These live sessions were recorded and a repository of exercise videos was created during the initial 4 weeks of the RCT. In the 4 weeks following the active intervention, CG and IG both had access to the repository of recorded exercise sessions. Weekly online questionnaires were circulated to participants in both groups to assess various outcome measures of physical and mental well-being. While the Move ASAP trial was a multicentre trial conducted in several countries and its statistics and results have been presented in a global format (Wilke *et al*., 2022), this study reports an analysis of the data collected in South Africa.

Participants

The South African study included 219 healthy participants (male: 27.4%, n=60; female: 72.6%, n=159) between the ages of 18-69 years (Mean age: 35.4± 11.5 years). Participants were recruited via DUT (Durban University of Technology) Pinboard (an online staff interface platform for communication), Facebook and WhatsApp. Interested participants were directed to a hyperlink that provided an online Physical Activity Readiness Questionnaire (PAR-Q). The questionnaire automatically excluded any participant with pre-existing health conditions that could be exacerbated by physical exercise. This included, but was not limited to chronic conditions involving the various systems of the body (neurological, arthritic, autoimmune, endocrinological, and cardiovascular diseases). Pregnant females were also excluded due to the uncertain effects that exercise may have on unique gestational situations.

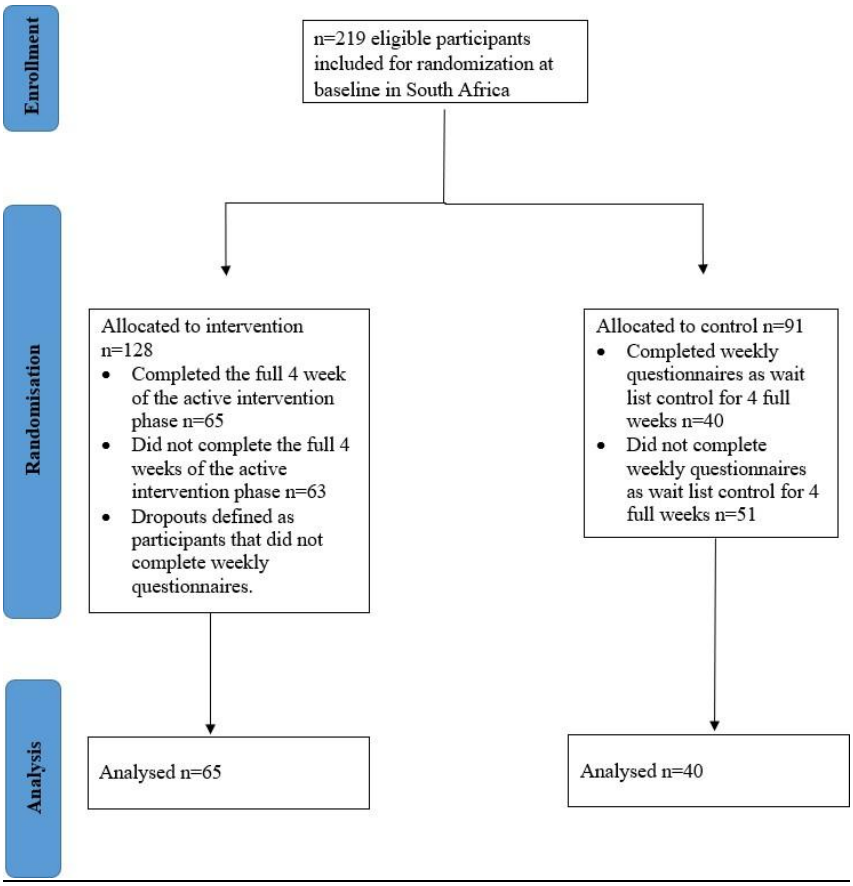

Figure 1: Participant flow diagram

Randomisation

Randomisation of the participants was done using the Soscisurvey software (Wilke *et al.*, 2022). During this stage, participants were required to complete their baseline surveys. Once considered eligible for inclusion, they were randomly assigned to IG (n=128; 58.5%) or CG (n=91; 41.6%) and automatically allocated participant identity codes by the software system.

Intervention

During the 4 weeks active intervention period, participants had access to live online video and audio sessions with a qualified physiotherapist trained in exercise

and sports therapy. The sessions were conducted using Microsoft Teams (MS Teams), and allowed for participants and the trainer to interact by turning on the camera and microphone during the virtual sessions. This provided participants with the opportunity to seek advice from the physical trainer and allowed the trainer to monitor the participants' progress and fitness status.

Exercise sessions were conducted on a scheduled time and day, from Monday to Friday weekly. These 45-60-minute sessions targeted different types of exercise categories, including strength, high-intensity interval training (HIIT) and stretch, core stability and mobility training. Strength training sessions were offered 5 times a week and included a mixture of basic strength prescriptions, adapted to equipment access at home but also manageable with body weight. These strength-training sessions focused on improving muscle strength, endurance and power. Sessions focusing on core training were offered 3 times a week. These core sessions involved a mix of Pilates-based mat work, as well as core and trunk rehabilitation exercises. The training also included low intensity, low impact exercises to improve core stability, endurance and posture for daily life. HIIT exercise sessions incorporated high-intensity exercises, with plyometric, scalable bodyweight movements as well as cardiovascular exercises. These HIIT sessions were conducted 4 times a week. Stretch, stability and mobility sessions were offered thrice weekly. These sessions utilised a mixture of static and dynamic stretching, together with some mat work as well as active recovery for improved adaptation and training effect. Participants were allowed to join as many sessions weekly as possible. The CG was not provided with the links or schedule for the live sessions; however, they had access to the video archive of all live sessions once the initial 4 weeks of the intervention was completed by the IG. Both CG and IG were required to complete weekly surveys to measure markers of physical and mental well-being.

Outcome measures

Participants completed weekly questionnaires; programme adherence was tracked based on virtual-session attendance and the number of weekly questionnaires submitted. These questionnaires utilised scales of physical and mental well-being to measure the participants' progress during the initial 4 weeks of live sessions as well as the subsequent 4 weeks of recorded sessions. The questionnaires included the Nordic Physical Activity Questionnaire -Short (NPAQ-Short) (Danquah et al., 2018), applied to measure changes in total PA, moderate PA (MPA) and vigorous PA (VPA) and the Self-Concordance Scale (SKK) (Seelig & Fuchs., 2006) used to assess PA motivation.

Ethical clearance

The Durban University of Technology (DUT), South Africa provided ethical approval before the commencement of data collection (IREC 090/20). This ethical approval was obtained in alignment with South African ethical research standards and the Declaration of Helsinki (World Medical Association, 2024). All participants completed an online informed consent form before participating in the study.

Statistical analysis

The South African data from the Move-ASAP RCT were isolated from the global RCT data for the analysis. The global data were analysed and reported in a separate manuscript (Wilke et al., 2022). The South African data analysis is reported in this manuscript.

The statistical analyses encompassed both descriptive and inferential techniques to comprehensively examine the data. Descriptive statistics, including frequencies and percentages, were utilised to summarise demographic characteristics and

categorical data, such as gender, race, role distribution, and departmental affiliation. Mean values and standard deviations were applied to continuous variables to describe central tendencies and variability within the data. Inferential statistics was used in testing hypotheses and drawing conclusions. The Chi-Square test of independence was applied to assess whether any significant associations existed between the categorical variables (gender, age, work mode, living environment and education). The Independent-Samples Kruskal-Wallis Test was used to compare the distribution of continuous variables across different groups, particularly when theoretical assumptions of ANOVA (analysis of variance) were not met. Additionally, the Pearson Chi-Square test, Likelihood Ratio, and Fisher-Freeman-Halton Exact Tests were utilised to verify the statistical significance of relationships within the data, adjusting for ties and small sample sizes. Furthermore, the Z proportions test was used to compare the proportions of categorical variables between groups. A probability level of $p \leq 0.05$ was used to determine significance.

Results

General characteristics

A total of 219 (male: 27.4%, n=60; female: 72.6%, n=159) participants were included in the South African cohort of the 'Move ASAP' study (Table 1). Of these, 11.9% were living in a rural environment and 88.1% resided in an urban setting. Nearly two-thirds (n=137; 62.6%) of the participants were university graduates.

Age

The mean (standard deviation (SD)) age, was 35.4 (11.5) years, 35.0 (12.3) years and 36.1 (10.2) years for the total sample, IG and CG, respectively. Statistically significant comparisons between IG and CG were noted in the 40-49 years (p=0.004) and 60-69 (p=0.036) years age categories. In the total sample and IG, the highest percentage of participants, 28.3% and 32% were within the 30-39 years age category. However, in CG most of the participants (34.1%) fell into the 40-49 years age category.

Work mode

Majority of the participants (n=75; 34.2%) reported working from home (baseline survey). Of these, 38 and 37 participants were allocated to IG and CG, respectively. Only 25 (11.4%) participants were working from an office (n=17 – IG and n=8 – CG), and one participant (0.5%) who was allocated to IG, did not specify their work status. The remaining 53.8% (n=59 in each group) of the participants were equally split between those who did not work at all and those who were working in an office as well as remotely. The comparison between IG and CG for work mode was statistically insignificant.

Physical Activity Levels

Table 2 presents the mean minutes per week (min/week) for moderate physical activity (MPA) and vigorous physical activity (VPA) in the 105 participants who completed the 4-week active intervention phase at baseline and the end of the active 4-week intervention for IG and CG.

At baseline, IG and CG reported mean MPA of 169.0 and 52.4 min/week respectively, yielding a statistically significant comparison between the groups (p=0.000). Measurements at the end of the 4-week active intervention period

showed a decrease in MPA in both IG (-55.1 min/week) and CG (-8.4 min/week). Although the results showed a higher percentage change in IG (32.6%) versus CG (16.1%) albeit in the opposite direction expected, no statistical significance was noted between group comparisons for MPA.

Table 1: General sample characteristics

Variable	Total SA Sample n=219	Intervention n=128	Control n=91	*p*
Age mean (SD)	35.4 (11.5)	35.0 (12.3)	36.1 (10.2)	*0.272*
Age Categories n (%)				
<19	14 (6.4%)	7 (5.5%)	7 (7.7%)	*0.514*
20-29	59 (26.9%)	36 (28.1%)	23 (25.3%)	*0.646*
30-39	62 (28.3%)	41 (32%)	21 (23%)	*0.146*
40-49	53 (24.2%)	22 (17.2%)	31 (34.1%)	*0.004**
50-59	25 (11.4%)	16 (12.5%)	9 (9.9%)	*0.552*
60-69	6 (2.7%)	6 (4.7%)	-	*0.036**
Sex n (%)				
Male	60 (27.4%)	34 (26.6%)	26 (28.6%)	*0.744*
Female	159 (72.6%)	94 (73.4%)	65 (71.4%)	*0.744*
Work Mode n (%)				
Home office	75 (34.2%)	38 (29.7%)	37 (40.6%)	*0.095*
Office	25 (11.4%)	17 (13.3%)	8 (8.8%)	*0.303*
Not working at all	59 (26.9%)	40 (31.3%)	19 (20.9%)	*0.088*
Both home and office	59 (26.9%)	32 (25%)	27 (29.7%)	*0.441*
Unspecified	1 (0.5%)	1 (0.8%)	-	*0.394*
Living Environment n (%)				
Rural	26 (11.9%)	19 (14.8%)	7 (7.7%)	*0.110*
Urban	193 (88.1%)	109 (85.2%)	84 (92.3%)	*0.110*
University Degree n (%)				
Yes	137 (62.6%)	77 (60.2%)	60 (65.9%)	*0.391*
No	82 (37.4%)	51 (39.8%)	31 (34.1%)	*0.391*

SA=South Africa, SD=standard deviation, n=number of participants, %=percentage, * statistical significance at p<0.0

Table 2: Physical activity levels pre- and post-intervention

Physical Activity Category	**Intervention n=65**	**Control n=40**	***p***
MPA pre (min/week)	169.0	52.4	*0.000**
MPA post (min/week)	113.9	44.0	*0.016**
MPA Difference (min/week)	-55.1	-8.4	*0.120*
Net change (%)	-32,6	-16,1	
VPA pre (min/week)	103.2	1.3	*0.000**
VPA post (min/week)	59.8	5.7	*0.001**
VPA Difference (min/week)	-43.4	4.3	*0.001**
Net change (%)	-42,1	330,0	

MPA=moderate physical activity; VPA=vigorous physical activity; pre=baseline; post=after intervention; min/week=minutes per week; *statistical significance at $p<0.05$.

VPA volume (minutes of PA per week) decreased by 42.1%, from 103.2 min/week to 59.8 min/week for IG. Whereas the CG's VPA volume more than tripled from a baseline value of 1.3 min/week to 4.7 min/week in a favourable direction. Comparisons between IG and CG were significant in the baseline, post-intervention and difference categories, with CG showing improvement whilst IG reported a decline in VPA levels.

Exercise motivation

Figure 2 depicts the change in participants' motivation to exercise before and after the 4-week active intervention period, using a self-concordance scale. At baseline, the exercise motivation for IG and CG were 14.1(8.7) and 12.9(9.5) points, respectively.

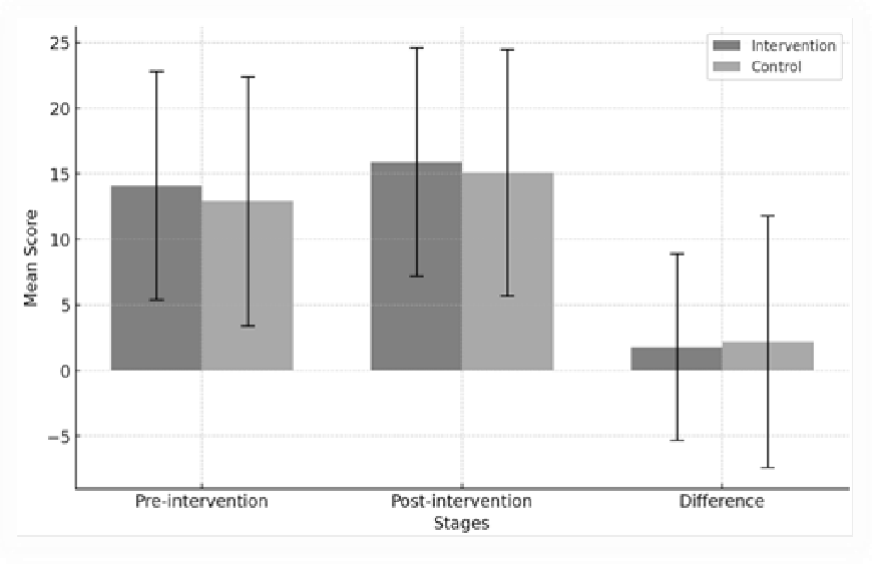

Figure 2: Self-Concordance Scale (SKK) for exercise motivation between intervention and control.

Both groups showed an increase in exercise motivation at the end of the active intervention period, with IG showing an increase of 13.1% and CG an increase of 16.9%. The between group comparison for exercise motivation was statistically insignificant.

Participant dropout

A 52.1% (n=114) dropout rate was recorded within the 4 weeks of the active exercise intervention for the South African cohort of the Move ASAP study. Of the initial 219 participants, only 105 (47.9%) completed the intervention, hence, only 105 participants were assessed for changes from baseline outcome measure values at the post-intervention (4-week) measurement point. Males and females accounted for 26.3% (n=30) and 73.7% (n=84) respectively, with no statistical significance noted in relation to sex and dropout rate. As indicated in Table 3,

dropouts comprised 63 participants (55.3%) from IG and 51 participants (44.7%) from CG. The percentage of dropouts was much higher in females than males, with females making up 69.8% (n=44) and 78.4% (n=40) of IG and CG dropouts respectively, although not statistically significant.

Age

The highest dropout rate was seen in the 20-29 years age category for the total dropout population (n=39; 34.2%) and IG (n=26; 41.3%). In CG, however, the 40-49 years age category produced the highest dropouts (n=21; 41.2%). The 60-69 years age category produced the least dropouts (n=1; 1.6%) - this participant had been allocated to IG. The lowest dropout rate in CG was noted in participants younger than 19 years of age (n=2; 3.9%). Comparisons across age categories were statistically significant between IG and CG in the 40-49 age category (p=0.000).

Work mode

Of the 114 participants who dropped out, 40 participants (35.1%) were working from home during the intervention period. In IG and CG, the highest dropout rate was noted among participants who were not working at all (39.7% and 27.5%). Dropouts from the 'office' work mode group were statistically significant between IG and CG.

Living Environment

Most dropout participants (86% of the total population, 69.8% of IG and 78.4% of CG) lived in urban environments. There was no statistical significance in the living environment comparison between IG and CG.

Formal tertiary education

More than half (n=63, 54.4%) of all dropouts and 68.6% (n=35) of CG dropouts were university graduates. Conversely, 57.1% (n=36) of IG dropouts did not possess a university degree. A statistical significance between IG and CG dropouts (p=0.006) was noted for participants who were university graduates and those who were not.

Table 3: Participant dropout characteristics

Category		Dropout Total SA Sample n=114	Dropout Intervention n=63	Dropout Control n=51	*p*
Age, n (%)					
<19		4 (3.5%)	2 (3.2%)	2 (3.9%)	*0.841*
20-29		39 (34.2%)	26 (41.3%)	13 (25.5%)	*0.078*
30-39		32 (28.1%)	21 (33.3%)	11 (21.6%)	*0.169*
40-49		28 (24.6%)	7 (11.1%)	21 (41.2%)	*0.000**
50-59		10 (8.8%)	6 (9.5%)	4 (7.8%)	*0.750*
60-69		1 (0.9%)	1 (1.6%)	-	*0.366*
Sex, n (%)					
Male		30 (26.3%)	19 (30.2%)	11 (21.6%)	*0.302*
	Female	84 (73.7%)	44 (69.8%)	40 (78.4%)	*0.302*
Work mode, n (%)					
	Home office	40 (35.1%)	18 (28.6%)	22 (43.1%)	*0.108*
	Office	15 (13.2%)	12 (19.0%)	3 (5.9%)	*0.040**
	Not working at all	39 (34.2%)	25 (39.7%)	14 (27.5%)	*0.174*
	Both home and office	19 (16.7%)	7 (11.1%)	12 (23.5%)	*0.079*
	Unspecified	1 (0.9%)	1 (1.6%)	-	*0.366*
Living environment, n (%)					
Rural		16 (14%)	9 (14.3%)	7 (13.7%)	*0.927*
	Urban	98 (86%)	54 (85.7%)	44 (86.3%)	*0.927*
University degree, n (%)					
Yes		62 (54.4%)	27 (42.9%)	35 (68.6%)	*0.006**
No		52 (45.6%)	36 (57.1%)	16 (31.4%)	*0.006**

SA = South Africa, n=number of participants; %=percentage; * statistical significance at $p<0.05$.

Weekly dropout statistics

Figure 3 depicts the dropout rates over the 4-week intervention period for the total, IG and CG.

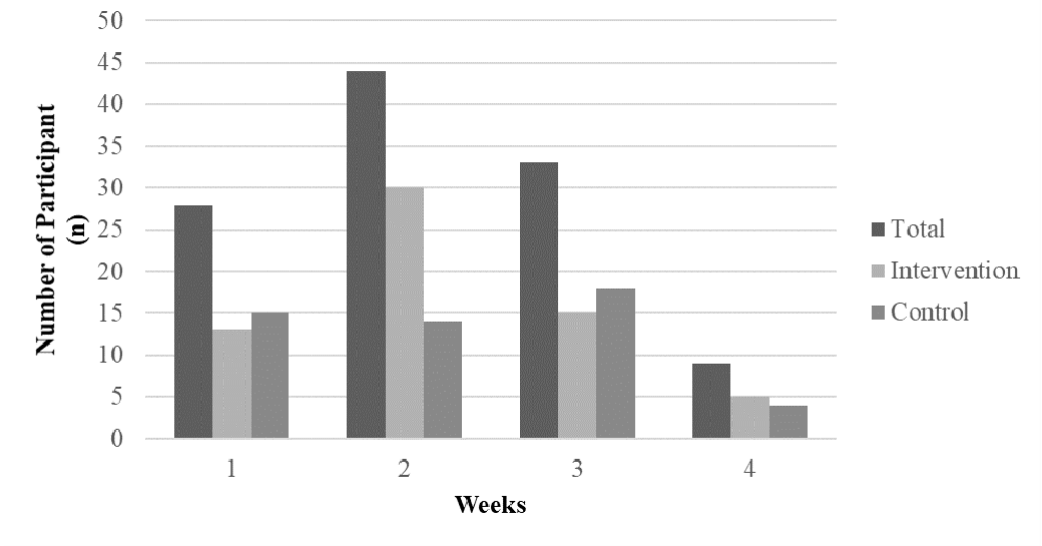

Figure 3: Weekly dropout rates

The highest dropout rates in the total sample and IG were recorded in the 2nd week of the trial (n=44, 38.6% and n=30, 47.6%). CG had its highest dropout rate in the 3rd week (n=18, 35.3%). The lowest dropout rates were seen in the 4th week of study for the total, IG and CG (n=9, 7.9%; n=5, 7.9% and n=4, 7.8%). Statistical significance between IG and CG weekly dropouts was noted in week 2 (p=0.029).

Discussion

A more focused look at the South African data from the 'Move ASAP' online exercise intervention revealed that in the initial active 4-week phase of the trial, there was a significant difference in MPA between IG and CG at baseline (p=0.000), and at the end of the 4-week active phase (p=0.016) with both groups reporting decreased MPA. The decrease in MPA noted in this cohort is at variance with the findings of several studies investigating the effectiveness of online PA intervention which reported improved PA levels (Steinberg *et al.,* 2009; Suner-Keklik *et al.*, 2021). However, the literature also shows that a number of interventions reporting no significant changes in some outcome measures (Brustio *et al.*, 2024), with a few studies also indicating that the positive results can be relative to study-specific methods and parameters

(Joseph *et al*., 2014). Upon a further scrutiny of these findings, we noted that at baseline there were fewer participants allocated to CG than IG. This has the potential to affect the results due to a lack of sufficient accommodation for a larger pool of participants with a plausible greater variation in external factors that may affect their PA levels. For instance, a larger sample has the potential to increase the possibility of work environment changes within the group, resulting in less available time for PA. Increased external responsibilities affecting availability of PA time may also surge with an increased number of participants in a group. Furthermore, there were significant differences in the baseline measures between IG and CG which inadvertently indicates that a smaller min/week change would be required to yield a higher percentage change in the pre-post comparison for the control group. Consequently, both these factors may have been contributory to the results obtained.

Results of the South African participants' PA levels differed from those reported in the global study (Wilke *et al*., 2022), which indicated increases in PA during the active 4-week intervention phase. This brings into focus a possible dilution of the South African data within the much larger study population from different participating countries (Dechartres *et al.*, 2011) - an aspect that may need careful consideration for future online PA interventions, particularly in the event of similar natural disasters and health crises. In South Africa, there were unique challenges that may have constrained attendance of virtual exercise sessions thus affecting reported PA levels. These included factors such as irregular electricity supply known as "load shedding" (Ritchie *et al.*, 2022), which may have affected participants ability to join online sessions due to unstable internet connection (Kgarose *et al*., 2023). Furthermore, it should be noted that the South African cohort was selected from a university located in Durban, the capital city of KwaZulu-Natal province which experienced rampant shortages of water supply during the pandemic (Selaelo, 2022). These challenges may have compounded the decreased PA levels among the participants as PA was probably deprioritised in the face of shortage of essential necessities. The difficulties experienced with regard to internet access and internet cost in South Africa may have further impacted the results obtained. An online intervention requiring live streaming interaction works optimally with strong and uncapped internet connectivity. In South Africa, this service is unaffordable for a large part of the population - a situation exacerbated by heightened unemployment during the pandemic (Hlatshwayo, 2022).

Regarding motivation to exercise, the trends in the measurement indicators in our study were found to be consistent with those reported in the global RCT, which indicated similar changes

in exercise motivation (Wilke *et al*., 2022). Although there was no direct correlation between the PA levels and the exercise motivation scores in the South African cohort, it is noteworthy that the pandemic was rapidly changing during the course of this intervention (South African Government, 2020), thus creating an unpredictable trend of stress and anxiety experienced by individuals (Gullo *et al.*, 2021; Pieh *et al.*, 2021). However, our study did not consider how additional stress may have affected the participants' baseline motivation to exercise, except that about a third of them were unemployed (26.9%). According to Posel *et al*. (2021), loss of income had the potential to increase the levels of mental distress experienced by the general healthy population. The decrease in anxiety in the less stringent lockdown measures during the pandemic, and a gradual return to work may have accounted for the higher exercise motivation noted in our participants as the weeks progressed.

High attrition rates during an intervention require careful consideration. Research has shown that in intervention studies, dropouts have the potential to weaken the results obtained (Bell *et al*., 2013; Meyerowitz-Katz *et al*., 2020). The 'Move ASAP' global report noted a dropout rate of 54% (Wilke *et al.*, 2022), and the South African cohort similarly reported a 52.1% (n=114) dropout rate. This point merits further discussion given its plausible impact on the overall results reported for the effectiveness of the South African segment of the global RCT. Specifically, the dropouts skewed the participants' distribution between the IG and CG from the initial 128 and 91 to 65 and 40, respectively after post-testing. A number of studies (e.g., Cramer *et al*., 2016; Dixon *et al.*, 2020) have drawn attention to the need to consider dropout rates when planning interventions programmes and suggested the adoption of strategies to prevent and account for dropouts during data collection and analysis. This shows that although the results of the South African cohort are relevant, they are impacted by several factors which could have yielded more desirable outcomes were they accounted for.

Strengths, limitations and recommendations

The focused analysis of the results of the South African cohort within the global study, highlights areas of potential future investigations with regards to online physical activity (PA) in South Africa, whilst, focusing on important disparities between South Africa and developed countries. The analysis was restricted to the participants that completed the 4-week active phase of the intervention. This limited the results, as a comparison between the 4-week active phase and the 4-week recorded phase could not be conducted in alignment with the global RCT.

Furthermore, our cohort formed part of an overall global intervention plan, which did not cater for specific limitations in the South African context with regard to resource availability and socioeconomic issues. The therapist utilised in the South African cohort was a physiotherapist specialising in sport and exercise therapy; although sufficiently qualified, this presented as a limitation as there are other professionals, biokineticists and sports scientists for example, who may have been better equipped to facilitate the virtual exercise programmes. The use of the NPAQ-short for measurement of PA levels is a subjective measure which could be inaccurately reported. Future studies should use objective measures such as accelerometers and pedometers to evaluate PA levels. We further recommend the development of an online PA intervention programme designed specifically for the South African population to allow for a reassessment of online PA intervention effectiveness within its distinctive local challenges such as load shedding, variable network availability, and internet costs. The analysis of the results did not include group by time interactions, which may have skewed the overall impact of the results, hence we recommend that any future studies ensure that the statistical analysis of such RCTs include group by time interaction calculations.

Conclusion

This study showed a decrease in MPA in the initial 4-week active phase of the "Move ASAP" trial, among South African participants. However, the findings did show an increase in exercise motivation among participants. The benefits of PA whether online or face-to-face are undeniable; however, such programmes need to be formulated according to specific contexts and nuances for members of specific populations to have proper access to these benefits. Such nuances, if carefully considered, can support improvements in the development and roll-out of future PA interventions, particularly in the context of impending pandemics and other unforeseen emergencies.

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Author Contributions

AKB, JW and JDP conceptualised the study; AKB performed the study, analysed and reported the findings; AKB, JW and JDP contributed to the drafting and finalising of the manuscript.

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CHAPTER SIX

DISCUSSION, GUIDELINES, RECOMMENDATIONS & CONCLUSION

This chapter (Chapter Six), presents a discussion of the composite findings of this thesis and how they relate to the relevant literature, whilst identifying and describing the strengths and limitations of the thesis. Thereafter, the chapter presents guidelines for future online PA interventions based on the findings and limitations of the various portions of this thesis. These guidelines consolidate the findings of this thesis with the literature supporting these findings into four major reflections that should be considered in the designing of future online PA interventions. Following this, the chapter presents recommendations for future research that stemmed from the results and setbacks identified in this thesis. The chapter concludes the thesis by highlighting the overall significance of the results and the way forward.

6.1. Discussion

The benefits of regular PA have been thoroughly researched and presented in detail in the literature over the years (Rhodes *et al.,* 2017). Specific emphasis has been placed on the positive effects that it has on physical well-being, mental well-being and in general an individual's overall quality of life. Aksay (2021) conducted a study investigating the effectiveness of an online PA program on adults between the ages of 60-89 years of age. This study concluded that online PA interventions can improve body strength, flexibility and balance in older individuals. A different study investigating the effects of PA on adolescents and their risk for mental illness, indicated that regular PA has the potential to significantly affect the risks of adolescent development thus positively impacting mental health risk (Belcher *et al.,* 2021).

Regular PA has been linked with a decreased risk for chronic disease, improved cardiovascular health, increased muscle strength. A survey study conducted by Ng *et al.,* 2020, evaluating the first chronic disease diagnosed in participants and its association with lifestyle patterns, showed that decreased levels of PA can contribute to the risk of the development of chronic diseases such as diabetes mellitus and cardiovascular disease.

In a review of the literature associated with the physiological and psychological benefits of PA participation on mental health, it was stated that PA engagement can enhance general mental well-being, reduced signs and symptoms associated with depression, anxiety and other psychiatric illness (Mikkelsen *et al.,* 2017). Another study conducted a systematic review and a meta-analysis of the literature pertaining to PA and its effects on the mental health of university students. This study highlighted the critical role that PA plays in ensuring optimal physical and mental health, thus emphasising the importance of including regular PA into individuals' daily routines (Huang *et al* 2024). A different study which investigated the relationship between decreased PA during the SARS-CoV-2 pandemic and mental health symptoms, indicated that individuals who were more physically active, exhibited fewer symptoms of depression, anxiety and stress (Jacob *et al.,* 2020).

In the recent years, the field of PA research has seen a notable shift towards the use of online and digital platforms to increase PA opportunities and PA engagement among healthy and unhealthy individuals across various demographics (Zangger *et al.,* 2023). Further to this a study conducted by Hansen *et al* (2017), showed that online PA can be used as a rehabilitation technique in patients with cardiac disease, thus, improving disease prognosis and decreasing

complications. A different study which looked at the effectiveness of self-directed online PA programs concluded that these programs can increase PA engagement and work well towards changing PA behaviours, especially when interventions are formulated on the basis of behaviour change theoretical frameworks (Stavric *et al.,* 2022).

The SARS-CoV-2 pandemic accelerated this shift, due to the necessitated restrictions on movement, which involved social distancing that led to limited access to conventional PA facilities (Hsu *et al.,* 2020). Online PA interventions have been shown to present additional benefits that include increased convenience, affordability and flexibility (Oliveira *et al.,* 2022). Digital PA offerings allow for enhanced PA opportunities, that aim to address previously identified challenges relating to access to PA prospects (López-Valenciano *et al.,* 2021).

Accessibility is one of the crucial advantages presented by online PA interventions (Broekhuizen *et al.,* 2016). This has the potential to change PA behaviour by increasing PA opportunity for individuals with busy daily schedules, those who lack the resources to travel to and use traditional PA amenities, as well as those who live in remote areas with limited access conventional PA facilities (Jahangiry *et al.,* 2017). Furthermore, online PA platforms often feature diverse PA styles, which cater for individual specific PA requirements (Senbekov *et al.,* 2020). These interventions offer users the chance to explore various types of leisure time PA activities, with the aim of improving overall PA levels and physical and mental health indicators (Reiner *et al.,* 2023). This inclusivity is particularly beneficial for populations that may feel intimidated by conventional fitness environments (Cunningham *et al.,* 2020). With the aim of contributing towards the evidence-based interventions that support online PA, particularly amidst the backdrop of the SARS-CoV-2 pandemic, this thesis comprised of a systematic review and meta-analysis, a survey and a RCT.

The systematic review and meta-analysis provide an updated critique of the existing online PA interventions, that targeted healthy adults and utilised physical and mental outcome measures. The evidence reviewed and analysed presents the effectiveness of OE when compared to NEX and OE when compared to face-to-face PA engagement. The findings indicate that online exercise is non-inferior to traditional face-to-face intentional PA participation in terms of improving various measures of physical function and mental health. However, OE is superior to NEX with regards to similar outcome measures. These findings are in keeping with the findings of previous studies conducted with similar objectives (van den Berg *et al.,* 2007; Davies *et al.,* 2012).

The outcome measures pooled into the motor performance analysis, included strength, endurance, balance, gait, flexibility, physical activity. Upon analysis a moderate-large improvement in measures of strength, endurance and balance. Strength training, which often forms a core component of these online programs, is known to increase muscle strength by engaging major muscle groups through resistance exercises (Kikuchi *et al.,* 2023). Endurance training aims to increase aerobic capacity by repeatedly activating the muscle (Mok *et al.,* 2022). Balance activities are beneficial in creating a healthy equilibrium between coordination and postural control (Papalia *et al.,* 2020). These PA engagements not only improve muscular strength, endurance and balance, but also enhance overall functional capacity, making daily tasks easier and reducing the risk of injuries (Montón-Martínez *et al.,* 2024).

These findings are consistent with previous studies conducted by van den Berg et al (2007) and Davies et al (2012), that have highlighted the benefits of structured exercise regimens in enhancing physical capabilities. These studies also showed significant positive changes in measures of motor performance when OE was compared to NEX. In contrast, there was a lack of significant changes in the analysis of measures of gait speed and flexibility. However, it is noteworthy that these outcomes were assessed in only two studies, which may have limited the statistical power required to detect meaningful differences. The limited scope of research on these specific outcome measures suggests that while strength, endurance and balance can be effectively improved through online PA interventions, aspects like gait speed and flexibility may require more tailored approaches or different modalities of training to elicit improvements.

In the analysis of mental health outcome measures, the meta-analysis pooled measures of depression, anxiety, mood/emotion, mental wellbeing, sleep, self-efficacy. The results of the analysis of measures of depression and self-efficacy were particularly prominent, yielding very large positive effects with SMDs of 1.08 and 1.1 respectively. These findings underscore the potential of online exercise to significantly enhance psychological well-being as indicated by other studies in the related literature (Singh *et al.,* 2023). The substantial effect sizes indicate that participants experienced significant reductions in depressive symptoms and improvements in their belief in their capabilities, which are critical for maintaining motivation and adherence to PA interventions (Sebastian *et al.,* 2021; Lewis *et al.,* 2016).

Additionally, while smaller effects were observed for mood/emotion and general mental wellbeing outcome measures, these positive effects further support the indications of previous studies, that regular PA has the potential to create improved mental health outcomes (Callow *et al.,* 2020). However, there was an unexpected lack of change in anxiety levels, which

contrasts the conclusions of other studies measuring the effects of PA on anxiety (Mikkelsen *et al.,* 2017; Belcher *et al.,* 2021). This suggests a need for further investigation into how different types of online PA delivery methods which may influence a variety of psychological outcome measures.

The findings of the meta-analysis in the thesis have significant implications for clinical practice in the field of online PA interventions. Traditionally, face-to-face exercise has been considered the most effective method for enhancing health and performance (Hall *et al.,* 2021). However, these updated results indicate that online PA programs can be just as effective especially in instances where the traditional PA opportunities, suggesting that the choice of exercise modality may ultimately depend on individual preferences. This flexibility is crucial, especially as we navigate the diverse needs of various populations (Lidegaard *et al.,* 2016; Blake *et al.,* 2017). The non-inferiority of OE when compared to FFE opens up a dialogue about personal choice in physical activity. Individuals may have different motivations and preferences regarding how they engage in exercise (Hosseini *et al.,* 2020). Research indicates that personal factors such as personality traits, motivations, and behavioural regulations significantly influence exercise behaviour (Manninen *et al.,* 2022). By allowing individuals to select their preferred mode of exercise be it online or face-to-face clinicians can enhance adherence to physical activity programs (Liu *et al.,* 2022).

The results of the meta-analysis emphasised a gap in knowledge regarding the effectiveness of online PA interventions. Addressing this gap through targeted research could yield valuable insights into how different populations respond to online PA interventions and inform best EBP implementation across varied demographic groups.

Upon identifying the need for additional PA interventions to strengthen the evidence present in the literature, this thesis aimed to identify the changes in PA noted during the SARS-CoV-2 pandemic by utilising a survey study. The initial study was a multicentred online survey, this thesis presents a re-analysis of the South African results as a stand-alone set of data.

The re-analysis of the ASAP survey data conducted by Wilke *et al* (2020) highlighted a notable decrease in PA in SA during the SARS-CoV-2 pandemic lockdown restrictions. The South African survey revealed a 53.5% reduction in moderate physical activity (MPA) and a 58.0% reduction in vigorous physical activity (VPA) when comparing PA levels during the lockdown restrictions with those before the implementation of restriction. These findings are particularly important as they indicate that the reduction in PA in SA was more severe than the global

average reductions, which were 41% in MPA and 42.2% in VPA reported in the global ASAP survey results (Wilke et al., 2021). These findings were consistent with the findings of other studies conducted during the pandemic that indicated a decline in PA levels.

Oliveira *et al* (2022), conducted a systematic review on the changes in PA levels in the older population during the SARS-CoV-2 pandemic and showed a distinct decrease in PA engagement. This correlated with the findings of the ASAP survey presented in this thesis. A different study that reported similar findings and supported the outcomes of the survey portion of this thesis was conducted by López-Valenciano *et al* (2021). López-Valenciano *et al* (2021), measuring PA participation in university students during the lockdowns and indicated marked declines in PA levels. Further to this, another South African study showed that there was a decrease in PA interaction during the lockdown restrictions, and these decreased levels had an impact on mental health outcomes in the general adult population (Lewis *et al.,* 2021). These studies strengthen the results presented in the survey of this thesis, showing that the decrease in PA participation during the SARS-CoV-2 pandemic and its related lockdown restrictions was a universal problem faced by diverse populations.

In addition to the decrease in PA levels there was a reduction in WHO PA recommendation compliance noted in 30% of the participants. This lack of WHO PA compliance raises the concern for much larger and long-standing public health concerns in the case of changes in PA behaviour during the SARS-CoV-2 pandemic. This concern was highlighted by Oni *et al* (2020) during their interrogation of the public health measures adopted during the pandemic and the negative effects of these measures on aspects of wellbeing such as compliance with PA recommendations. A different study conducted by Dlamini et al (2024), reported similar in the adolescent population during and after the pandemic. Hence, the findings of the survey presented in this thesis are support by local and global studies investigation WHO PA guideline compliance and the SARS-CoV-2 pandemic.

These reductions in PA levels and WHO PA guidelines compliance places the associated risk for the health-related complications in a position of great concern. The literature extensively indicates the increased risk for the development of physical and mental health conditions, that accompanies a decrease in PA engagement (Anderson and Durstine, 2019). This was further exacerbated by the onset of the SARS-CoV-2 pandemic, where the effects of the pandemic infiltrated the field of PA (Hoffman *et al.,* 2022). The research conducted during the pandemic relating to PA and pathology revealed that lower PA levels can increase the severity of existing

conditions as well as exacerbate the likelihood of the development of new pathologies in previously healthy individuals (Paudel *et al.,* 2023; Ficarra *et al.,* 2022).

The pandemic was also associated with an increase in mental health related conditions due to the increased mental strain placed on individuals due to the uncertainty of the progression of the pandemic. This coupled with the decreased PA participation exponentially increased the risk and the occurrence of mental health symptoms. Generally, PA elicits a positive effect on the mental well-being of an individual, however, during the pandemic the restrictions on movement and interaction lead to decreased PA engagement, which indicated that usual benefits of PA could not be yielded. Hence, the accumulative risk for mental health diagnoses increased substantially during the pandemic, especially during the lockdown restrictions when movement and interactions were limited the most.

Investigations into differences in PA level between sexes, reveal that females tend to engage less in physical activity compared to males (Hugh-Jones *et al.,* 2023). Females tend to engage in less intense PA at a much lower volume, despite the known benefits for disease prevention and management in the female population (Puccinelli *et al.,* 2021). Although no significant differences were observed during lockdown in this survey (MPA p=0.461; VPA p=0.163), this aligns with broader findings indicating that males are generally more active than females, potentially heightening health risks for females during periods of inactivity (Vaccarezza *et al.,* 2020).

The analysis of age-related changes in PA revealed significant statistical differences among various age groups, indicating that younger individuals (18-29 years of age) maintained higher activity levels compared to older cohorts (50-69 years of age) (p-values ranging from <0.001 to 0.047). This trend supports existing literature that associates increasing PA with positive health outcomes as individuals age, suggesting that regular engagement in PA can mitigate age-related declines in both mental and physical function (McPhee *et al.,* 2016). Maher *et al* (2015) emphasize that as individuals grow older, their overall well-being may diminish, increasing vulnerability to physical and mental health issues. However, consistent PA can counteract these effects, promoting better health outcomes during aging (Marquet *et al.,* 2020).

Further to this the survey study presented in this thesis measured and analysed the WHO PA guideline compliance among participants. The WHO recommends PA engagement of least 150 minutes of moderate-intensity or 75 minutes of vigorous-intensity physical activity weekly, which contributes towards lowering the risk of mental and physical health diseases (Bull *et al.,*

2020). The findings of this survey revealed that prior to the implementation of SARS-CoV-2 lockdown measures, 30% of participants were compliant with these guidelines. However, during the lockdown, this compliance dropped significantly, indicating that many individuals reduced their physical activity levels due to restricted access to exercise facilities and outdoor spaces (Idowu *et al.*, 2022).

The South African cohort of the ASAP survey results indicated a contrast in PA compliance before and during the lockdown, 32.9% of participants-maintained compliance with WHO guidelines both before and during the lockdown. Additionally, 32.9% were consistently non-compliant, showing that a significant portion of the population did not meet recommended activity levels regardless of the restrictions. Finally, 30% of participants who were compliant before the lockdown became non-compliant during the restrictions, reflecting a broader trend of decreased physical activity amid pandemic-related limitations (Elliott *et al.*, 2022).

Interestingly, a small fraction of participants (4.2%) transitioned from non-compliance prior to lockdown to compliance during this period. This shift could be attributed to individuals adapting to new home-based exercise routines or utilizing digital fitness resources that became more widely available during the pandemic (Polero *et al.*, 2021). The WHO PA guidelines serve as a crucial foundation for promoting healthy PA practices across diverse populations; therefore, non-compliance can lead to increased risks for both mental and physical health issues (Elliott *et al.*, 2022). The decrease in PA guideline compliance during lockdown raises concerns about the long-term health implications for individuals (Wilke *et al.*, 2021b).

The survey's findings highlight the importance of encouraging PA participation even in challenging circumstances. Public health strategies must focus on providing accessible resources and support systems to help individuals maintain or increase their PA levels during similar future crises to prevent the exacerbation of disease progression (Schuch and Vancampfort, 2021). This can be achieved by the development of sound evidence-based interventions that aim to at presenting PA opportunity when access to traditional PA facilities is not possible.

In response to the results from the ASAP survey, which underscored the need for an online PA intervention with the potential to increase PA interactions during the SARS-CoV-2 pandemic, the Move ASAP RCT was formulated. This RCT aimed to provide participants with the opportunity to engage with online PA activities according to a daily schedule with a trained PA

practitioner virtually guiding them through training routines. The results of the SA cohort were analysed as a part of this thesis.

The RCT analysis focused on evaluating the difference in PA participation between the IG and the CG during the initial four-week active engagement phase of the Move ASAP intervention in SA. Interestingly the results indicated a decrease in PA MPA for both the IG and CG, which contrasted with the findings of other studies that measured the effects of online interventions on PA levels during the SARS-CoV-2 pandemic (Bagherian *et al.,* 2021). Parker *et al* (2021) indicated that healthy individuals who had access to digital PA opportunity were more likely to increase their PA participation. Another study conducted by Newton *et al* (2020), showed that patients with cancer benefited from exposure to online PA interventions during the pandemic related restrictions. These results analyses highlight the important considerations regarding sample size, baseline differences, and external factors affecting PA, which have resulted in the contrasting outcomes between the SA cohort and the global Move ASAP cohort which indicated an increase in PA levels in the initial weeks of the RCT (Wilke *et al.,* 2022).

The findings of this RCT showed that both IG and CG experienced a significant reduction in MPA, with *p*-values indicating strong statistical significance at baseline (p=0.000) and at the end of the four-week phase (p=0.016). These outcomes contrasted with the findings of other studies such as the study conducted by Suner-Keklik *et al* (2021), which indicated positive outcomes from online physical activity interventions, suggesting increased levels of physical activity post-intervention. The contrast between the findings of this trial and other studies is noteworthy. While several other interventions report improvements in PA levels (Bagherian *et al.,* 2021; Parker *et al.,* 2021; Suner-Keklik *et al.,* 2021), this RCT indicates a reduction in PA, which prompts a deeper investigation into potential causes. However, there are instances in the literature where interventions yielded no significant changes in outcomes for online PA interventions, as noted by Brustio *et al* (2024), indicating that results can vary based on specific methodologies and study designs.

A point of significant importance is the reduced number of participants in the CG compared to the IG at baseline. This inconsistency could have introduced bias into the results, as a smaller control group may not adequately represent the broader population's variability in PA levels. A higher number of participants in the CG might have provided insight into a wider range of external influences affecting participants' PA participation, such as changes in work environment or increased personal responsibilities during the pandemic (Torres *et al.,* 2021). Further to this the smaller sample size in the CG could lead to enhanced effect sizes due to

reduced variability in responses, indicating that regardless of its magnitude of the effect it may appear more significant in the smaller sample during calculations of changes between pre- and post-intervention measures (Serdar *et al.*, 2021).

The divergence in the results of the SA cohort in comparison with the global analysis indicates that there may be a disparity in the representativeness of the South African data within a broader context of the global study (Andrade, 2020). The findings suggest that the unique socio-economic and infrastructural challenges faced by South Africans may have had a negative impact on their participation and engagement in the online PA program (Ritchie *et al.*, 2022).

One of the primary potential drawbacks experienced in the SA context was "load shedding," a term used in South Africans to describe scheduled electricity interruptions due to electricity resource inadequacies (Ritchie *et al*., 2022). The lack of electricity supply can severely interrupt daily activities, including participation in virtual exercise sessions, as it directly affects internet connectivity (Kgarose *et al*., 2023). Unstable internet connections hinder access to online platforms that require live streaming, which are crucial for real-time interaction and engagement in exercise programs. Research indicates that reliable internet access is essential for the success of such interventions, yet many South Africans face barriers due to high costs and limited availability of uncapped internet services.

In addition, South Africans experienced water supply shortages experienced in certain parts of the country during the pandemic. This may have exacerbated the poor participation in physical activities (Torres *et al.,* 2021). A lack of access to basic necessities such as the supply of clean water can significantly impact individuals' priorities, leading them to deprioritize PA interactions. This situation highlights how external factors can influence health behaviours and outcomes, particularly in vulnerable populations (Tafireyi and Grace, 2022).

The economic landscape during the pandemic changed drastically during the pandemic and its resultant lockdown (Endris Mekonnenand Kassegn Amede, 2022). Unemployment rates increased with the threat of further increases in unemployment even after the pandemic (Altman, 2022). The high unemployment rate enhanced the existing socioeconomic inequalities, making it difficult for many individuals to afford necessary services, including internet access required for online PA interventions (Gqoboka *et al*.,2022). The financial strain on the lives and livelihoods of the generally disadvantaged populations may have further contributed to the reduced participation rates in virtual exercise programs as people prioritized immediate survival over health-related activities (Zimu *et al*., 2020).

High dropout rates during the active phase of this intervention is an aspect that needs to be integrated. The literature on evidence-based interventions indicated that increased dropout rates during interventions have the potential to weaken the results obtained (Meyerowitz-Katz *et al*., 2020). The Move ASAP global analysis presented a 54% dropout rate, whereas the SA RCT presented in this thesis showed a dropout percentage of 52.1%. This particular subject warrants a deeper examination due to its significant potential influence on the overall findings regarding the effectiveness of the South African segment within the broader context of the global RCT. The data reveals that participant dropout rates have notably distorted the distribution of individuals between the IG and CG. Initially, there were 128 participants in the IG and 91 in the CG; however, post-testing figures indicate a concerning decline to just 65 and 40 participants, respectively. This substantial reduction raises questions about the representativeness of the results obtained from this study.

Other studies, such as those conducted by Cramer *et al.,* (2016) and Dixon *et al.,* (2020), have underscored the importance of considering dropout rates when designing intervention programs. These researchers encourage the implementation of strategies aimed at both preventing participant dropouts and effectively accounting for them during data collection and analysis phases. The implications of these dropout rates are important; while the outcomes derived from the South African cohort hold relevance, they are indisputably shaped by various factors that, if adequately addressed, could have led to more favourable results. The need for comprehensive strategies to mitigate dropout rates is not merely an academic concern but a practical necessity for enhancing the reliability and applicability of research findings in real-world settings (Meyerowitz-Katz *et al*., 2020).

This discussion underscores, the benefits of online PA and the increased need for online PA during the SARS-Cov-2 pandemic due to high levels of PA decline during lockdown restrictions. Additionally, the results of the SA RCT highlighted the need for future online PA interventions to consider these unique challenges faced by specific populations, especially during crises. Introducing tailoring into online PA interventions to address local conditions such as providing offline resources or alternative engagement strategies could enhance participation rates and improve health outcomes.

The findings of the various parts of this thesis show consolidated support for online PA and the positive effects it elicits on overall physical and mental well-being. These findings further highlight the need for individualisation of online PA programs, which can increase program adherence, thus optimising the benefits yielded from online PA. Understanding these

contextual factors is crucial for designing effective public health strategies that are inclusive and equitable.

6.2. Strengths and Limitations

6.2.1. Strengths

- The systematic review and meta-analysis conducted included measures of mental wellbeing when presented in the same study as measures of physical function and physical activity in healthy adult participants. This allowed for the inclusion of multifaceted studies in the review process.
- The meta-analysis stage utilised GRADE classification to establish the level of confidence in each outcome measure effect size, thus increasing the quality of the findings reported.
- The study inclusion was limited to RCTs which has, in the literature, been reported as a high-quality study method for effectiveness investigations.
- The original survey data contributed to a global statistics report during the SARS-CoV-2 pandemic and assisted in bringing into focus the drastic decreases in the PA levels during the pandemic.
- The re-analysis of the SA-specific data provided a nuanced look at the manner in which the PA levels within the SA population were affected by the lockdown restrictions.
- The comparison of the SA-specific data, to that of the overall global statistics, assisted in identifying SA related limitations with regards to online PA.
- The RCT used qualified exercise therapists to conduct the live-streaming sessions which added significantly to the integrity of the exercise programs that were delivered.
- The exercise schedules allowed participants the choice of which sessions to join, adding a level of catering for individual needs within the target group.
- The control group was given access to recorded videos after the initial active exercise stage, thus further improving the overall PA opportunities present for participants.
- The thesis as a whole presented various study types, using a variety of data collection and analysis methods. This strengthened the quality of the presented results.
- The involvement of various testing sites for the participant related portions of this thesis presented an opportunity for real-time comparisons between countries with different socio-economic backgrounds. This strengthen the thesis by placing emphasis on the potential flaws that may exist in multi-centred study designs, which allowed for

identification of shortfalls that can be addressed in future studies.

6.2.2. Limitations

- The review only included studies that assessed mental outcomes with motor function, and excluded articles that solely measured mental health outcomes.
- This review only assessed studies utilising healthy participants, which did not allow for measurement of the quality of evidence available in the general adult population.
- The SA survey and RCT were planned and implemented as portions of larger global studies, which limited the use of South African-specific context in the preparation and execution of the studies.
- The survey findings were based on PA levels in relation to the availability of PA opportunities but did not consider the effects of external factors during the pandemic that may have hampered PA engagement.
- The difference in the global and SA RCT results highlighted that there is a gap in the study with regard to country specific needs.
- The RCT was conducted during the SARS-CoV-2 pandemic and as much as this provided vital information with regards to the online PA interventions during the pandemic, the pandemic itself may have affected results.
- An analysis comparing the PA levels across age ranges pre-lockdown was not conducted, this could have increased variables of comparison between pre-and post-lockdown measures for the RCT.
- Sub-analyses based on type of OE were not conducted in the systematic review and meta-analysis, this could have provided a more in-depth insight into the results.
- The investigations included in the thesis, began during the lockdown, however, as the pandemic was dynamic and unpredictable, the findings may have been affected by the constant change in the pandemic, which lead to constant change in PA behaviour.

6.3. Guidelines

The overall findings and limitations of this thesis have highlighted certain critical aspects that need to be taken into consideration in the planning and implementation of future online PA interventions. These guidelines based upon the consideration of four critical aspects; Cultural and Socioeconomic Considerations, Cost Implications for Participants and Accessibility, Behavioural Change, and Intervention Duration, Sample Size and Drop-Out Analysis.

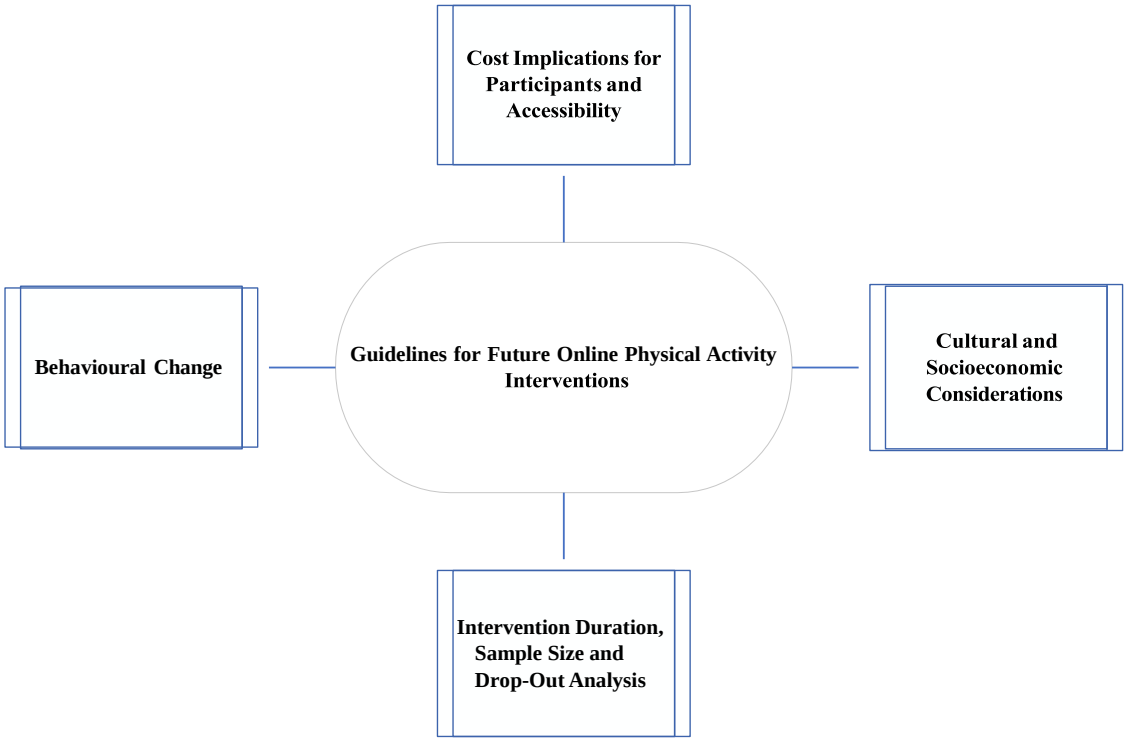

Figure 1. Guidelines for Future Online Physical Activity Interventions

6.3.1. Cultural and Socioeconomic Considerations

A major limitation noted in this thesis was the lack of intervention specifications that could address the cultural and socioeconomic imbalances that may have influenced the manner in which South African participants responded to and engaged with the online PA intervention. The literature on the topic of cultural and socioeconomic implications in PA interventions shows that taking these aspects into consideration can improve intervention participation and effectiveness. A study investigating the effectiveness of an online PA intervention in Hispanic women in the United States of America highlighted the important role played by cultural and socioeconomic factors in activities of everyday life. This study recommended that is it vital for researchers to accommodate for these population characteristics when designing online PA interventions (Marcus *et al*., 2016).

Another study investigating the same target population concluded that the effectiveness of online PA interventions may be influenced by cultural and socioeconomic history. Therefore, these demographic factors must be integrated into intervention planning (Hartman *et al*., 2017). By catering for these individual participant traits within online PA interventions, researchers have the ability to provide valuable PA opportunities to portions of the population that may not

have access to regular PA facilities thus increasing the effectiveness of the online intervention (Hartman *et al*., 2022). These findings relate to the findings in this thesis which relate the decreased online PA engagement to possible SA specific challenges. Hence, future online PA interventions should include a level of consideration of cultural and socioeconomic considerations (Mendoza-Vasconez *et al.*, 2022).

6.3.2. Cost Implications for Participants and Accessibility

The survey and RCT portions of this thesis, were both conducted online, in SA good, stable internet connections are not universally available (Lembani *et al*., 2020). There are immense disparities that occur in the South African context with regards to the availability of internet among rural and urban populations due to the cost of internet connections (Aruleba and Jere, 2022). The lack of adequate internet access could be a key factor in the decreased PA interactions in the RCT portion of this thesis. The concept of cost efficacy has been reported in several other studies investigating online PA interventions (Hartman *et al*., 2017; Wadhen and Cartwright 2021; Lindsay *et al.*, 2019). An epidemiological report of the PA energy expenditure in 12002 adult participants in the United Kingdom indicated that participants with higher incomes tend to perform better with online PA interventions (Lindsay *et al*., 2019). Wadhen and Cartwright (2021) investigated the effectiveness of a 6-week yoga intervention on 34 healthy adult participants. This study reported that there is room for improving lower income population engagement with online PA by ensuring online PA interventions are cost effective in comparison to traditional PA resources. Participants need to be provided with the opportunity to engage in online PA without the burden of increased cost on their part. This can be addressed by choosing online platforms that do not require large data consumption or high internet speeds. The use of group exercise platforms can limit cost by allowing for more than one participant to log onto the platform at a time (Lightner *et al*., 2023). Based on the findings of this thesis and the evidence available on cost implications and accessibility to the resources for engagement in online PA interventions, future online programs would benefit from designs that are cost effective and caters for accessibility in lower income populations.

6.3.3. Behavioural Change

The overall goal of online PA interventions should be to encourage long term PA intervention adherence that translates into positive changes in PA behaviour. Changed PA behaviours will translate into long-term PA benefits; hence it is deemed essential for researchers to include

behavioural change tools in the planning of online PA interventions (Hartman et al., 2017). The intervention design of our RCT, may have enhanced the lack of PA engagement as it did not include aspects of theoretical frameworks for behavioural change. Other similar studies conducted showed that aspects of behavioural change such as goal setting, participant logs and progress tracking showed increased engagement that may have been related to underpinning of behavioural change theories (Marcus *et al*., 2016).

Another study Beauchamp *et al*., (2021) investigated the effectiveness of an online PA intervention during the emergence of the SARS-CoV-2 pandemic in Canada. The findings of this study that included 239 participants aged 65 years and older indicated that by tracking progress towards participants' pre-set goals, the interface presents the participants with a level of motivation to adhere to the intervention and complete the prescribed exercises. Better intervention adherence inevitably leads to higher intervention effectiveness.

Another effective behavioural change tool that could have been beneficial in improving program retention and interaction for our RCT, is self-monitoring, where participants are encouraged to track and log their PA choices and behaviours over the course of the intervention (Schroé *et al.,* 2020). Online PA interventions should consider the use of personalised participant tracking and interactions (Dekker-van Weering 2017). Schwartz *et al* (2021) reported positive effects in relation to the inclusion of personalised trainer feedback based on participants' techniques and activity logs in a study investigating the feasibility of a Zoom based exercise program delivered to 28 Israeli participants. Interestingly our RCT did include a qualified exercise trained physiotherapist who implemented the virtual exercise regimen and provided feedback to participants. However, it must be acknowledged that perhaps a more specific PA professional such as a biokineticist or and personal trainer may have been a more Hence, in providing guidelines towards the development of future PA interventions, the findings and limitations of this thesis, encourage the use behavioural change related frameworks to encourage intervention engagement and participant retention.

6.3.4. Intervention Duration, Sample Size and Dropout Analysis

The global Move ASAP study analysed two phases of the program (four weeks active exercise; four weeks pre-recorded exercise). The SA RCT analysis presented in this thesis, focused solely on the four-week active phase of the program. This raises the question of whether or not the results may have been different if the entire 8 weeks were analysed. Other studies have indicated that longer durations are said to provide participants with sufficient time to engage

with the intervention, allowing them to become more familiar with the interface and technicalities associated with the intervention. Hence, it is recommended that online PA interventions utilise active exercise timeframes that are greater than 12 weeks in duration (Levy *et al*., 2015)

According to Yi and Yim (2021) it is essential that the concepts applied to the development of online PA intervention are capable of evolving into programs that can be generalised for consumption by the overall population. In order to allow for generalisability, it is essential to gauge the long-term effects of the online PA intervention. To achieve this, researchers need to incorporate a period of follow-up measurements (Tekin and Cetisli-Korkmaz 2022: 714; Marcus *et al*. 2016: 1). Therefore, it can be recommended that in the planning of future online PA interventions there is a need for longer durations and long-term follow-ups to gauge the effects on PA behavioural changes.

This thesis also presented a limitation that was inconsistent participant allocations with regards to IG and CG, as already discussed this may have affected the results and the analysis thereof. The literature states that the effectiveness of any online PA intervention can be skewed if the sample size is not large enough (Dekker-van Weering *et al.,* 2017). Large sample sizes are recommended to ensure proper understanding of the extent of the intervention effect (Beauchamp *et al*., 2021). Researchers must perform statistically correct sample size calculations and account for dropouts when stipulating the desired sample size for the intervention (Kikuchi *et al*., 2021). In our RCT, we had a high dropout rate, however, there was no thorough investigations into the reasons for dropouts. It is hence, recommended that future online interventions include critical analysis of the dropouts during the intervention duration.

6.4. Recommendations

- Future studies should conduct reviews and analyses that investigate mental health outcomes only. This will allow for a deeper look into the effects of online PA on mental health outcomes.
- Systematic reviews and meta-analyses should delve into the literature pertaining to unhealthy participants and the effects of online PA interventions on their health status. This will increase the generalisability of the effectiveness, while also allowing for the comparison of PA changes noted between healthy and unhealthy populations.

- Opportunities should be explored for research to specifically target the SA population and its PA levels as well as its response to online PA interventions. The studies in this thesis were a part of a global plan which despite its benefits did not allow for accommodation or analysis of the SA-specific context. By conducting context-specific interventions, the opportunity for comparison between national and international populations will present, researchers with the resources needed to apply findings from one region to others with similar backgrounds and circumstances.
- Future studies, during unforeseen calamities, could improve findings by accommodating for the effects of the particular event on PA motivation rather than focusing solely on a decrease in PA opportunity. This will assist by creating the platform for the identification and analysis of external factors during periods of crisis, which impact PA engagement and participant retention in online PA programs.
- In order to ascertain more detailed results regarding the effects of the online PA interventions, it would be necessary to conduct the same trial outside of an active pandemic. In doing so enables the distinction between true effectiveness of the intervention versus effectiveness results that may be skewed due to the various compounding factors that may have affected PA participation during the pandemic.
- The next step from this thesis would be investigation creating a framework based on the findings of this these, which may have application potential in future online PA intervention designs.

6.5. Conclusion

As local and global populations progress, there is a need for constant improvement in the manner in which we examine and evaluate health and health related topics. PA forms a principal part of a much larger public health endeavour, where the focus is placed on preventative measures rather than curative and a strategy that can be adopted in order to increase the health status of the generalised public, more easily and affordably. The benefits of PA have been discussed and established for many years; however, this area of research still requires a considerable amount of development, refinement and improvement. The SARS-CoV-2 pandemic served as a reminder of the ever-changing nature of healthcare. This pandemic illuminated the need for health and health related sectors to use the advanced technology at its fingertips to deliver effective, low-cost and high-quality PA opportunities to individuals. If future online PA interventions are developed by taking specified considerations

into account as reported in the literature and findings of this thesis, there is potential to change the face of online PA interventions. Thus, creating the potential for such interventions to be as beneficial as face-to-face PA and potentially further overcoming some of the limitations of face-to-face PA interventions. This may allow us to provide the health benefits of regular PA to populations across the world that are currently not experiencing these benefits due to a lack of accessibility. It is therefore essential that the area of online PA research gives due consideration to optimising the effects and the usage of online PA opportunities.

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APPENDICES

Appendix 1: Ethics Approval

Institutional Research Ethics Committee
Research and Postgraduate Support Directorate
2nd Floor, Berwyn Court
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24 August 2020

Dr A K Bhundoo
Unit 27 Highland Hills
94 Bardia Avenue
Reservoir Hills
4090

Dear Dr Bhundoo

Physical activity and health during the sars-cov2 pandemic towards developing a framework for online physical activity interventions
Ethical Clearance number IREC 090/20

The Institutional Research Ethics Committee acknowledges receipt of your gatekeeper permission letter.

Please note that FULL APPROVAL is granted to your research proposal. You may proceed with data collection.

Any adverse events [serious or minor] which occur in connection with this study and/or which may alter its ethical consideration must be reported to the IREC according to the IREC Standard Operating Procedures (SOP's).

Please note that any deviations from the approved proposal require the approval of the IREC as outlined in the IREC SOP's.

Yours Sincerely

_____
Prof J K Adam
Chairperson: IREC

Appendix 2: ASAP Survey

ASAP → base 27.03.2020, 18:18

Seite 01

Start

Welcome

The outbreak of the novel coronavirus has changed our life within shortest time. In many countries, public life has been reduced or canceled (e.g. by means of business closures, bans of public gathering or quarantine) in order to reduce social contact and, with this, contain the pandemic. For many individuals, regular access to gyms, sports clubs or sports facilities is no longer possible.

We, scientists of Frankfurt University (Germany), Harvard Medical School (USA) and the University Medical Centers Amsterdam (Netherlands), aim to help all those being affected by the current situation. To promptly create new exercise programs, contents and methods, we conduct a brief survey assessing your physical activity levels well-being during the pandemic. Our survey will take less than 10 minutes.

The guidelines of good ethical research stipulate that participants in empirical studies explicitly and comprehensibly agree to participate.
Voluntary. Your participation in this investigation is voluntary. You are free to cancel your participation at any time in this study without incurring any disadvantages.

Anonymity. Your data is treated confidentially, will be stored encrypted and password-protected, only be evaluated anonymously and not be passed on to third parties. All collected data will only be used for scientific purposes. Demographic information such as age or gender does not allow a clear conclusion to be drawn with regard to yourself.

Questions. If you still have questions about this study, you can find the contact details of the principal investigator of this study in the bottom of each page (’Contact’).

By participating in this survey (indicated by clicking the ‘Participate’-button), I confirm that I am older than 18 years and have read and understood the informed consent.

Participate

Seite 02

SD

Please indicate your sex.

- ◯ Male
- ◯ Female
- ◯ Non-binary
- ◯ I prefer not to say

What is your age?

_____ years

Where do you live?

[Please choose]

Where do you work since the virus outbreak in your country?

- ◯ Remotely (Home office)
- ◯ Office/regular place of work
- ◯ both
- ◯ I do not have a formal employment.
- ◯ I do not want to tell.

Seite 03

Arbeit

Do you currently work part-time or full-time?

- ◯ full-time
- ◯ part-time
- ◯ I do not want to tell

Seite 04

KH

Have you had any symptoms beyond a minor respiratory tract infection since the virus outbreak in your country?
Only choose yes, if you had to stay in bed or reduce your regular movement behaviour due to these symptoms.

- ◯ yes
- ◯ no

Seite 05

Corona

Have you been diagnosed with the novel Coronavirus?

Only choose “yes” if you have been diagnosed by a helathcare professional.

- ◯ yes
- ◯ no
- ◯ I do not want to tell

Seite 06

Einschraenkung

Please indicate the approximate number of days you have been limited in your ability to leave your home and move freely due to restrictions of public life (e.g. prohibition of face-to-face contact, business closures, lockdowns).

_____ days

Seite 07

Erklaerung

From here, we will repeatedly ask how certain situations and conditions have changed in your country since the outbreak of the novel coronavirus. For instance, if you just stated to be restricted in your ability to move freely since 14 days, please always compare the situation during these last 14 days to 14 typical days prior to the outbreak. If you chose 30 days, please compare these 30 days with 30 typical days prior to the outbreak.

Seite 08

KAFrei

Physical activities in leisure time

We would like to know, how physically active you have been in your **free time** (including commuting from and to work). We only ask about moderate and vigorous activities – light activities do not need to be reported.

Moderate activities are those where your hearbeat increases and you breathe faster (e.g. brisk walking, cycling as a means of transport or as a exercise, heavy gardening, running or recreational sports).

Vigorous activities are those that get your heart racing, make you sweat and so short of breath that you find it difficult to speak (e.g. swimming, running, cycling at high speeds, cardio training, weigh-lifting or team sports such as football).

Moderate and vigorous activities

On a typical week, how much time do you spend in total on both moderate and vigorous physical activities?

Please sum all activities with a minimal duration of 10 minutes. Leave this field empty if there was not at least one activity of more than 10 minutes.

before the outbreak		Minutes per week.
since the outbreak		Minutes per week.

Vigorous activities only

How much of that time you indicated above, do you spend in total on **vigorous physical activities** only?
Please sum all activities with a minimal duration of 10 minutes. Leave this field empty if there was not at least one activity of more than 10 minutes.

before the outbreak		Minutes per week.
since the outbreak		Minutes per week.

Seite 09

KAJob

Physical activity in your job

While the previous questions addressed free time, the following two focus on work/occupational time. Again, we only ask about moderate and vigorous activities – light activities do not need to be reported.

Moderate activities are those where your hearbeat increases and you breathe faster (e.g. brisk walking).

Vigorous activities are those that get your heart racing, make you sweat and so short of breath that you find it difficult to speak (e.g. repeated lifting of heavy weights).

Moderate and vigorous activities

On a typical week, how much time do you spend in total on both moderate and vigorous physical activities?

Please sum all activities with a minimal duration of 10 minutes. Leave this field empty if there was not at least one activity of more than 10 minutes.

before the outbreak		Minutes per week.
since the outbreak		Minutes per week.

Vigorous activities only

How much of that time you indicated above, do you spend in total on **vigorous physical activities** only?

Please sum all activities with a minimal duration of 10 minutes. Leave this field empty if there was not at least one activity of more than 10 minutes.

before the outbreak		Minutes per week.
since the outbreak		Minutes per week.

Seite 10

Aktivitaetsniveau

Please indicate the impact of the restrictions in public life on your overall level of activity (now including also light and very light activities such as shopping, walking, etc.)

strongly negative influence	slight negative influence	no influence	modest positive impact	strongly positive influence
○	○	○	○	○

Seite 11

KA3

How did you engage in sport or exercise before the virus outbreak in your country?

Multiple choice possible.

- [ ] Gym
- [ ] Sports club
- [ ] Self-organised outdoor (e.g. running, cycling in nature)
- [ ] Self-organised at home (e.g. cycle ergometer, dumbbells)
- [ ] others
- [ ] not at all

How did you engage in sport or exercise since the virus outbreak in your country?

Multiple choice possible.

- [ ] self-organised outdoor (e.g. running, cycling in nature)
- [ ] self-organised at home (e.g. cycle ergometer, dumbbells)
- [ ] others
- [ ] not at all

Seite 12

Pain

Please indicate whether you suffered from musculoskeletal pain before and/or since the virus outbreak.

The musculoskeletal system comprises all parts of the skeletal system with bones, muscles, ligaments, tendons, joints and their functions.

	no pain	very light pain	light pain	moderate pain	strong pain	very strong pain
before outbreak	○	○	○	○	○	○
since outbreak	○	○	○	○	○	○

How much did pain interfere with your normal work (including both work outside the home and housework)?

	no pain	not at all	a little bit	moderately	quite a bit	extremely
before outbreak	○	○	○	○	○	○
since outbreak	○	○	○	○	○	○

Seite 13

Checkliste

question('WB15', 'combine=WB16')

Please list all body regions where you had pain before (left boxes) and/or side (right boxes) the onset. Multiple selections in both columns are possible.

	before outbreak	since outbreak
I did not have pain.	☐	☐
Neck/cervical spine	☐	☐
Shoulder	☐	☐
Upper arm	☐	☐
Elbow	☐	☐
Forearm	☐	☐
Wrist	☐	☐
Hand	☐	☐
Fingers	☐	☐
Thoracic spine/upper back	☐	☐
Sternum/Ribs	☐	☐
Lumbar spine/lower back	☐	☐
Abdomen	☐	☐
Pelvis/buttock	☐	☐
Hip	☐	☐
Groin	☐	☐
Thigh	☐	☐
Knee	☐	☐
Lower leg	☐	☐
Ankle/achilles tendon	☐	☐
Foot/toes	☐	☐

Seite 14

WHO5

Please indicate for each of the five statements which is closest to how you have been feeling before the outbreak of the novel coronavirus.

	all the time	most of the time	a little more than half of the time	a little less than half of the time	every now and then	at no time
Before the outbreak...						
...I have felt cheerful and in good spirits	○	○	○	○	○	○
...I have felt calm and relaxed	○	○	○	○	○	○
...I have felt active and vigorous	○	○	○	○	○	○
...I woke up feeling fresh and rested	○	○	○	○	○	○
...my daily life has been filled with things that interest me	○	○	○	○	○	○

Please indicate for each of the five statements which is closest to how you have been feeling since the outbreak of the novel coronavirus.

	all the time	most of the time	a little more than half of the time	a little less than half of the time	every now and then	at no time
Since the outbreak						
...I have felt cheerful in good spirits	○	○	○	○	○	○
...I have felt calm and relaxed	○	○	○	○	○	○
...I have felt active and vigorous	○	○	○	○	○	○
...I woke up feeling fresh and rested	○	○	○	○	○	○
...my daily life has been filled with things that interest me	○	○	○	○	○	○

Seite 15

WB

In general, how would you rate the influence of restrictions by government due to the novel coronavirus (e.g., the closure of sports facilities and gyms, bans of public gathering or quarantine) on your personal well-being?

	strong negative influence				no influence				strong positive influence
mental well-being	○	○	○	○	○	○	○	○	○
physical well-being	○	○	○	○	○	○	○	○	○

Since the outbreak of the novel coronavirus, sport and/or physical activity helps me deal with the overall situation.

completely disagree			rather disagree			rather agree			totally agree
○	○	○	○	○	○	○	○	○	○

Seite 16

TP

Would you be interested in a free online exercise training program that you could use home-based despite the restrictions in public life?

- ○ yes
- ○ no

Seite 17

TP2

How much time per week would you like to spend for such a training program?

Minutes per training session/workout

How often would you like to exercise?

- daily
- 4-6 times a week
- 3-4 times a week
- 1-2 times a week

Which type of exercise would you like to perform?

Multiple choice possible.

- Strength
- Endurance
- Coordination/Balance
- Cognition
- Flexibility/Stretching
- Relaxation
- no preference

Seite 18
Code

Almost there!

We work hard to develop training programs which, based on these results, take your specific situation into account. With a personal code you can register for the training program after it has been created.

Please make a note of this code so that you can register for the training program in the form of live videos on the following website:

http://asap-study.mystrikingly.com/

Further information (multilingual), such as dates for the live videos, can be found on our Facebook and Instagram pages:

https://www.facebook.com/ASAP.ExerciseAtHomeButNotAlone/

https://www.instagram.com/asap_exerciseathomebutnotalone/

Please feel free to share this survey with your family, work colleagues and friends.

Click "Next" to send the questionnaire.

Letzte Seite

Thank you for participating!

Your answers have been saved, you can now close the browser window.

Jan Wilke, Goethe University Frankfurt – 2020

Appendix 3: Move ASAP Baseline Questionnaire

Seite 01

Willkommen

SC02

Welcome

The outbreak of the coronavirus (COVID-19) has changed our live within shortest time. Numerous countries have restricted or suspended public life in order to reduce social contact. This does also mean that access to fitness studios, sports clubs or sports facilities is no longer possible. We, an association of multiple universities, offer you to participate in our study, which examines the effects of digital home training programs on well-being and physical activity.

What we offer: Our study has a total duration of 8 weeks. During the first 4 weeks (study part 1), you will be randomly allocated to a training or control group. In the training group, you can engage in a live exercise program live streamed online as often as you wish. The workouts have a duration of 10 to 60 minutes and are guided by trained instructors. If needed, you have the possibility to ask the trainer questions about the correct execution of the exercises. However, you can also switch off camera and sound at any time and there will be no recording by us. After the four weeks of live training you will receive unlimited access to our large online archive with numerous workouts for another four weeks (study part 2).

If you are in the control group, you will not receive any home training offer for the first four weeks (study part 1). However, subsequently, you will have access to our large online archive with various workouts and exercises for four weeks (study part 2), which you can use as often as you like.

What we need from you: Does our training help you? Please let us know once a week during the study by completing a short online questionnaire (only about 5-8 minutes each). In the questionnaire, we ask you about your mental and physical well-being and how often you have used our workouts.

Risks: Physical activity and sport are very healthy and the positive effects almost always outweigh possible negative consequences. Nevertheless, there may also be a risk of pain or other health issues (e.g. injuries or circulatory problems). Participation in the study is only possible for adults without serious cardiovascular diseases (e.g. cardiac rhythm disorders, high blood pressure, history of heart attack or stroke), neurological diseases (e.g. Parkinson's disease, Multiple Sclerosis), metabolic diseases (e.g. Diabetes Mellitus) or mental illnesses (e.g. depression). If you have been informed by a doctor that you are not allowed to participate in sports without load limitation, please do not participate.

SC01

The guidelines of good scientific practice and ethical research stipulate that participants in empirical studies must explicitly and comprehensibly declare their agreement to participate.

Voluntary. Your participation in this study is voluntary. You are free to cancel your participation at any time during the study without giving reasons and without incurring any disadvantages. You also have the right to demand the immediate deletion of your personal data at any time.

Data security. Your data is, of course, confidential and will be stored encrypted and password protected on computers of the Goethe University Frankfurt. The data will not be passed on to third parties or parties not involved in the project and will be used exclusively for scientific purposes (evaluation and re-analysis).

Anonymity. Apart from your email address, no information is collected that could directly identify you. We need your email address in order to send you information necessary for the study (e.g. access to the online training programme and the web address of the surveys). The email address will not be used for any other purposes. After completion of the study, your email address will be deleted from our data set so that the data is only available in anonymised form and cannot be linked to you personally.

Questions. If you have any questions about this study, you will find the contact details of the study director ('Imprint ASAP') on each page of the questionnaire below.

By participating in this survey (and clicking on 'Participation') I confirm that

- I am over 18 years old and healthy,

- I have read and understood the information and declaration of consent,

- and I agree to the use of my data as stated above.

Participation

Seite 02

PA01

Dear participant,
With the following questions, we want to assess whether there are fundamental concerns for the engagement in exercise.

Please answer the following questions with “yes” or “no”.

	No	Yes
Has your doctor ever said that you have a heart condition and that you should only perform physical activity recommended by a doctor?	○	○
Do you feel pain in your chest when you perform physical activity?	○	○
In the past month, have you had chest pain when you were not performing any physical activity?	○	○
Do you lose your balance because of dizziness or do you ever lose consciousness?	○	○
Do you have a bone or joint problem that could be made worse by a change in your physical activity?	○	○
Is your doctor currently prescribing any medication for your blood pressure or for a heart condition?	○	○
Do you know of any other reason why you should not engage in physical activity?	○	○

Seite 03

Code I

C004

Please *** absolutely*** save this code. Only with it, you will be able to participate in the **training program**.

Seite 04

SD I

SD01

Please indicate your sex.

- ◯ Male
- ◯ Female
- ◯ Non-binary
- ◯ I prefer not to say

SD02

What is your age?

_____ years

SD07

Do you have a university degree (Bachelor, Master, PhD)?

- ◯ Yes
- ◯ No

SD08

Where do you live?

[Please choose]

SD06

How would you describe your (living) environment?

- ◯ rural
- ◯ urban

SD04

Where do you work since the virus outbreak in your country?

- ◯ Remotely (Home office)
- ◯ Office/regular place of work
- ◯ both
- ◯ I do not have a formal employment.
- ◯ I do not want to tell.

Seite 05

SD II

KS06

With the following questions we would like to find out to what extent your possibilities to do sports are currently limited due to the coronavirus pandemic.

question('KS02', 'combine_items=yes', 'combine=KS04', 'gap=line', 'combine_items=yes')

KS02 KS04

Is access to indoor sports facilities (e.g. fitness studio) possible?

During the last 7 days

- Yes
- No
- Partly

During the last 4 weeks

- Yes
- No
- Partly

question('KS03', 'combine_items=yes', 'combine=KS05', 'gap=line', 'combine_items=yes')

KS03 KS05

Is access to outdoor sports facilities (e.g. parks, sports fields, etc.) possible?

During the last 7 days

- Yes
- No
- Partly

During the last 4 weeks

- Yes
- No
- Partly

AZ01

How much do you agree with the following statement?

I find it easy to accept the restrictions of public life.

do not agree	rather not agree	rather agree	agree

Seite 06

Sport

KS01

Please indicate to what extent the following statements apply to you personally.

I have the intention to be active in sports regularly over the next weeks and months, ...	doesn't apply at all					that's exactly right
...because I just enjoy it.	○	○	○	○	○	○
... because people I care about are pushing me to do it.	○	○	○	○	○	○
... because the positive consequences are simply worth the effort.	○	○	○	○	○	○
... because otherwise I'd blame myself.	○	○	○	○	○	○
... because sporting activity is simply part of my life.	○	○	○	○	○	○
... because otherwise I get into trouble with other people.	○	○	○	○	○	○
... because it's good for me.	○	○	○	○	○	○
... because otherwise I have a bad conscience.	○	○	○	○	○	○
... because it gives me experiences I wouldn't want to miss.	○	○	○	○	○	○
... because others tell me to be active in sports.	○	○	○	○	○	○
... because I have good reasons to be.	○	○	○	○	○	○
... because I think that sometimes you have to force yourself to do something.	○	○	○	○	○	○

Seite 07

Schmerz I

CP09

The following section asks about with your pain situation. The questions relate to different time periods. Please read the questions carefully.

CP01

How would you rate your pain on a 0-10 scale at the present time, this is right now, where 0 is 'no pain' and 10 is 'pain as bad as it could be'?

0 no pain	1	2	3	4	5	6	7	8	9	10 pain as bad as it could be
○	○	○	○	○	○	○	○	○	○	○

CP02

How intense was your worst pain rated on a 0-10 scale where 0 is 'no pain' and 10 is 'pain as bad as it could be'?

	0 no pain	1	2	3	4	5	6	7	8	9	10 pain as bad as it could be
During the past 7 days	○	○	○	○	○	○	○	○	○	○	○
During the past 4 weeks	○	○	○	○	○	○	○	○	○	○	○

CP03

On <u>average</u>, how intense was your pain rated on a 0-10 scale? (That is your usual pain at times you were experiencing pain)

	0 no pain	1	2	3	4	5	6	7	8	9	10 pain as bad as it could be
During the past <u>7 days</u>	○	○	○	○	○	○	○	○	○	○	○
During the past <u>4 weeks</u>	○	○	○	○	○	○	○	○	○	○	○

Seite 08

Schmerz II

CP04

About how many days have you been kept from your usual activities (work, school, housework) because of this pain?

In the last 7 days on about _____ days.

In the last 4 weeks on about _____ days.

CP05

How much has this pain interfered with your daily activities rated on a 0-10 scale where 0 is 'no interference' and 10 is 'unable to carry on activities'?

	0 no interference	1	2	3	4	5	6	7	8	9	10 unable to carry on activities
During the past 7 days	○	○	○	○	○	○	○	○	○	○	○
During the past 4 weeks	○	○	○	○	○	○	○	○	○	○	○

CP06

How much has this pain changed your ability to take part in recreational, social and family activities?

	0 no change	1	2	3	4	5	6	7	8	9	10 extreme change
During the past 7 days	○	○	○	○	○	○	○	○	○	○	○
During the past 4 weeks	○	○	○	○	○	○	○	○	○	○	○

CP07

How has this pain changed your ability to work (including housework)?

	0 no change	1	2	3	4	5	6	7	8	9	10 extreme change
During the past 7 days	○	○	○	○	○	○	○	○	○	○	○
During the past 4 weeks	○	○	○	○	○	○	○	○	○	○	○

Seite 09

Checklist

question('CL15', 'combine=CL16')

Please list all body regions where you had pain recently.

CL15
CL16

Multiple selections in both columns are possible.	**During the last 7 days**	**During the last 4 weeks**
I did not have pain.	☐	☐
Neck/cervical spine	☐	☐
Shoulder	☐	☐
Upper arm	☐	☐
Elbow	☐	☐
Forearm	☐	☐
Wrist	☐	☐
Hand	☐	☐
Fingers	☐	☐
Thoracic spine/upper back	☐	☐
Sternum/Ribs	☐	☐
Lumbar spine/lower back	☐	☐
Abdomen	☐	☐
Pelvis/buttock	☐	☐
Hip	☐	☐
Groin	☐	☐
Thigh	☐	☐
Knee	☐	☐
Lower leg	☐	☐
Ankle/achilles tendon	☐	☐
Foot/toes	☐	☐

Seite 10

SC I

SL04

The following section deals with your sleep behavior and sleep quality as well as your well-being.

question('SL01', 'combine_items=yes', 'combine=SL05', 'gap=line', 'combine_items=yes')

SL01
SL05

How long did it usually take for you to fall asleep?

During the past 7 days

- 0-15 minutes
- 16-30 minutes
- 31-45 minutes
- 46-60 minutes
- More than 60 minutes

During the past 4 weeks

- 0-15 minutes
- 16-30 minutes
- 31-45 minutes
- 46-60 minutes
- More than 60 minutes

SL02

On the average, how many hours did you sleep each night ?

During the past 7 days average _____ hours per night.

During the past 4 weeks average _____ hours per night.

Seite 11

SC II

SL03

Please mark to what extent the following statements apply to you for the past 7 days.

How often during the past 7 days did you…	All of the time	Most of the time	A good bit of the time	Some of the time	A little of the time	None of the time
feel that your sleep was not quiet (moving restlessly, feeling tense, speaking, etc., while sleeping)?	○	○	○	○	○	○
get enough sleep to feel rested upon waking in the morning?	○	○	○	○	○	○
awaken short of breath or with a headache?	○	○	○	○	○	○
feel drowsy or sleepy during the day?	○	○	○	○	○	○
have trouble falling asleep?	○	○	○	○	○	○
awaken during your sleep time and have trouble falling asleep again?	○	○	○	○	○	○
have trouble staying awake during the day?	○	○	○	○	○	○
snore during your sleep?	○	○	○	○	○	○
take naps (5 minutes or longer) during the day?	○	○	○	○	○	○
get the amount of sleep you needed?	○	○	○	○	○	○

SL06

Please mark to what extent the following statements apply to you for the past 4 weeks.

How often during the past 4 weeks did you…	All of the time	Most of the time	A good bit of the time	Some of the time	A little of the time	None of the time
feel that your sleep was not quiet (moving restlessly, feeling tense, speaking, etc., while sleeping)?	○	○	○	○	○	○
get enough sleep to feel rested upon waking in the morning?	○	○	○	○	○	○
awaken short of breath or with a headache?	○	○	○	○	○	○
feel drowsy or sleepy during the day?	○	○	○	○	○	○
have trouble falling asleep?	○	○	○	○	○	○
awaken during your sleep time and have trouble falling asleep again?	○	○	○	○	○	○
have trouble staying awake during the day?	○	○	○	○	○	○
snore during your sleep?	○	○	○	○	○	○
take naps (5 minutes or longer) during the day?	○	○	○	○	○	○
get the amount of sleep you needed?	○	○	○	○	○	○

Seite 12

WHO5

WB01

Please indicate for each of the five statements which is closest to how you have been feeling over the last 7 days.

During the last 7 days	all the time	most of the time	a little more than half of the time	a little less than half of the time	every now and then	at no time
...I have felt cheerful and in good spirits	○	○	○	○	○	○
...I have felt calm and relaxed	○	○	○	○	○	○
...I have felt active and vigorous	○	○	○	○	○	○
...I woke up feeling fresh and rested	○	○	○	○	○	○
...my daily life has been filled with things that interest me	○	○	○	○	○	○

WB02

Please indicate for each of the five statements which is closest to how you have been feeling over the last 4 weeks.

During the last 4 weeks	all the time	most of the time	a little more than half of the time	a little less than half of the time	every now and then	at no time
...I have felt cheerful and in good spirits	○	○	○	○	○	○
...I have felt calm and relaxed	○	○	○	○	○	○
...I have felt active and vigorous	○	○	○	○	○	○
...I woke up feeling fresh and rested	○	○	○	○	○	○
...my daily life has been filled with things that interest me	○	○	○	○	○	○

Seite 13

GAD7 I

GA01

Over the last 7 days, how often have you been bothered by the following problems?

	Not at all	Several days	More than half the days	Nearly every day
Feeling nervous, anxious or on edge	○	○	○	○
Not being able to stop or control worrying	○	○	○	○
Not being able to stop or control worrying	○	○	○	○
Trouble relaxing	○	○	○	○
Being so restless that it is hard to sit still	○	○	○	○
Becoming easily annoyed or irritable	○	○	○	○
Feeling afraid as if something awful might happen	○	○	○	○

GA02

Over the last 4 weeks, how often have you been bothered by the following problems?

	Not at all	Several days	More than half the days	Nearly every day
Feeling nervous, anxious or on edge	○	○	○	○
Not being able to stop or control worrying	○	○	○	○
Not being able to stop or control worrying	○	○	○	○
Trouble relaxing	○	○	○	○
Being so restless that it is hard to sit still	○	○	○	○
Becoming easily annoyed or irritable	○	○	○	○
Feeling afraid as if something awful might happen	○	○	○	○

Seite 14

AK GE

question('GE01', 'combine_items=yes', 'combine=GE02', 'gap=line', 'combine_items=yes')

In general, how would you rate the following factors?

GE01
GE02

During the past 7 days	extremely poor								very well
Wellbeing	○	○	○	○	○	○	○	○	○
Quality of life	○	○	○	○	○	○	○	○	○
Pain situation	○	○	○	○	○	○	○	○	○

During the past 4 weeks	extremely poor								very well
Wellbeing	○	○	○	○	○	○	○	○	○
Quality of life	○	○	○	○	○	○	○	○	○
Pain situation	○	○	○	○	○	○	○	○	○

Seite 15

KA I

KA07

Physical activities in leisure time

We would like to know, how physically active you have been in your free time (including commuting from and to work). We only ask about moderate and vigorous activities – light activities do not need to be reported.

Moderate activities are those where your hearbeat increases and you breathe faster (e.g. brisk walking, cycling as a means of transport or as a exercise, heavy gardening, running or recreational sports).

Vigorous activities are those that get your heart racing, make you sweat and so short of breath that you find it difficult to speak (e.g. swimming, running, cycling at high speeds, cardio training, weigh-lifting or team sports such as football).

KA02

Moderate and vigorous activities

On a typical week, how much time do you spend in total on both moderate and vigorous physical activities?

Please sum all activities with a minimal duration of 10 minutes. Leave this field empty if there was not at least one activity of more than 10 minutes.

during the last 7 days		Minutes per week.
during the last 4 weeks		Minutes per week.

KA03

Vigorous activities only

How much of that time you indicated above, do you spend in total on vigorous physical activities only?

Please sum all activities with a minimal duration of 10 minutes. Leave this field empty if there was not at least one activity of more than 10 minutes.

during the last 7 days		Minutes per week.
during the last 4 weeks		Minutes per week.

Seite 16

KA II

KA04

Physical activity in your job

While the previous questions addressed free time, the following two focus on work/occupational time. Again, we only ask about moderate and vigorous activities – light activities do not need to be reported.

Moderate activities are those where your hearbeat increases and you breathe faster (e.g. brisk walking).

Vigorous activities are those that get your heart racing, make you sweat and so short of breath that you find it difficult to speak (e.g. repeated lifting of heavy weights).
KA10

KA05
Rahmen

Moderate and vigorous activities

On a typical week, how much time do you spend in total on both moderate and vigorous physical activities?

Please sum all activities with a minimal duration of 10 minutes. Leave this field empty if there was not at least on of more than 10 minutes.

during the last 3 days		Minutes per week.
4 weeks ago		Minutes per week.

KA06

Vigorous activities only

How much of that time you indicated above, do you spend in total on vigorous physical activities only?

Please sum all activities with a minimal duration of 10 minutes. Leave this field empty if there was not at least one activity of more than 10 minutes.

during the past 3 days		Minutes per week.
4 weeks ago		Minutes per week.

Seite 17

KA III

KA09

Please estimate your total amount of activities - now including light and easy activities (e.g. shopping or walking).

	0 very small amount	1	2	3	4	5	6	7	8	9	10 very large amount
During the past 7 days	○	○	○	○	○	○	○	○	○	○	○
During the past 4 weeks	○	○	○	○	○	○	○	○	○	○	○

KA10

Please briefly describe your average sports activity per week for the last month according to the following pattern (example):

- 45 min running
- 60 min gymnastic exercises
- ...

Please list activities within the study.

Seite 18

Ausschluss

PA02

Unfortunately, participation in the study and the training program is not possible due to your health conditions.

You can close the browser window now.

Seite 19

Email

IN01

Please enter your e-mail address here.

We need your email address to send you study-relevant information (e.g. access to the online training). It will not be used for other purposes and will not be passed on to third parties. After completion of the study the email address will be deleted.

E-Mail

Seite 20

RN

question('RN01')

text('RN03')

You’re in the intervention group.

Let the training begin! You will soon receive an e-mail with further information.

text('RN04')

You’re in the waiting control group.

What does that mean?
- You also get free online workouts, but your training phase will start in about 4 weeks. You will soon receive an e-mail with further information.

question('RN14')

question('RN11')

question('RN05')

question('RN06')

question('RN21')

text('RN23')

Unfortunately there is no intervention in your country. But you will get access to the video archive with all training programs in 4 weeks.

Letzte Seite

Thanks a lot for your participation!

We would like to thank you very much for your help.

Your answers have been saved, you can close the browser window now.

Appendix 4: Move ASAP Weekly Questionnaire

moveASAPWoche4 → move-ASAP 29.04.2020, 09:44

Seite 01

Code I

C006

Welcome to the weekly survey!

Please enter your 8-digit code here.

Seite 02

SD II

question('KS02', 'combine_items=yes', 'combine=KS04', 'gap=line', 'combine_items=yes')

KS02 **KS04**

Is access to indoor sports facilities (e.g. fitness studio) possible?

During the last 7 days

- ○ Yes
- ○ No
- ○ Partly

During the last 4 weeks

- ○ Yes
- ○ No
- ○ Partly

question('KS03', 'combine_items=yes', 'combine=KS05', 'gap=line', 'combine_items=yes')

KS03 **KS05**

Is access to outdoor sports facilities (e.g. parks, sports fields, etc.) possible?

During the last 7 days

- ○ Yes
- ○ No
- ○ Partly

During the last 4 weeks

- ○ Yes
- ○ No
- ○ Partly

AZ01

How much do you agree with the following statement?

I find it easy to accept the restrictions of public life.

○	○	○	○
do not agree	rather not agree	rather agree	agree

Seite 03

Sport

KS01

Please indicate to what extent the following statements apply to you personally.

I have the intention to be active in sports regularly over the next weeks and months, ...	doesn't apply at all					that's exactly right
...because I just enjoy it.	○	○	○	○	○	○
... because people I care about are pushing me to do it.	○	○	○	○	○	○
... because the positive consequences are simply worth the effort.	○	○	○	○	○	○
... because otherwise I'd blame myself.	○	○	○	○	○	○
... because sporting activity is simply part of my life.	○	○	○	○	○	○
... because otherwise I get into trouble with other people.	○	○	○	○	○	○
... because it's good for me.	○	○	○	○	○	○
... because otherwise I have a bad conscience.	○	○	○	○	○	○
... because it gives me experiences I wouldn't want to miss.	○	○	○	○	○	○
... because others tell me to be active in sports.	○	○	○	○	○	○
... because I have good reasons to be.	○	○	○	○	○	○
... because I think that sometimes you have to force yourself to do something.	○	○	○	○	○	○

Seite 04

Schmerz I

CP09

The following section asks about with your pain situation. The questions relate to different time periods. Please read the questions carefully.

CP01

How would you rate your pain on a 0-10 scale at the present time, this is right now, where 0 is 'no pain' and 10 is 'pain as bad as it could be'?

0 no pain	1	2	3	4	5	6	7	8	9	10 pain as bad as it could be
○	○	○	○	○	○	○	○	○	○	○

CP02

How intense was your worst pain rated on a 0-10 scale where 0 is 'no pain' and 10 is 'pain as bad as it could be'?

	0 no pain	1	2	3	4	5	6	7	8	9	10 pain as bad as it could be
During the past 7 days	○	○	○	○	○	○	○	○	○	○	○
During the past 4 weeks	○	○	○	○	○	○	○	○	○	○	○

CP03

On average, how intense was your pain rated on a 0-10 scale? (That is your usual pain at times you were experiencing pain)

	0 no pain	1	2	3	4	5	6	7	8	9	10 pain as bad as it could be
During the past 7 days	○	○	○	○	○	○	○	○	○	○	○
During the past 4 weeks	○	○	○	○	○	○	○	○	○	○	○

Seite 05

Schmerz II

CP04

About how many days have you been kept from your usual activities (work, school, housework) because of this pain?

In the last 7 days on about _____ days.

In the last 4 weeks on about _____ days.

CP05

How much has this pain interfered with your daily activities rated on a 0-10 scale where 0 is 'no interference' and 10 is 'unable to carry on activities'?

	0 no interference	1	2	3	4	5	6	7	8	9	10 unable to carry on activities
During the past 7 days	○	○	○	○	○	○	○	○	○	○	○
During the past 4 weeks	○	○	○	○	○	○	○	○	○	○	○

CP06

How much has this pain changed your ability to take part in recreational, social and family activities?

	0 no change	1	2	3	4	5	6	7	8	9	10 extreme change
During the past 7 days	○	○	○	○	○	○	○	○	○	○	○
During the past 4 weeks	○	○	○	○	○	○	○	○	○	○	○

CP07

How has this pain changed your ability to work (including housework)?

	0 no change	1	2	3	4	5	6	7	8	9	10 extreme change
During the past 7 days	○	○	○	○	○	○	○	○	○	○	○
During the past 4 weeks	○	○	○	○	○	○	○	○	○	○	○

Seite 06

Checklist

question('CL15', 'combine=CL16')

Please list all body regions where you had pain recently.

CL15
CL16

Multiple selections in both columns are possible.	**During the last 7 days**	**During the last 4 weeks**
I did not have pain.	☐	☐
Neck/cervical spine	☐	☐
Shoulder	☐	☐
Upper arm	☐	☐
Elbow	☐	☐
Forearm	☐	☐
Wrist	☐	☐
Hand	☐	☐
Fingers	☐	☐
Thoracic spine/upper back	☐	☐
Sternum/Ribs	☐	☐
Lumbar spine/lower back	☐	☐
Abdomen	☐	☐
Pelvis/buttock	☐	☐
Hip	☐	☐
Groin	☐	☐
Thigh	☐	☐
Knee	☐	☐
Lower leg	☐	☐
Ankle/achilles tendon	☐	☐
Foot/toes	☐	☐

Seite 07

SC I

SL04

The following section deals with your sleep behavior and sleep quality as well as your well-being.

question('SL01', 'combine_items=yes', 'combine=SL05', 'gap=line', 'combine_items=yes')

SL01
SL05

How long did it usually take for you to fall asleep?

During the past 7 days

- 0-15 minutes
- 16-30 minutes
- 31-45 minutes
- 46-60 minutes
- More than 60 minutes

During the past 4 weeks

- 0-15 minutes
- 16-30 minutes
- 31-45 minutes
- 46-60 minutes
- More than 60 minutes

SL02

On the average, how many hours did you sleep each night ?

During the past 7 days average _____ hours per night.

During the past 4 weeks average _____ hours per night.

Seite 08

SC II

SL03

Please mark to what extent the following statements apply to you for the past 7 days.

How often during the past 7 days did you…	All of the time	Most of the time	A good bit of the time	Some of the time	A little of the time	None of the time
feel that your sleep was not quiet (moving restlessly, feeling tense, speaking, etc., while sleeping)?	○	○	○	○	○	○
get enough sleep to feel rested upon waking in the morning?	○	○	○	○	○	○
awaken short of breath or with a headache?	○	○	○	○	○	○
feel drowsy or sleepy during the day?	○	○	○	○	○	○
have trouble falling asleep?	○	○	○	○	○	○
awaken during your sleep time and have trouble falling asleep again?	○	○	○	○	○	○
have trouble staying awake during the day?	○	○	○	○	○	○
snore during your sleep?	○	○	○	○	○	○
take naps (5 minutes or longer) during the day?	○	○	○	○	○	○
get the amount of sleep you needed?	○	○	○	○	○	○

SL06

Please mark to what extent the following statements apply to you for the past 4 weeks.

How often during the past 4 weeks did you…	All of the time	Most of the time	A good bit of the time	Some of the time	A little of the time	None of the time
feel that your sleep was not quiet (moving restlessly, feeling tense, speaking, etc., while sleeping)?	○	○	○	○	○	○
get enough sleep to feel rested upon waking in the morning?	○	○	○	○	○	○
awaken short of breath or with a headache?	○	○	○	○	○	○
feel drowsy or sleepy during the day?	○	○	○	○	○	○
have trouble falling asleep?	○	○	○	○	○	○
awaken during your sleep time and have trouble falling asleep again?	○	○	○	○	○	○
have trouble staying awake during the day?	○	○	○	○	○	○
snore during your sleep?	○	○	○	○	○	○
take naps (5 minutes or longer) during the day?	○	○	○	○	○	○
get the amount of sleep you needed?	○	○	○	○	○	○

Seite 09

WHO5

WB01

Please indicate for each of the five statements which is closest to how you have been feeling over the last 7 days.

During the last 7 days	all the time	most of the time	a little more than half of the time	a little less than half of the time	every now and then	at no time
...I have felt cheerful and in good spirits	○	○	○	○	○	○
...I have felt calm and relaxed	○	○	○	○	○	○
...I have felt active and vigorous	○	○	○	○	○	○
...I woke up feeling fresh and rested	○	○	○	○	○	○
...my daily life has been filled with things that interest me	○	○	○	○	○	○

WB02

Please indicate for each of the five statements which is closest to how you have been feeling over the last 4 weeks.

During the last 4 weeks	all the time	most of the time	a little more than half of the time	a little less than half of the time	every now and then	at no time
...I have felt cheerful and in good spirits	○	○	○	○	○	○
...I have felt calm and relaxed	○	○	○	○	○	○
...I have felt active and vigorous	○	○	○	○	○	○
...I woke up feeling fresh and rested	○	○	○	○	○	○
...my daily life has been filled with things that interest me	○	○	○	○	○	○

Seite 10

GAD7 I

GA01

Over the last 7 days, how often have you been bothered by the following problems?

	Not at all	Several days	More than half the days	Nearly every day
Feeling nervous, anxious or on edge	○	○	○	○
Not being able to stop or control worrying	○	○	○	○
Not being able to stop or control worrying	○	○	○	○
Trouble relaxing	○	○	○	○
Being so restless that it is hard to sit still	○	○	○	○
Becoming easily annoyed or irritable	○	○	○	○
Feeling afraid as if something awful might happen	○	○	○	○

GA02

Over the last 4 weeks, how often have you been bothered by the following problems?

	Not at all	Several days	More than half the days	Nearly every day
Feeling nervous, anxious or on edge	○	○	○	○
Not being able to stop or control worrying	○	○	○	○
Not being able to stop or control worrying	○	○	○	○
Trouble relaxing	○	○	○	○
Being so restless that it is hard to sit still	○	○	○	○
Becoming easily annoyed or irritable	○	○	○	○
Feeling afraid as if something awful might happen	○	○	○	○

Seite 11

AK GE

question('GE03', 'combine_items=yes', 'combine=GE04', 'gap=line', 'combine_items=yes')

In general, how would you rate the following factors?

GE03
GE04

During the past 7 days	extremely poor								very well
Wellbeing	○	○	○	○	○	○	○	○	○
Quality of life	○	○	○	○	○	○	○	○	○
Pain situation	○	○	○	○	○	○	○	○	○

During the past 4 weeks	extremely poor								very well
Wellbeing	○	○	○	○	○	○	○	○	○
Quality of life	○	○	○	○	○	○	○	○	○
Pain situation	○	○	○	○	○	○	○	○	○

Seite 12

KA I

KA07

Physical activities in leisure time

We would like to know, how physically active you have been in your free time (including commuting from and to work). We only ask about moderate and vigorous activities – light activities do not need to be reported.

Moderate activities are those where your hearbeat increases and you breathe faster (e.g. brisk walking, cycling as a means of transport or as a exercise, heavy gardening, running or recreational sports).

Vigorous activities are those that get your heart racing, make you sweat and so short of breath that you find it difficult to speak (e.g. swimming, running, cycling at high speeds, cardio training, weigh-lifting or team sports such as football).

KA02

Moderate and vigorous activities

On a typical week, how much time do you spend in total on both moderate and vigorous physical activities?

Please sum all activities with a minimal duration of 10 minutes. Leave this field empty if there was not at least one activity of more than 10 minutes.

during the last 7 days		Minutes per week.
during the last 4 weeks		Minutes per week.

KA03

Vigorous activities only

How much of that time you indicated above, do you spend in total on vigorous physical activities only?

Please sum all activities with a minimal duration of 10 minutes. Leave this field empty if there was not at least one activity of more than 10 minutes.

during the last 7 days		Minutes per week.
during the last 4 weeks		Minutes per week.

Seite 13

KA II

KA04

Physical activity in your job

While the previous questions addressed free time, the following two focus on work/occupational time. Again, we only ask about moderate and vigorous activities – light activities do not need to be reported.

Moderate activities are those where your hearbeat increases and you breathe faster (e.g. brisk walking).

Vigorous activities are those that get your heart racing, make you sweat and so short of breath that you find it difficult to speak (e.g. repeated lifting of heavy weights).
KA10

KA05
Rahmen

Moderate and vigorous activities

On a typical week, how much time do you spend in total on both moderate and vigorous physical activities?

Please sum all activities with a minimal duration of 10 minutes. Leave this field empty if there was not at least on of more than 10 minutes.

during the last 3 days		Minutes per week.
4 weeks ago		Minutes per week.

KA06

Vigorous activities only

How much of that time you indicated above, do you spend in total on vigorous physical activities only?

Please sum all activities with a minimal duration of 10 minutes. Leave this field empty if there was not at least one activity of more than 10 minutes.

during the past 3 days		Minutes per week.
4 weeks ago		Minutes per week.

Seite 14

KA III

KA09

Please estimate your total amount of activities - now including light and easy activities (e.g. shopping or walking).

	0 very small amount	1	2	3	4	5	6	7	8	9	10 very large amount
During the past 7 days	○	○	○	○	○	○	○	○	○	○	○
During the past 4 weeks	○	○	○	○	○	○	○	○	○	○	○

KA10

Please describe briefly for the last 7 days your average sports activity per week according to the following pattern (example):

Letzte Seite

Thanks a lot for your participation!

Have fun exercising.

Your answers have been saved, you can close the browser window now.

Imprint ASAP – 2020

Appendix 5: Move ASAP Information for Control Group Participants

Dear Study Participants

Welcome! We are very pleased that you have registered for our study. Have fun! In this email you will find all important information for the training.

General information:

Our trainers are already recording numerous workouts. In four weeks you will get access to our large archive for one month, which you can access 24 hours a day. Are you interested in strength training? Mobility training? Coordination/balance/stability? relaxation? No problem! You will find several offers for all these topics. You are also welcome to send us your wishes (see email address below). We will then try to use your waiting time to prepare appropriate workouts especially for you. A little candy is also available: On request we can extend your access to the database for another two weeks! In this case, just contact us briefly.

What do we want from you? Nothing, because our offer is completely free of charge. The only thing we ask for is to fill out our weekly questionnaire in advance and during your workout. You will need your test person code for this. Please understand that if you do not answer the questionnaire correctly or do not complete it, your participation in the study must be terminated.

Questions:

Is anything unclear to you? If you have any questions, please do not hesitate to contact us (to adeller@dut.ac.za or move.asap-study@gmail.com) . In urgent cases, it is recommended to put all three email addresses in the cc. We will get back to you as soon as possible.

Stay healthy and fit!

Your study team

Appendix 6: Move ASAP Information for Intervention Group Participants

Dear Study Participants

Welcome! We are very pleased that you have registered for our study. You were lucky: You have landed in our training group! Have fun! In this email you will find all important information for the training.

General information:

As you surely know by now, you have access to our live-workouts for 4 weeks from now on. We try to offer you training sessions every day. All you need is your test person code and the software described below. After the 4 weeks it is not over: You will then get another 4 weeks access to our large workout archive. Our offer is completely free. In return, however, we ask you to fill in our questionnaire every week. This questionnaire will be a little shorter than the first one for the following times. The invitation will be sent to this email address. The completion of the questionnaires is a prerequisite for further participation. We think 5-10 minutes of your time per week is a fair "price".

Access to live training:

The training is offered via the Vidyo platform. The courses run on the servers of the Goethe University Frankfurt, so that a high level of data protection is guaranteed. Instructions on how to use Vidyo can be found as an attachment to this email. In principle, it can be used via smartphone, tablet or computer. We recommend a laptop. Please do not choose (see instructions) access via browser, but download the app as described. Only then the connection will be sufficiently fast.

The access data (please refer to the instructions in the appendix) are

Address: https://vc.uni-frankfurt.de/join/G0xqsZl8

PIN: 042020

When you log in, please always enter your respondent code as your name. Without it, participation is not possible. If you have not noted down your code, please send an email to adeller@dut.ac.za or move.asap-study@gmail.com . Please also do not pass on your access data. Please understand that we have to terminate your participation in the study if you pass it on to third parties. You are welcome to tell family and friends about our study. Registration for new participants is currently still possible here: http://goethe.link/ASAP-MOVE.

Technical check:

To ensure that everything runs smoothly during the training, we would like to ask you to test the software in advance to make sure it works. You can also enter our virtual classroom without a course taking place. Therefore, please try to enter the course room as described in the manual (appendix). Please also check if you can activate the camera and see a picture of yourself. If any technical problems occur, you can contact _____

Training:

If you like, it will start immediately. There will be two courses in the morning and two in the evening. This gives you the opportunity to choose flexibly from various offers (e.g. strength/back, balance, flexibility) and to train at different times. You do not need to register and can participate whenever you feel like it. However, please be in the classroom a few minutes before the start so that you can start on time. Please also note that if there is too much interest in a particular date, we may have to limit the number of participants.

You will find the course schedule for the next weeks in the appendix.

The individual courses last between 30 minutes (morning) and 40 minutes (evening).

Security:

As you have seen in our declaration of consent, participation is only possible for healthy persons. Especially if you have not been physically active for a long time, please do not overdo it. We recommend that you do not start with more than 4 classes per week (ideally with a day off). You can of course take part more often, but you should then possibly take it more slowly.

Questions:

Is anything unclear to you? If you have any questions, please do not hesitate to contact the course instructor after the course or write an email to adeller@dut.ac.za or move.asap-study@gmail.com . In urgent cases it is recommended to put both email addresses in the cc. We will get back to you as soon as possible.

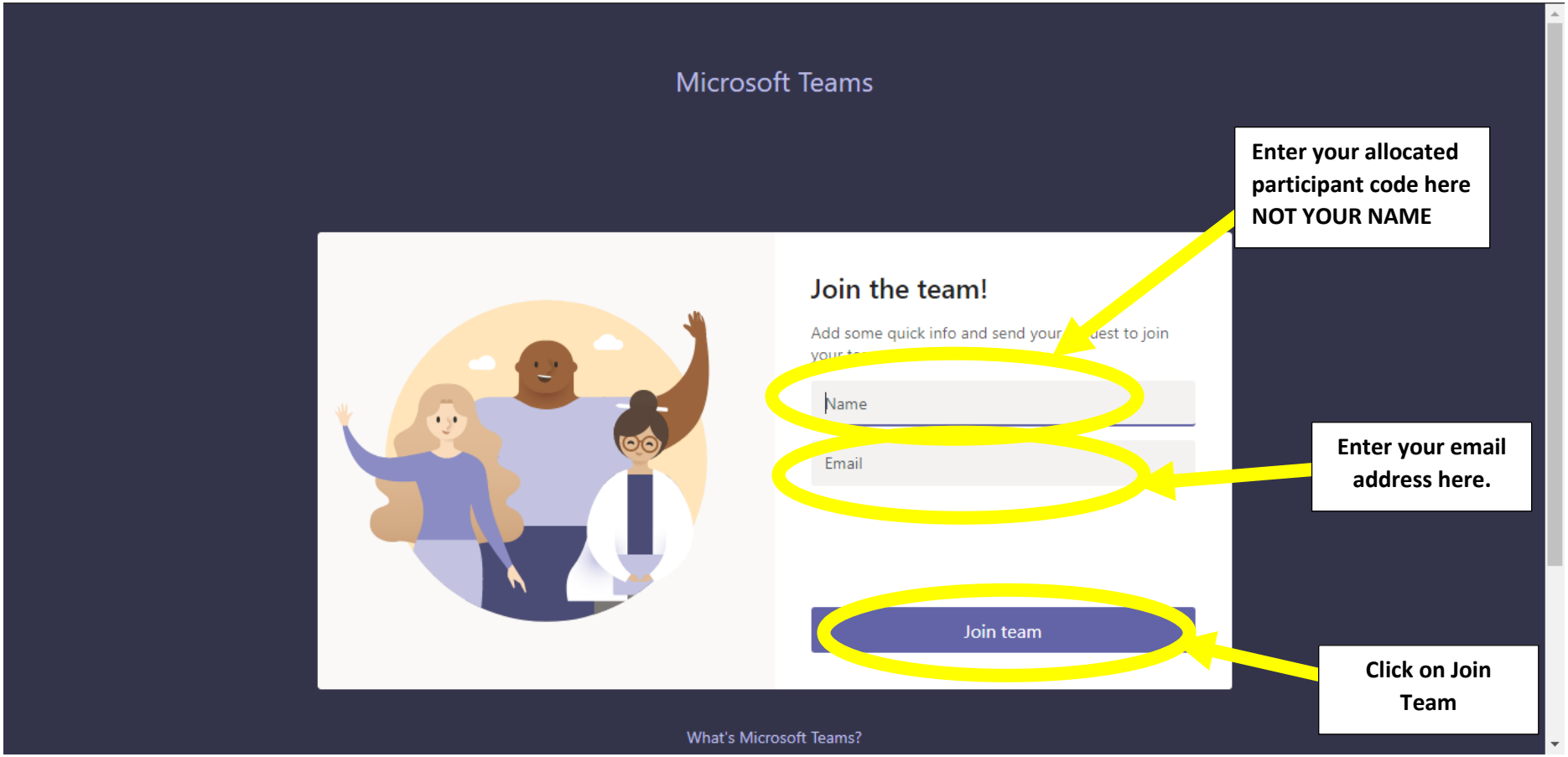
Have fun while training.

Your study team

Appendix 7: South African Cohort Microsoft Teams Participant User Guide

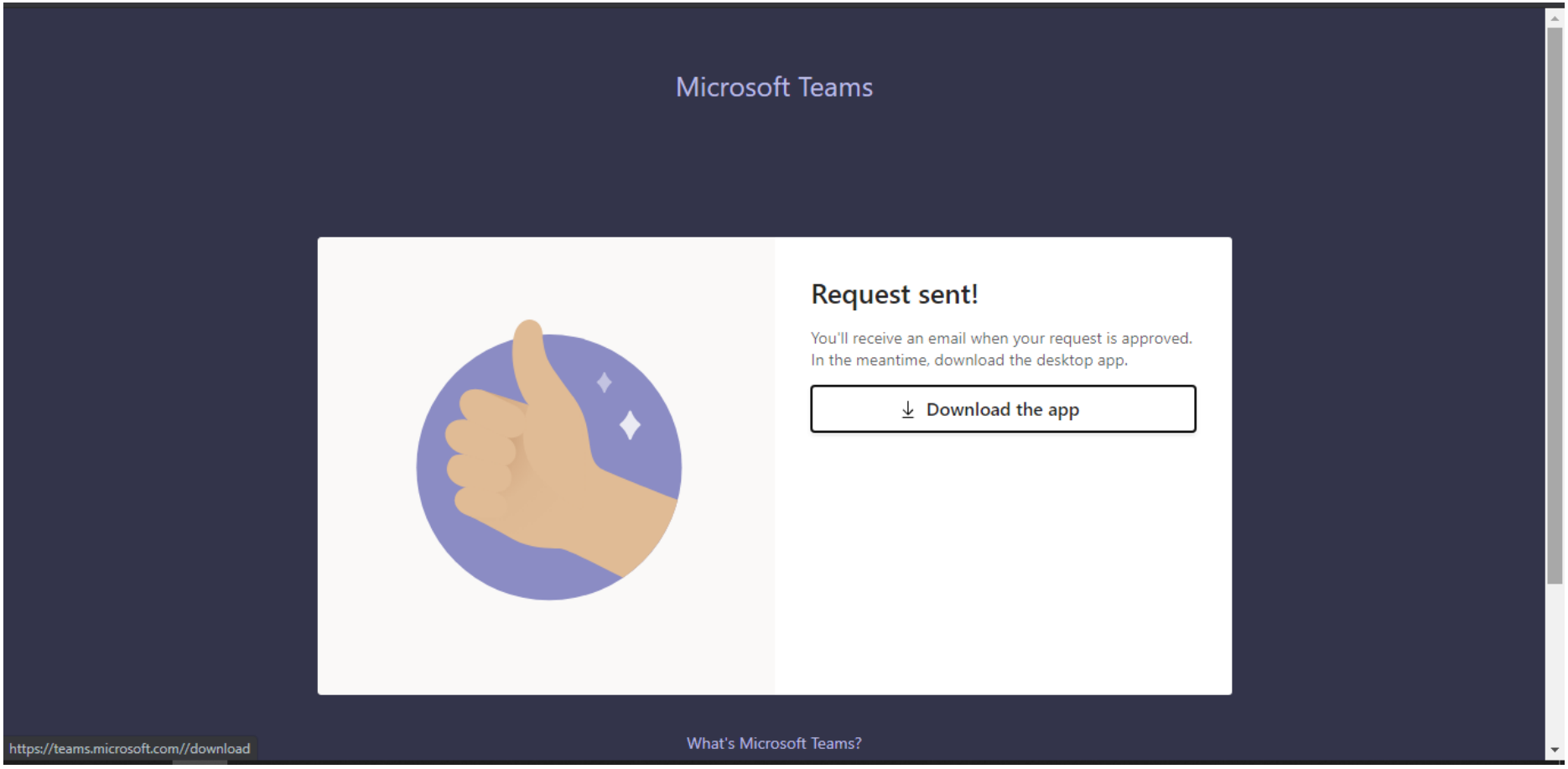
Registering and signing into MS Teams

Once you click on the link to join the team in the body of the email you will be taken to a page that looks like the one below



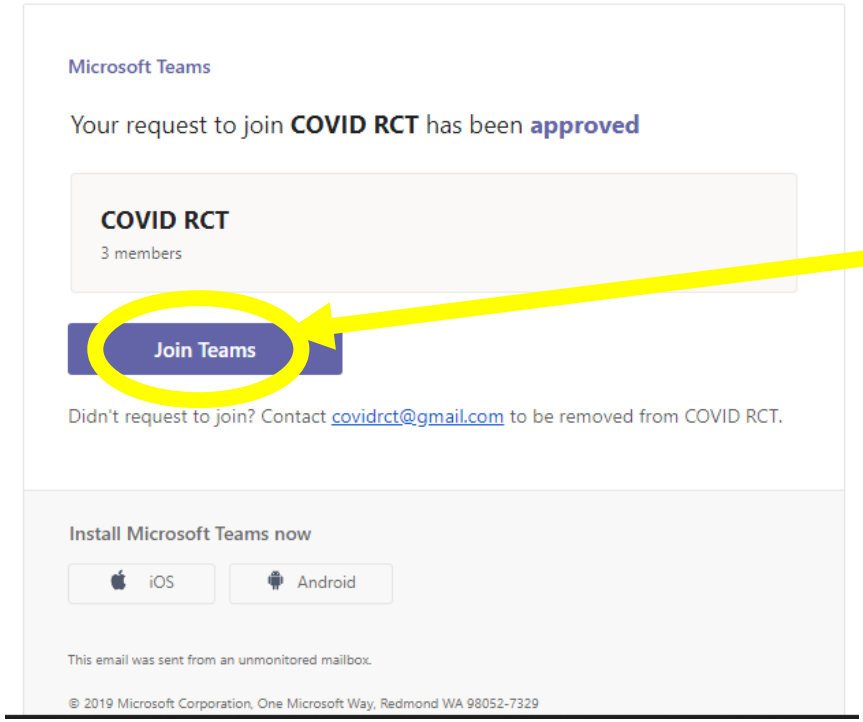
Registering and signing into MS Teams

A request will be sent to the study team for you to join our team. You will see the screen below. You can close your browser once you see this.



Registering and signing into MS Teams

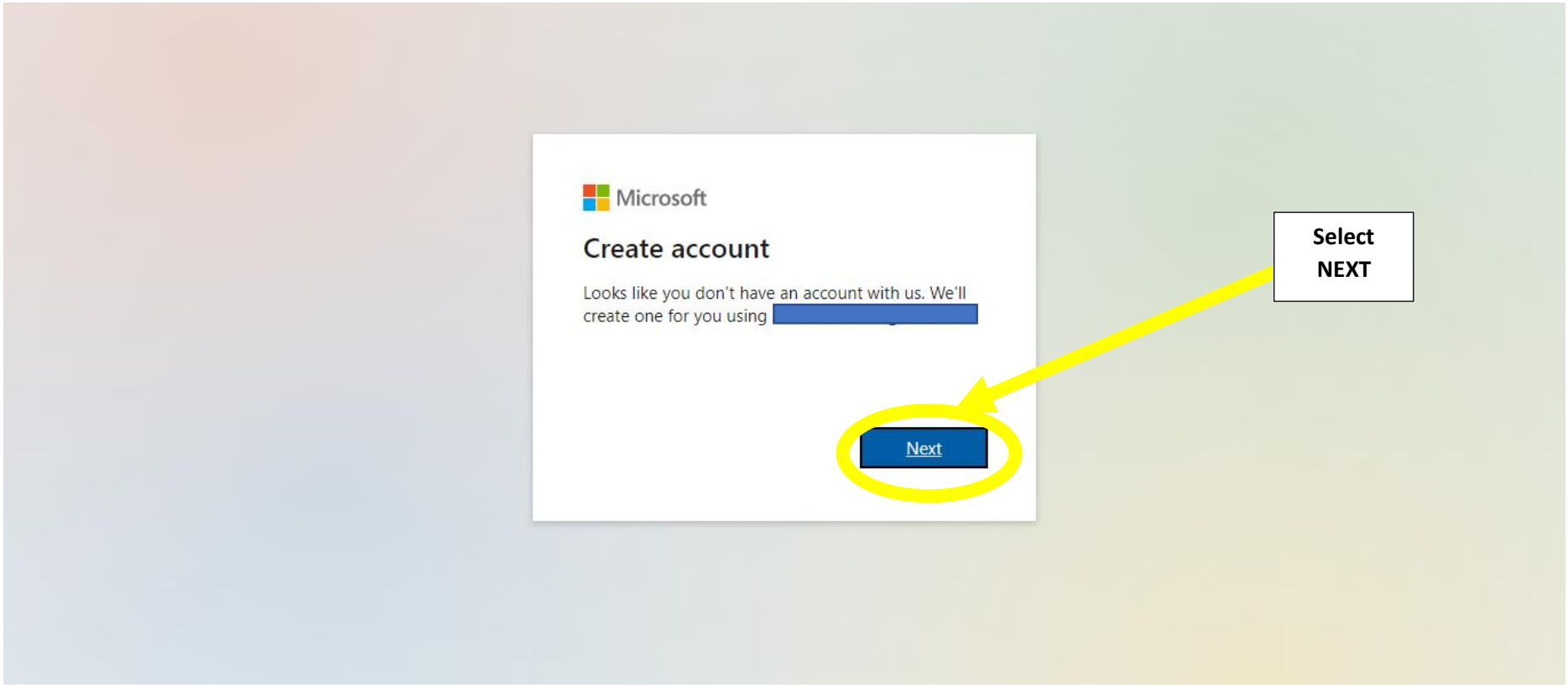
As soon as we receive your request to join you will be sent an email as seen below.



Click on join Teams

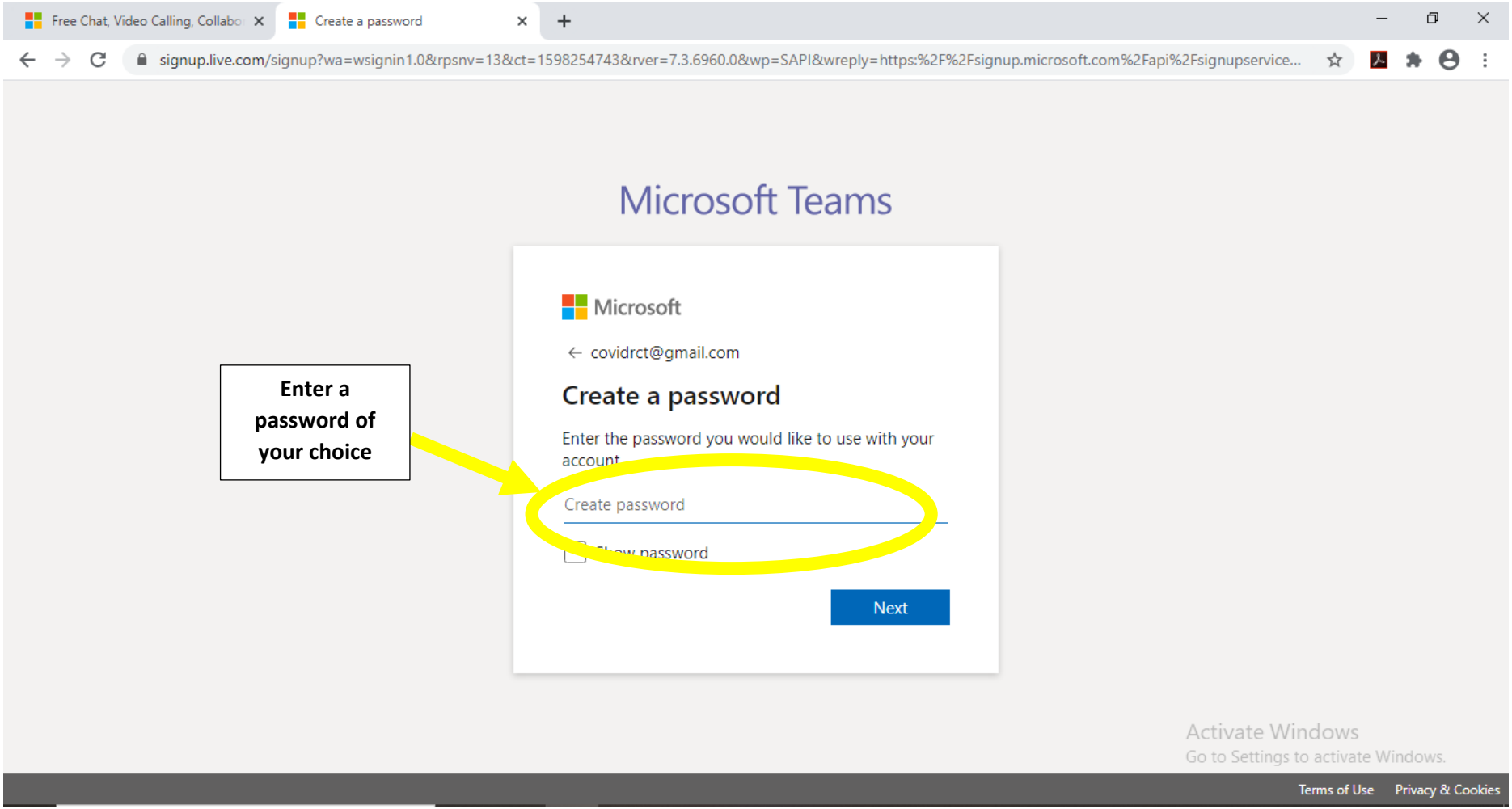
Registering and signing into MS Teams

If you do not have an existing MS Teams account you will see the below screen.

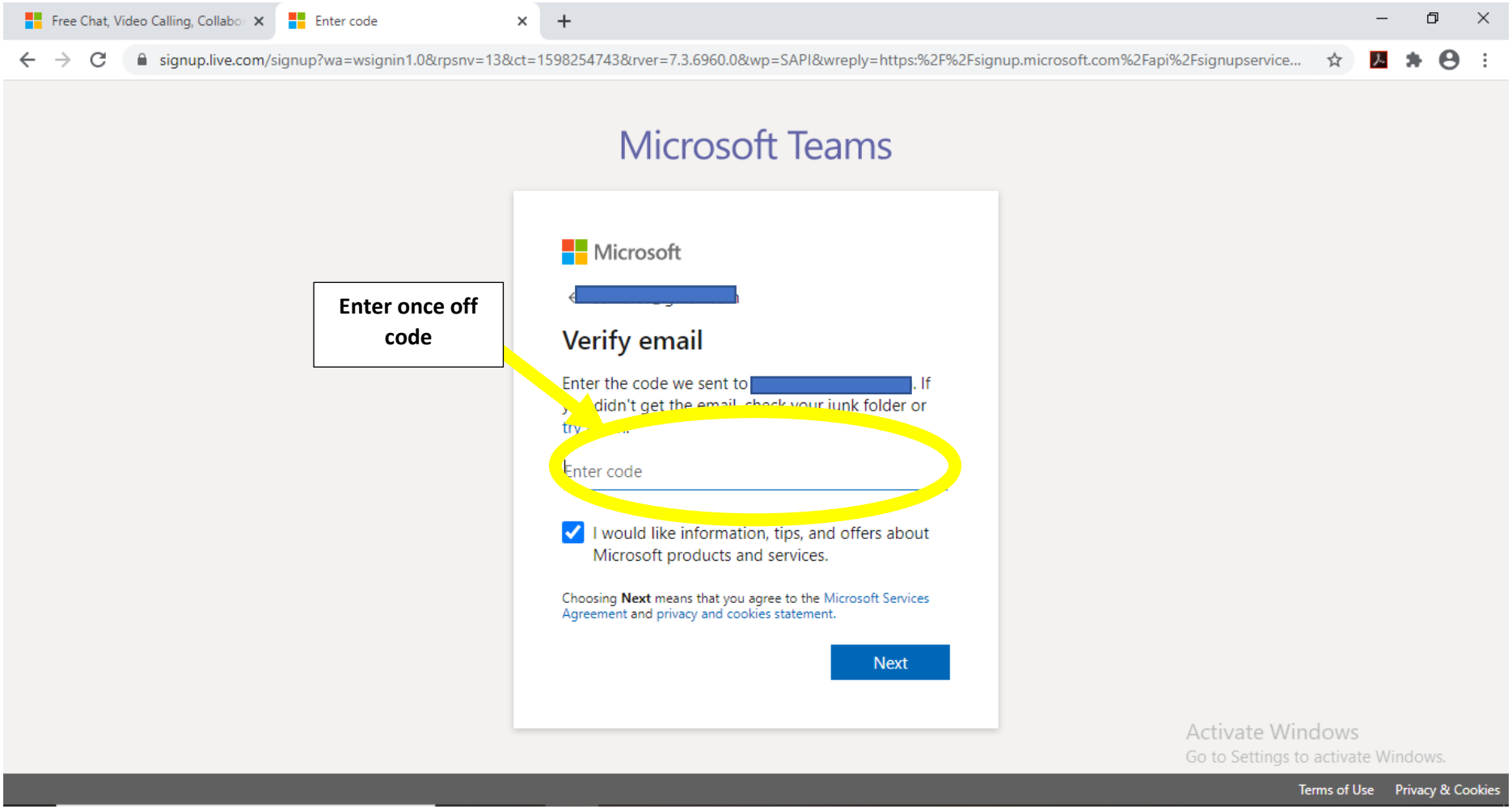


Registering and signing into MS Teams

Choose a password that you prefer and enter it when you see the screen below

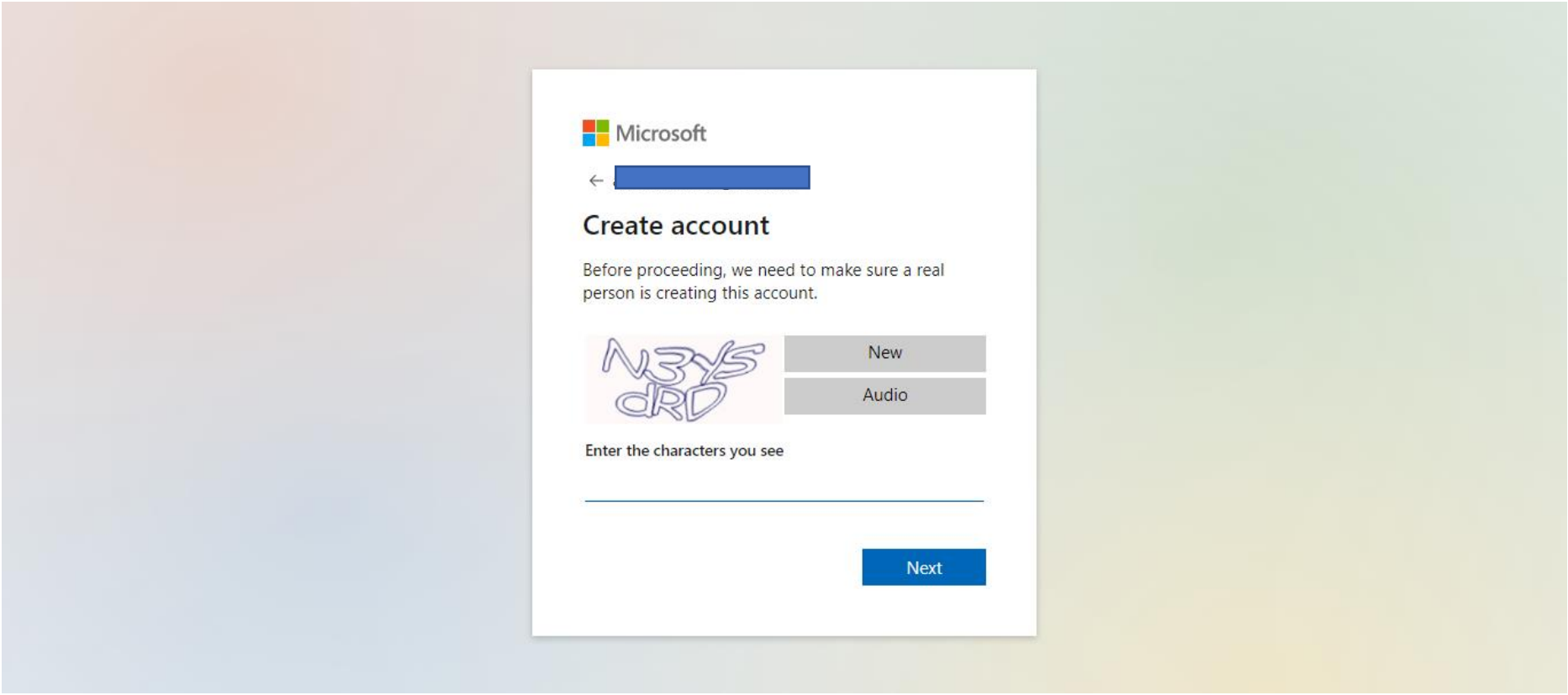


An email will be sent to your email address with a once off code. Enter the once off code

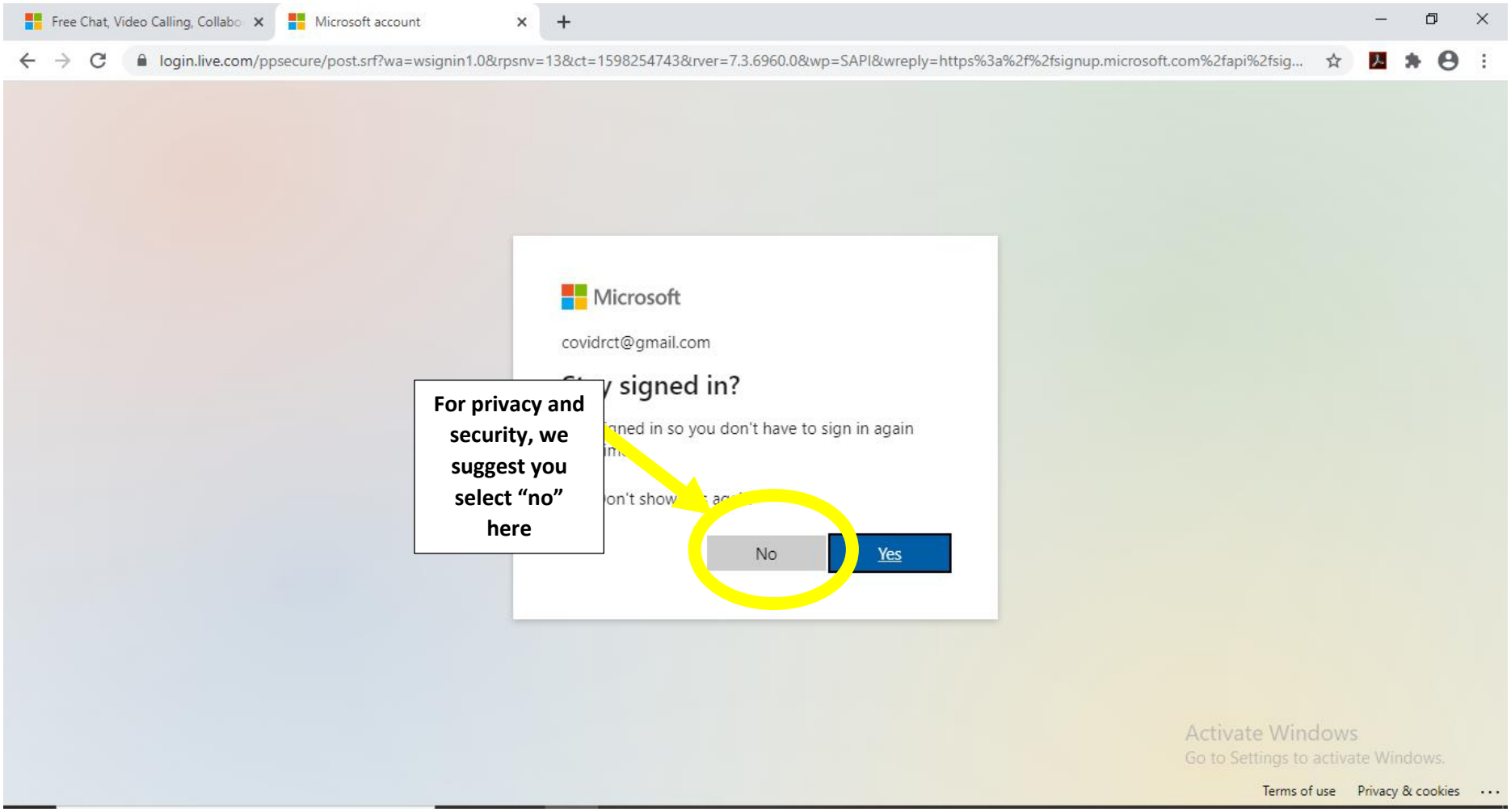


Registering and signing into MS Teams

The screen below will appear. Follow the instructions and click “Next”

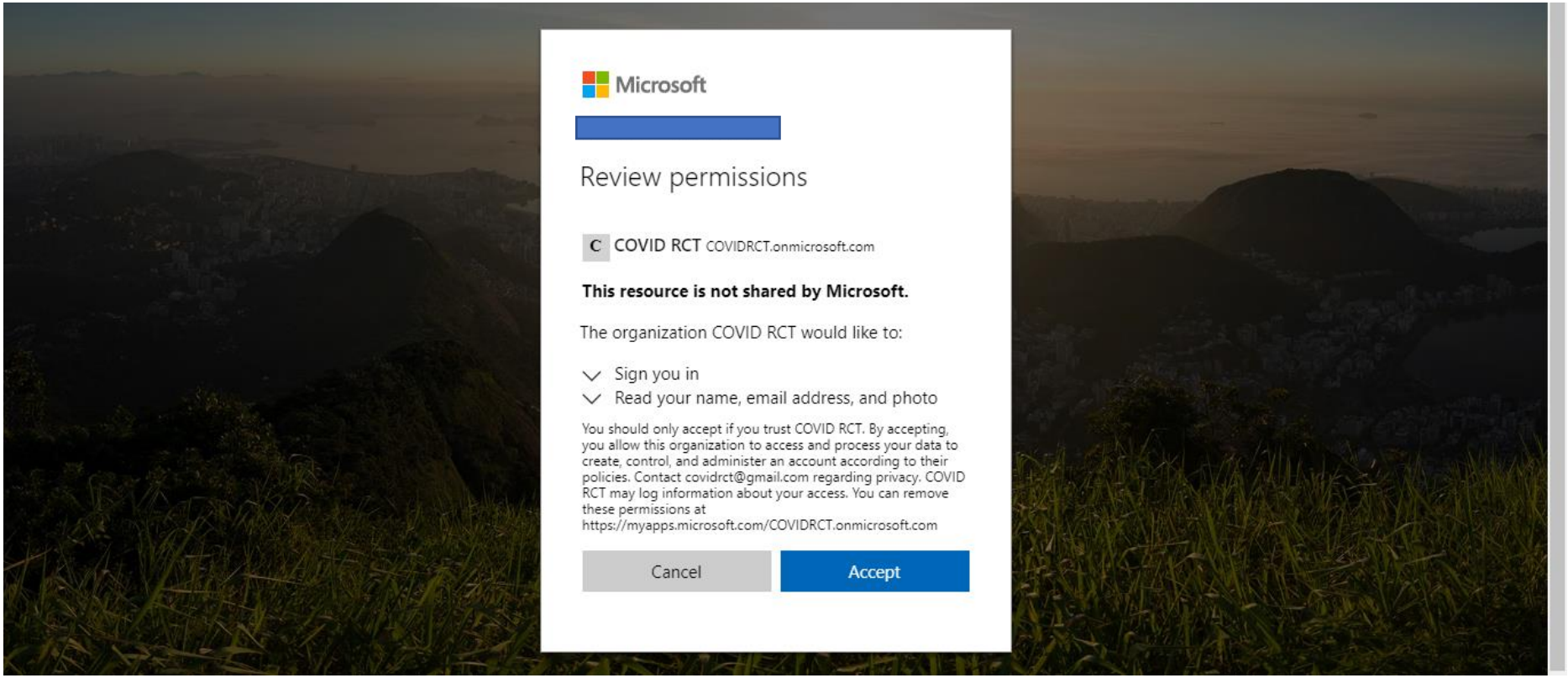


Registering and signing into MS Teams

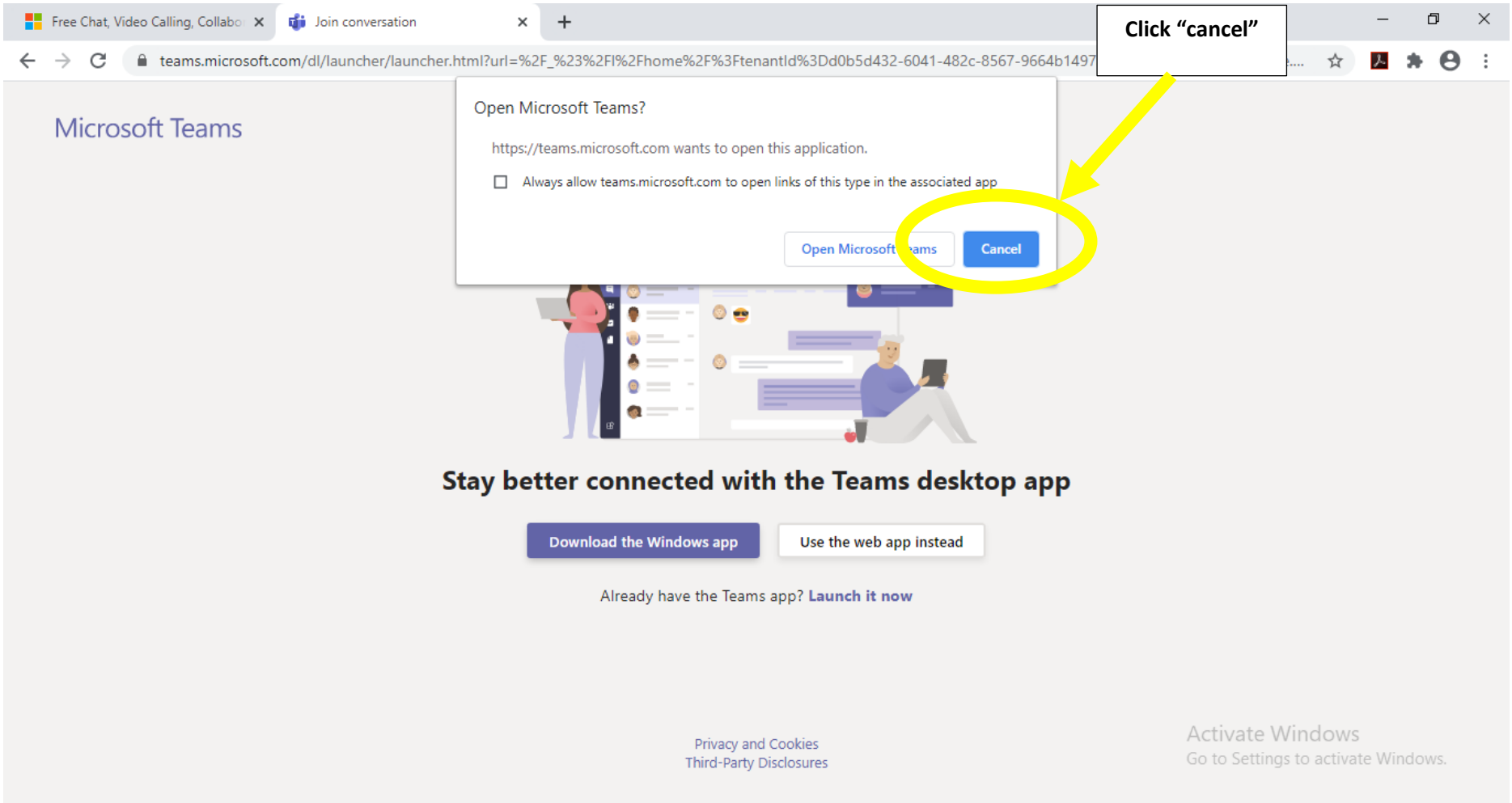


Registering and signing into MS Teams

Click on “Accept” when you see the screen below



Registering and signing into MS Teams



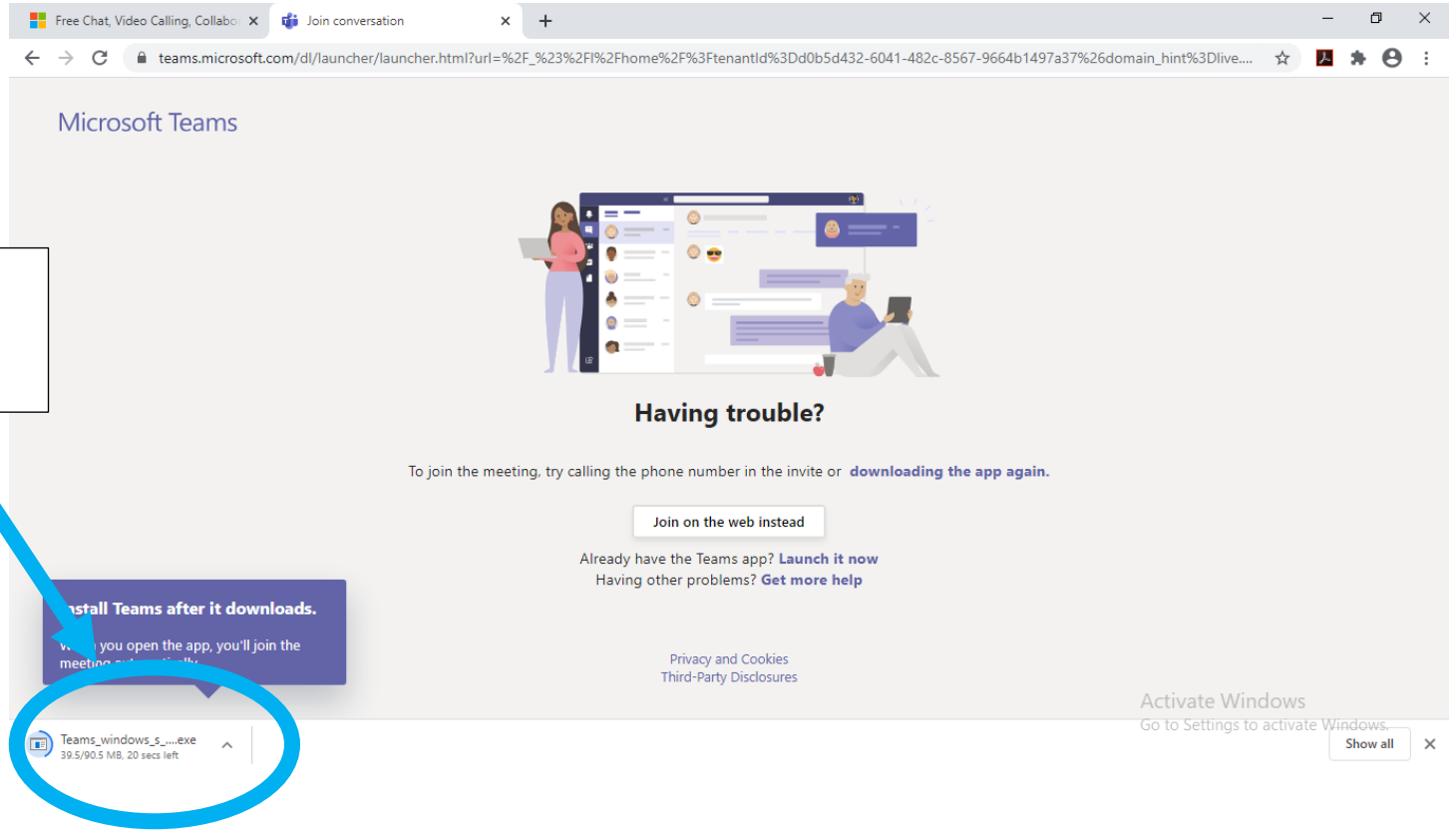
At this point you have the option of downloading the app (app size approximately 95MB) or using the web app instead. We suggest that you download the app for easy signing into your selected exercise sessions.

Registering and signing into MS Teams

Step 1. Click on **“download the windows app”**

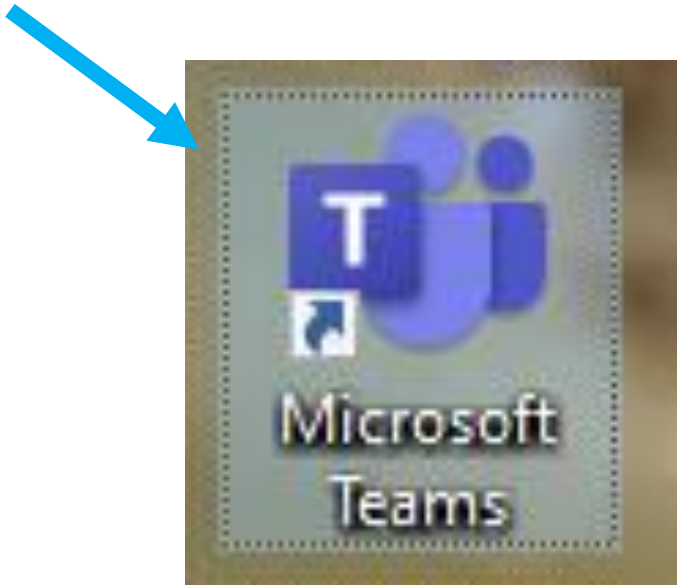
Step 2. Wait for the download to complete (this may take a few minutes)

Step 3. Click on the file to install the app (this may take a few minutes)



Once the download is complete click here to install the app

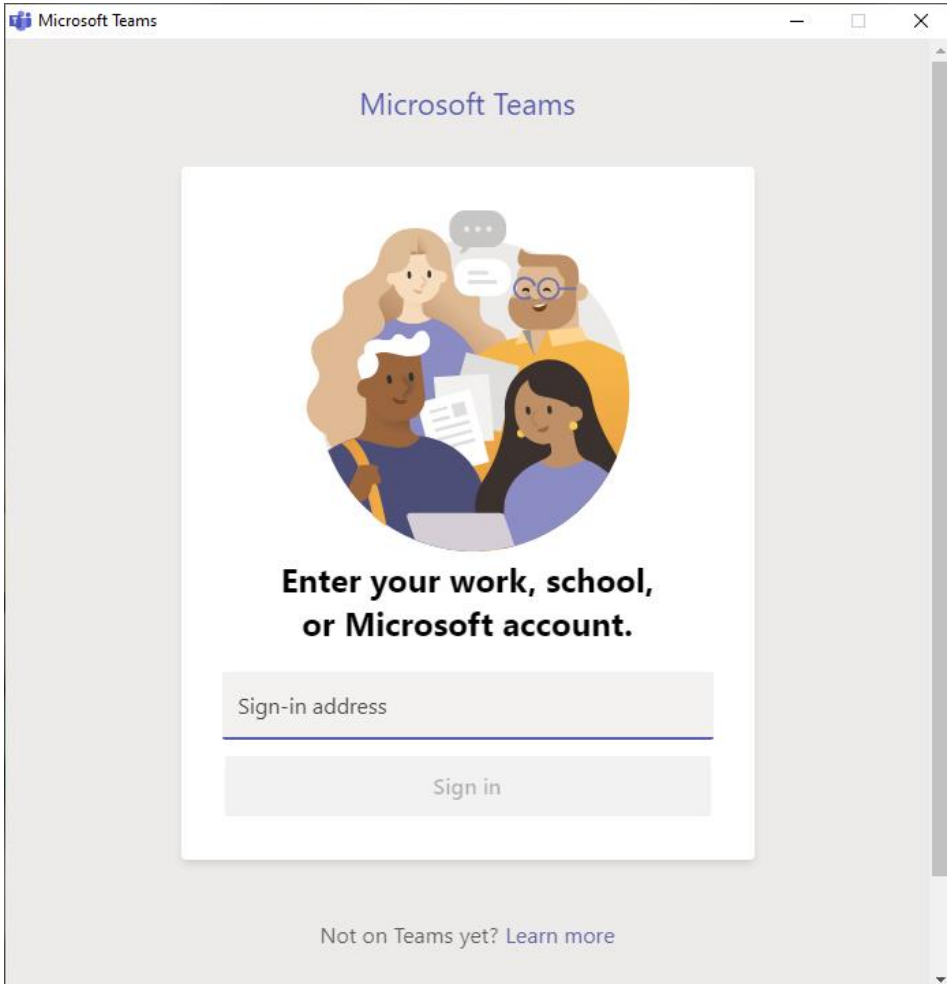
Step 4. Once the app has been installed this icon will appear on your desktop

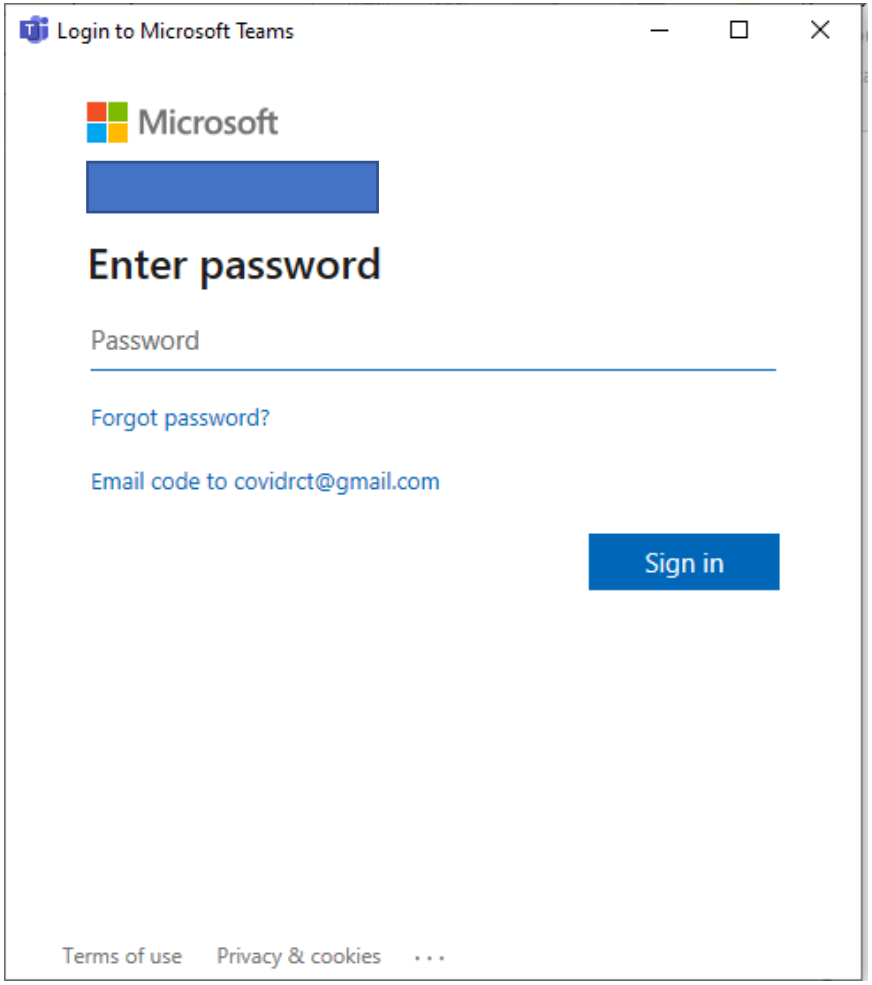


Registering and signing into MS Teams

To sign in simply double click on the “Microsoft Teams” icon and sign in with **your email address** and **your chosen password.**

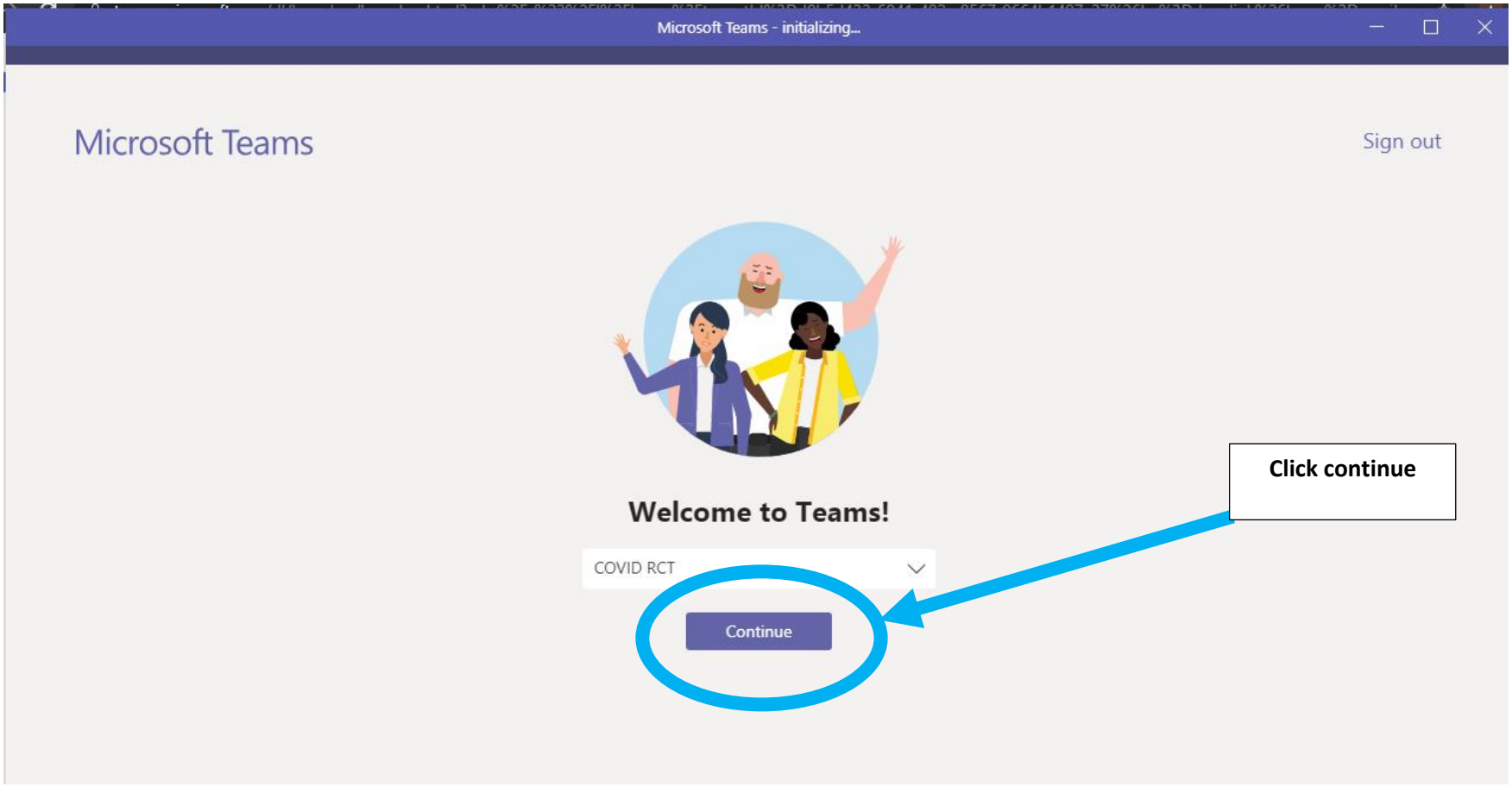
NB if this is the first time, you’re using MS Teams – it may take a while for the first sign in



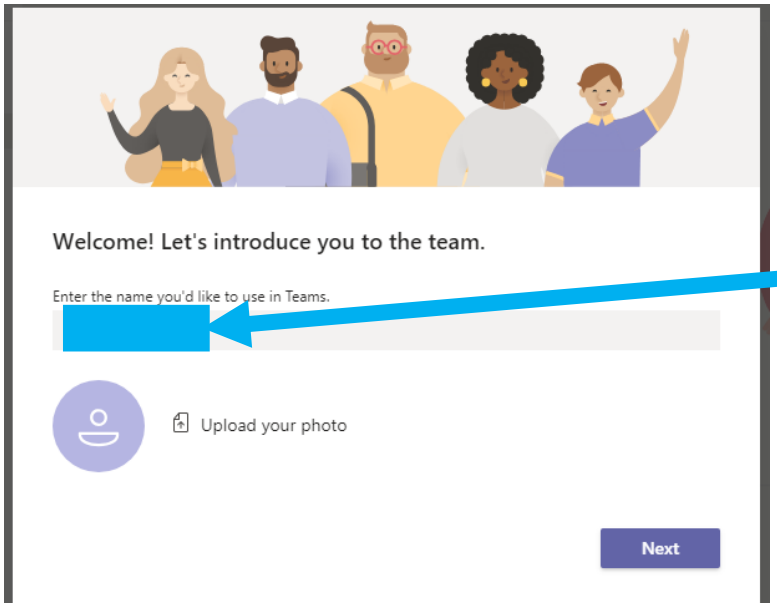


Registering and signing into MS Teams

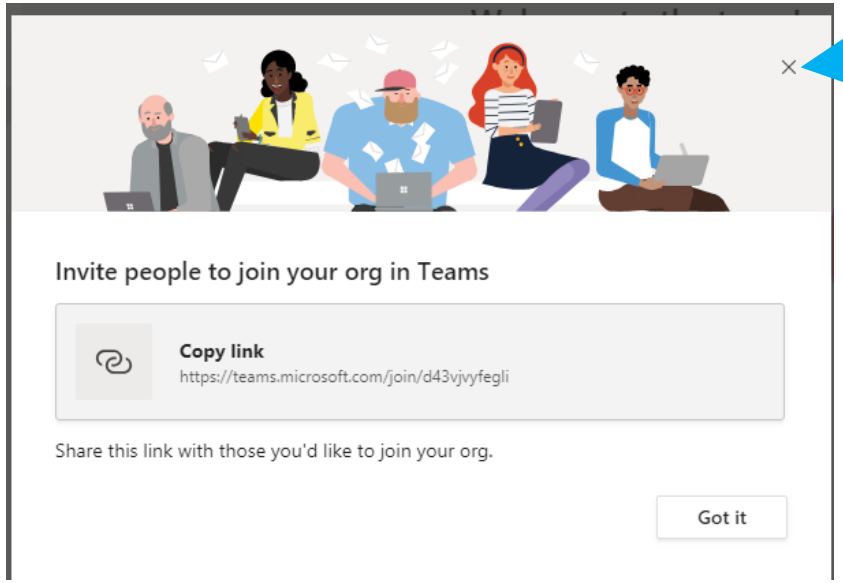
Once you've signed your screen will look like this



Registering and signing into MS Teams

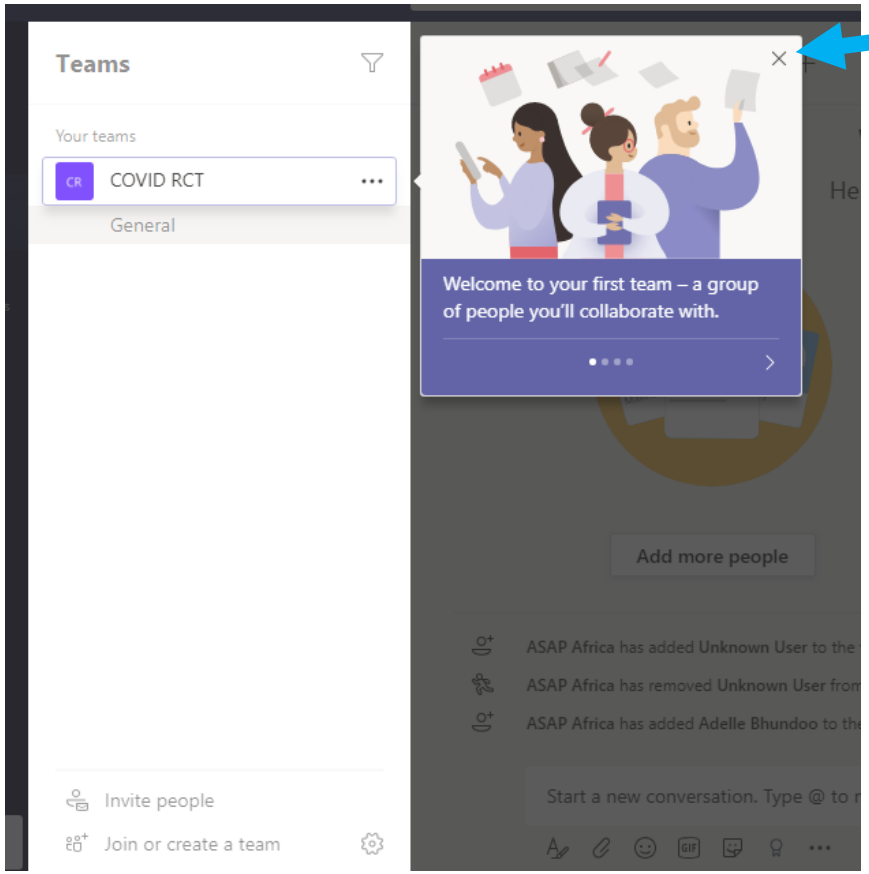


Ensure that your allocated participant code appears here. If it does not, please enter it then click "NEXT"



Close this box by clicking the X

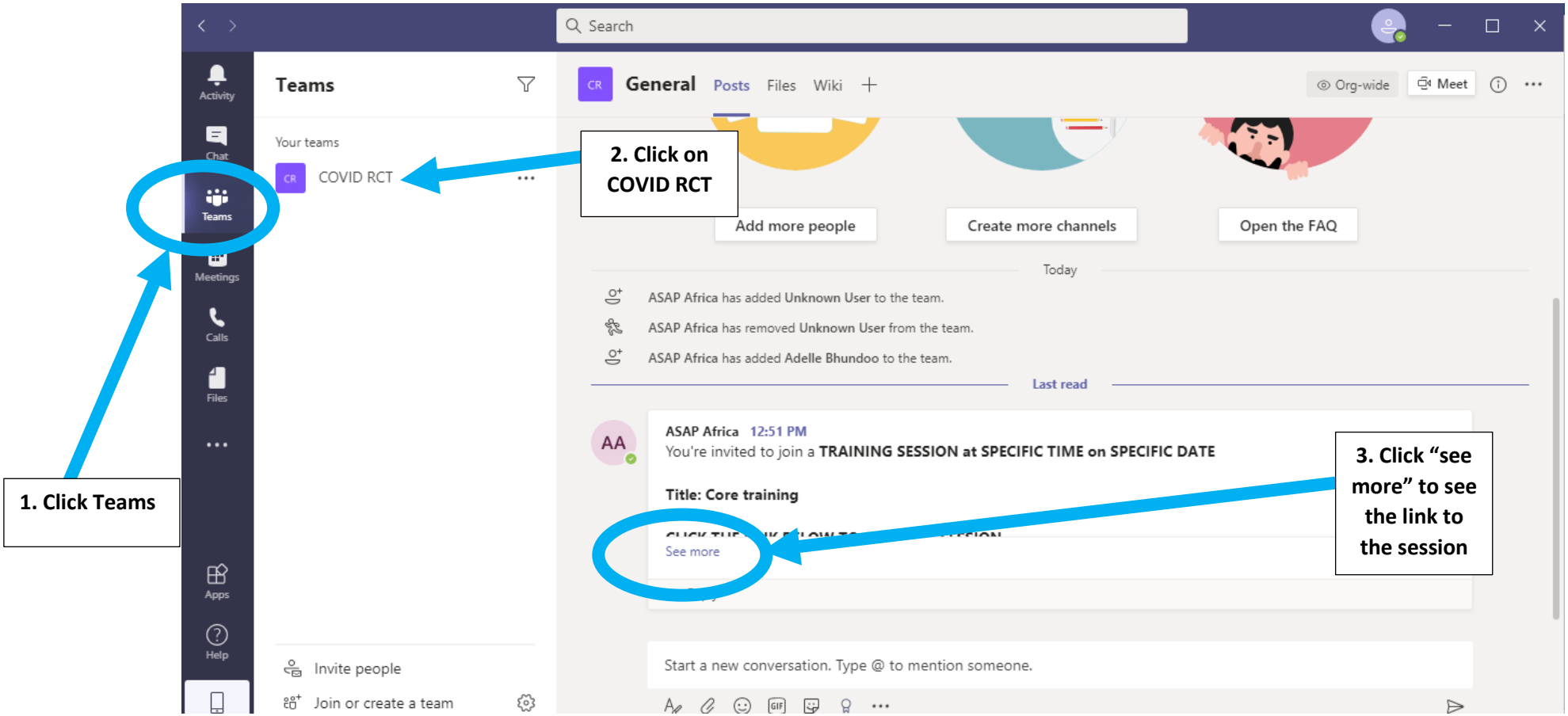
Registering and signing into MS Teams



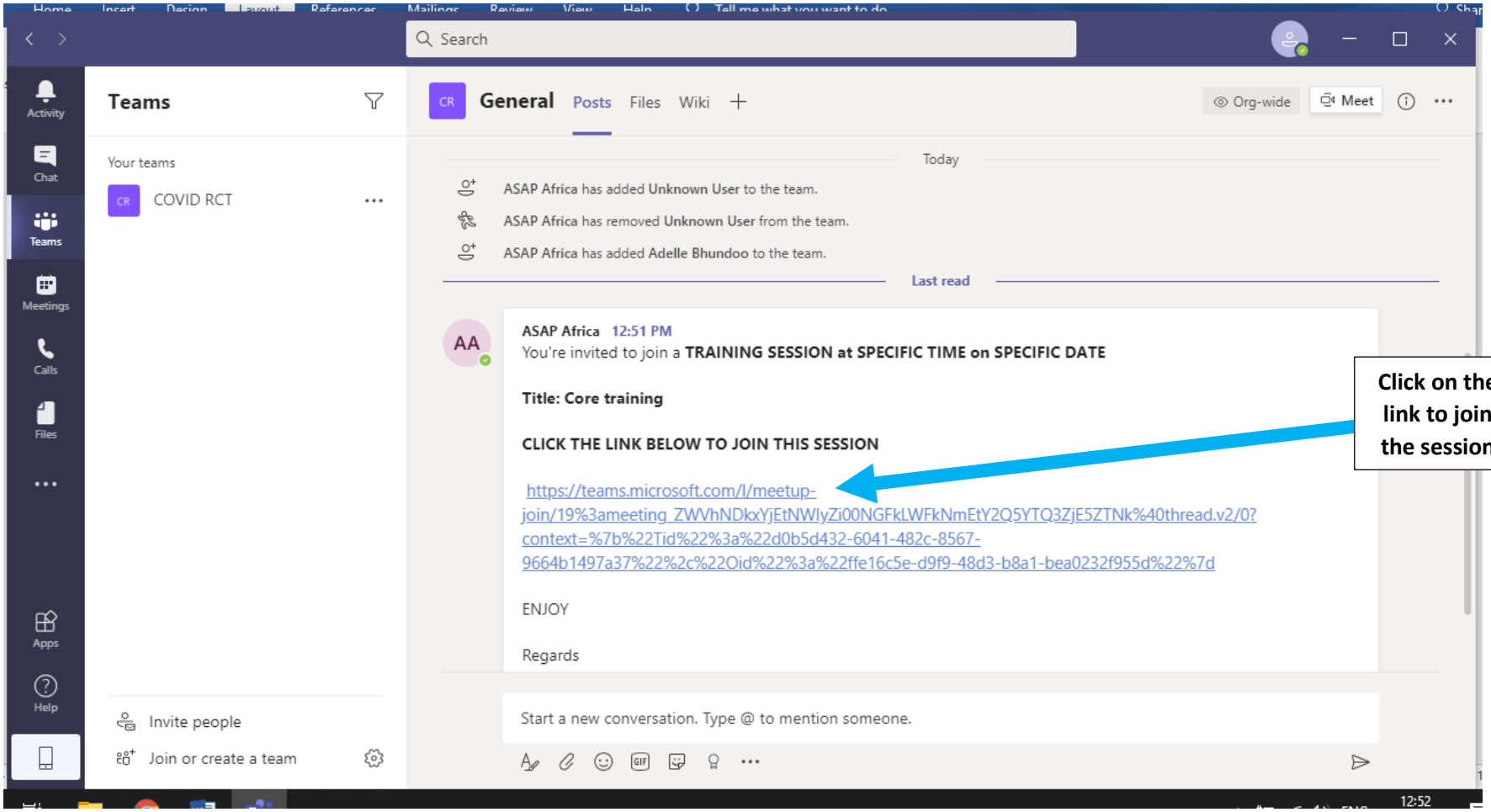
Close this box by clicking the X

The steps explained above will only need to be done for the FIRST time you join the team.

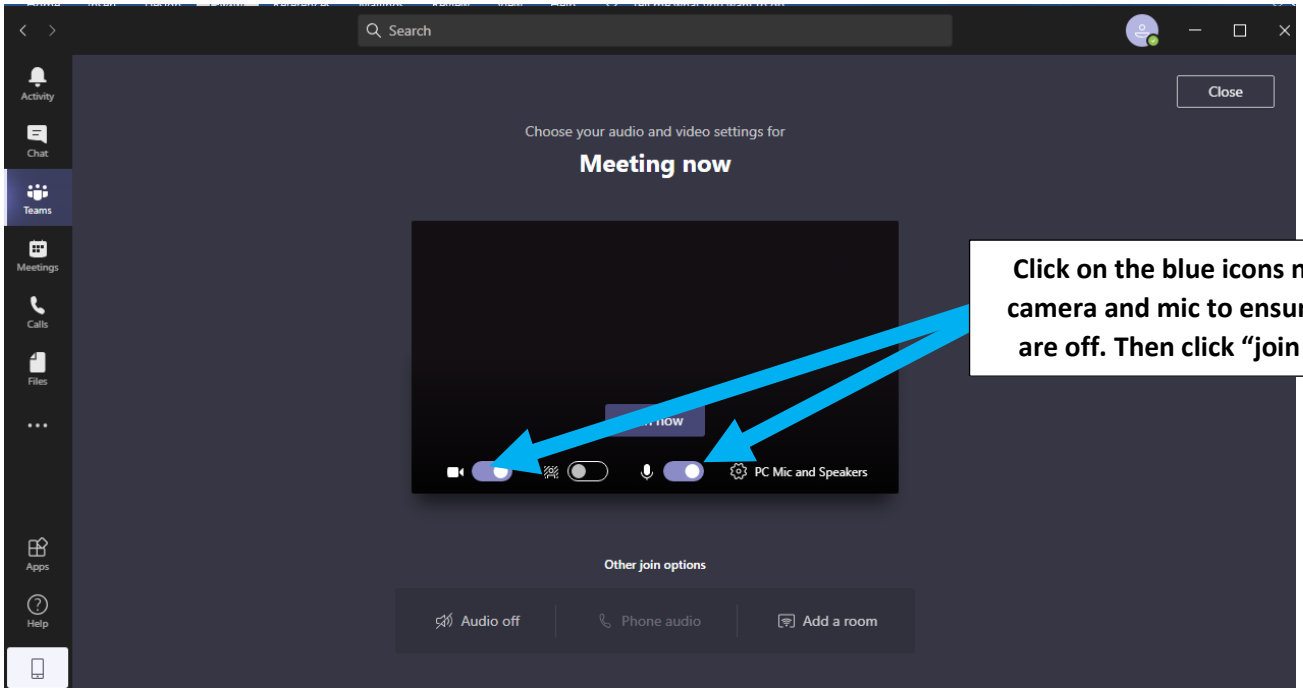
For all future sign ins, you will simply enter your email and password and then be taken to the screens below



Registering and signing into MS Teams



Registering and signing into MS Teams



You now have all the technical information you may require to register with and sign into your sessions.

We suggest you do your registration as soon as you receive this guide to avoid any delays in joining the sessions that will begin tomorrow.

Thank you and Regards

YOUR STUDY TEAM

Appendix 8: South African Cohort Weekly Exercise Schedule for South African Cohort

Time	Monday	Tuesday	Wednesday	Thursday	Friday
07.00	Strength	Core	Stretch	Strength	HIIT
12.00	HIIT	Strength	HIIT	Stretch	Stretch
18.00	Core	HIIT	Strength	Core	Strength

Strength:

A mix of basic strength prescriptions, adapted to equipment access at home, but also manageable with body weight. Programmed for the training goal of muscle strength, endurance and power. Strength and resilience for life's daily challenges without breaking participants down!

Core:

A mix of pilates based matt work, as well as core and trunk rehabilitation exercises. Low intensity, low impact, with the goal of improving, core stability, endurance and posture for daily life.

HIIT:

A light to moderate sweat and intense session is vital in any exercise program if done in the right volumes. This will get the heart-rate racing, with some plyometric, scalable bodyweight movements and some cardio exercises that will strengthen the cardiovascular and multiple bodily systems.

Stretch:

Mobility, stability and stretching – to supplement our daily movements or lack thereof. A mixture of static and dynamic stretching, some matt work as well as active recovery for improved adaptation and training effect.

Appendix 9: Move ASAP Weekly RCT Questionnaire Reminder

Dear study participants,

Yesterday we asked you to fill out our weekly survey. We would like to remind you once again. The link below will take you to the questionnaire, which takes only a few minutes to complete.

https://survey.studiumdigitale.uni-frankfurt.de/moveASAPWoche1/

Your personal code is:

Please note again that further participation in the study is only possible if you complete the form promptly - otherwise we cannot use your data and must exclude you from further participation. This is the only way we can ensure that training units and the workout archive are offered. Many thanks!

Best regards and stay healthy,

Your study team