

Physical Activity Levels in Children with Bronchiectasis Living in Counties Manukau, New Zealand

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Abstract

The ability to participate in physical activity is widely accepted as one of the most important indicators of a child's overall health and wellbeing. Current bronchiectasis guidelines state that children should be encouraged to participate in regular physical activity, but there is minimal guidance supporting these recommendations and limited knowledge surrounding current physical activity participation within Counties Manukau, New Zealand. Therefore, the primary aim of this study was to investigate how physically active children with bronchiectasis living in this population, are compared to their healthy peers, and how often they achieved daily recommendations of at least 60 minutes of moderate to vigorous physical activity (MVPA) across the week. Secondary aims sought to identify whether there were associations between MVPA and demographic or disease severity markers, and the mode of activity and time of day children with bronchiectasis were engaged in physical activity.

A quantitative, cross sectional, observational study was undertaken. The study aimed to recruit 90 children between 7 to 12 years old from Counties Manukau District Health Board. However, due to the impact of COVID-19 restrictions, only 31 children (18 children with bronchiectasis and 13 healthy children) were able to complete the study. Daily minutes spent in MVPA was measured objectively over seven consecutive days using wrist-based ActiGraph wGT3X+ accelerometers. Mode of activity and time of day children engaged in physical activity were measured using the Physical Activity Questionnaire for Children (PAQ-C).

On average children within the Bronchiectasis group, completed 31.63 ($p = 0.034$) less minutes of MVPA per day than the children within the Control group, with both groups demonstrating significantly higher ($p = 0.002$) MVPA minutes on weekdays compared to weekend days. On average, 62.3% of the Bronchiectasis group and 86.4% of the Control group achieved daily MVPA recommendations across the week, as outlined by the World Health Organization. There were weak to moderate associations found between MVPA minutes and body mass index (BMI) and socioeconomic hardship, with trends suggestive that fewer MVPA minutes were achieved by children with bronchiectasis who were female, who had lower FEV1% predicted (50-79%), less than three lobes with bronchiectasis, and a recent hospital admission. Children from both groups demonstrated they were most active at school during the week and primarily during informal school yard games, compared to organised activities.

These findings show that children with bronchiectasis are less active than their peers and would benefit from routine physical activity assessment, as part of standardised bronchiectasis management. Interventions and community-led initiatives that promote physical activity

participation, especially over the weekend, are required to increase general MVPA achievement, improve overall health and wellbeing and reducing secondary co-morbidities associated with inactivity.

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Attestation of Authorship

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.



Laura Rensford

Signature

24/02/2023

Date

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Chapter 1 Introduction

1.1 Statement of the problem

Counties Manukau is one of the largest and fastest growing regions in New Zealand, comprising of more than 567,000 people and representing 11% of New Zealand's total population (Lees et al., 2021). Counties Manukau's population is young, with children under 14 years accounting for 23% of the total population. This community is also ethnically diverse, including large populations of Māori and Pasifika, and economically challenged. In fact, 44% of its people live in communities with high socioeconomic deprivation, NZDep Index 9 and 10 as defined by the NZDep Index, (Atkinson et al., 2019). Unfortunately, many of Counties Manukau's children also experience poorer health outcomes; this is particularly evident for respiratory illnesses in Māori and Pasifika children (Byrnes & Trenholme, 2010; Simpson et al., 2018). High levels of repeated, often severe, respiratory infections coupled with high socioeconomic deprivation, has resulted in Counties Manukau being home to one of the largest groups of children with bronchiectasis in New Zealand (Telfar Barnard & Zhang, 2018).

Bronchiectasis, unrelated to cystic fibrosis, is a chronic respiratory disease characterised by a chronic wet cough, sputum production and abnormal and permanent dilation of the bronchial walls (Chang, Fortescue, et al., 2021). Bronchiectasis is the end outcome of a viscous vortex of recurrent airway infection, inflammation, mucociliary dysfunction and structural disease, from an array of known and idiopathic causes (Flume et al., 2018). In addition to a wet or productive cough, children may also experience dyspnoea, reduced physical activity, faltering growth, and poor quality of life (Chang et al., 2018; Chang, Fortescue, et al., 2021). Due to the heterogeneous nature of bronchiectasis, many children experience an indolent onset of respiratory symptoms, which may persist for several years, before a final bronchiectasis diagnosis is made (Brower et al., 2014; Twiss et al., 2005).

Bronchiectasis is an under recognised global burden with incidence rising in both developing and developed countries (Goyal et al., 2016). In developed countries, incidence exhibits a significant social gradient with higher rates observed in indigenous and socially disadvantaged populations (McCallum & Binks, 2017; Singleton et al., 2014). In New Zealand, similar patterns are observed. In 2019 the national incidence of children with bronchiectasis was 11.8 per 100,000, with significant ethnic disparities seen in Māori (New Zealand's Indigenous population) (19.2 per 100,000) and Pasifika (21.7 per 100,000) children (Telfar Barnard & Zhang, 2021). The exact prevalence of children with bronchiectasis residing in Counties

Manukau, is unknown due to the absence of a disease registry and a standardised model of care.

This large and growing population of children with bronchiectasis, places a significant strain on Counties Manukau's healthcare system, due to the life-long specialised care required to manage their health (Bibby et al., 2015). Treatment focuses on optimising lung growth, preserving lung function and enhancing quality of life by reducing exacerbation frequency, hospitalisations and preventing co-morbidities (Chang et al., 2015; Chang, Fortescue, et al., 2021). This is most often achieved with daily airway clearance programmes, regular physical activity, and antibiotic/nebulised therapy as required for infection (Chang et al., 2018; Chang, Fortescue, et al., 2021).

Although bronchiectasis research has expanded exponentially over the last decade or so, most treatment-based studies are aimed at airway clearance and pharmacological interventions. There are few studies exploring physical activity in children, yet it remains a cornerstone of bronchiectasis management, included in best practice guidelines internationally (Chang et al., 2015; Chang et al., 2018; Chang, Fortescue, et al., 2021). To date, there is only one small Australian study (Joschtel et al., 2019) that measured physical activity levels in children with bronchiectasis. Consequently, it remains largely unknown, especially in the New Zealand population, whether bronchiectasis affects participation in physical activity and if targeted interventions are required to better support this population. Furthermore, there are no studies examining the physiological or psychological effects that physical activity or exercise training, has on children with bronchiectasis (Joschtel et al., 2018). As a result of the limited research in this field, current physical activity recommendations for children with bronchiectasis are based on low level evidence, clinical experience, or extrapolation from similar population studies such as cystic fibrosis (Bell et al., 2018; Chang, Fortescue, et al., 2021). Further bronchiectasis specific research is desperately needed to better understand the role physical activity plays within bronchiectasis management for children (Chang, Boyd, et al., 2021).

1.2 Study rationale

Current bronchiectasis guidelines state that children should be encouraged to participate in regular physical activity (Chang et al., 2015; Chang, Fortescue, et al., 2021; Starship Respiratory Service, 2020). Recommendations are non-specific and provide minimal guidance to physiotherapists providing physical activity interventions. As a result, physiotherapists need to rely on other physical activity guidelines, such as from the World Health Organization (WHO), to support their clinical practice. The WHO recommends children, aged 5 - 17 years, including

those with chronic disability or disease (where able), participate in at least an average of 60 minutes per day of moderate to vigorous physical activity (MVPA) across the week (World Health Organization, 2020a).

Physical activity and in particular the ability to participate in activity, is widely accepted as one of the most important indicators of a child's overall health and wellbeing (Janssen & LeBlanc, 2010; Joschtel et al., 2019). The benefits of physical activity, particularly MVPA, are numerous and multi-dimensional: physical, cognitive, emotional, social, and have been well documented in the literature (Bull et al., 2020; Chaput et al., 2020; Janssen & LeBlanc, 2010; World Health Organization, 2019). Yet the percentage of children achieving daily physical activity recommendations continues to decline each year, while co-morbidities secondary to inactivity increase (Smith et al., 2018; Sport New Zealand, 2020a; World Health Organization, 2018). In 2020, it was estimated that globally only 27 - 33% of all children, aged 5 - 17 years, achieve daily MVPA recommendations (Aubert et al., 2022).

In New Zealand, physical activity figures vary between studies, with estimates ranging between 7 - 59% of healthy children achieving MVPA recommendations (Aubert et al., 2022; Smith et al., 2018; Sport New Zealand, 2020a; Wilson et al., 2023). It is unknown how physically active, children with bronchiectasis are, in the New Zealand context. A recent qualitative study, which included a Counties Manukau population, highlighted that many children felt their bronchiectasis interrupted their ability to participate in physical activities to the level they wanted, and in some cases prevented them from participating at all (Blamires, 2020). With no objective evidence to support these claims, the aim of this study was to establish how physically active Counties Manukau's children with bronchiectasis are and extract fundamental physical activity data, to inform planning of future physical activity initiatives and research.

1.3 Study questions

To address the identified gap in the literature, this study aimed to investigate physical activity levels of children with bronchiectasis living in Counties Manukau, framed by four research questions:

1. How physically active are children aged 7 to 12 years with bronchiectasis living in Counties Manukau compared to healthy matched controls?
2. Do children with bronchiectasis achieve daily MVPA recommendations, as outlined by the WHO?

3. Is there an association between MVPA and demographic or disease severity markers in children with bronchiectasis?
4. What mode of physical activities are children with bronchiectasis engaging in and when do they engage in these activities?

1.4 Hypotheses

Based on the physical activity evidence available and clinical experience, the following hypotheses were predicted for the study.

Hypothesis 1: Children with bronchiectasis will be less active than their healthy matched controls.

Hypothesis 2: Children with bronchiectasis will achieve daily MVPA recommendations but less frequently than their healthy peers.

Hypothesis 3: Lower MVPA minutes will be associated with increased body mass index (BMI), reduced lung function ($\leq 80\%$ FEV1 predicted) and recent hospital admissions. Boys will be more active than girls.

Hypothesis 4: Children with bronchiectasis will engage in a wide range of activities, with a bias towards inexpensive and informal school and backyard games/activity. Children with bronchiectasis will participate in less physical education classes at school, but like their peers, will be more active during the week compared to the weekend.

1.5 Significance of this study

This will be the first study in New Zealand, and second internationally, to investigate physical activity levels in children with bronchiectasis. As such, findings will be significant to both New Zealand and the international bronchiectasis community, including health professionals, and may influence future physiotherapy practice and recommendations for physical activity guidelines for children with bronchiectasis.

Results from this study will establish whether children with bronchiectasis, living in Counties Manukau, are less active than their healthy peers, and to what extent they achieve daily MVPA recommendations, as per the 2020 WHO physical activity guidelines. Results will determine if physiotherapists, especially those working in Counties Manukau, need to place a greater emphasis on physical activity during bronchiectasis assessment and management. Results may

also stimulate further research into this field, exploring avenues to assess, treat and monitor physical activity deficits, so children with bronchiectasis can better achieve the health benefits associated with completing daily MVPA recommendations.

The study also has the potential to identify key demographic and disease severity markers associated with insufficient MVPA completion. This information would enable physiotherapists to identify children at highest risk and facilitate early and targeted physical activity interventions. A more proactive approach has the potential to improve child health outcomes and reduce some of the burden that is placed on the healthcare system because of their life-long specialised care needs. Furthermore, the ability to easily identify children with the greatest healthcare needs, would be greatly beneficial for assisting busy physiotherapy services, where currently, regular assessment and intervention for every child with bronchiectasis is not a feasible option.

This will be the first study to investigate mode (type of activity) and time of day, when children with bronchiectasis are engaging in physical activity. Mode of physical activity will provide valuable insights into the activities children are interested in, and have available within their community, such as sports teams, backyard games, school programmes, cultural groups, active transport. To date, participation in physical activity has been assessed by weekdays and weekends, with children typically more active on weekdays (Brazendale et al., 2021; Fairclough et al., 2015), including children with bronchiectasis (Joschtel et al., 2019). Therefore, our study aimed to examine this further by exploring the time of day during the week, children with bronchiectasis were most active: morning tea, lunch time, physical education class, afterschool, or evenings. The addition of mode and time of day data will provide clinicians and researchers, novel and fundamental information to incorporate into physical activity interventions and initiatives that specifically fit the needs and interests of Counties Manukau children. Although results will be specific to those children, findings will also be relevant to children with bronchiectasis living throughout New Zealand.

Chapter 2 Background and Literature Review

The following chapter provides a review of the literature related to physical activity in children with bronchiectasis. Due to the paucity of research in this area, a systematic review was unable to be completed. Five smaller narrative critiques were subsequently performed to justify the rationale for the study and the methodology selected, to best answer the study's aims and prove the hypotheses. To commence, a thorough review of the literature was completed, according to a comprehensive and methodological approach to that search; refer to Appendix A.

The first section of this chapter describes bronchiectasis in children, providing relevant background information related to aetiology, incidence, management, and disease burden. The second section introduces key outcome measures used for assessing disease severity, applicable to this study. The third section introduces physical activity benefits and recommendations for children, identifies a substantial gap in physical activity knowledge for children with bronchiectasis, and then critiques the literature of two physical activity outcome measures selected for the current study. The final section critiques the available literature investigating physical activity levels in children with bronchiectasis.

Within the literature, there is a wide variation of age used when defining child populations. Given this study is aimed at children with bronchiectasis aged 7 to 12 years, for the purpose of this thesis the term 'children' will be defined as 5 to 12 years, unless otherwise stated.

2.1 Bronchiectasis in children

As previously highlighted, bronchiectasis is a chronic respiratory disease characterised by abnormal dilation and destruction of airway walls in one or more bronchi (Chang et al., 2015; Chang et al., 2018; Chang, Fortescue, et al., 2021). For most children, bronchial dilation is permanent, however early diagnosis combined with intensive management may provide an element of reversibility for some children (Chang, Fortescue, et al., 2021; Gaillard et al., 2003). Disease trajectory is generally considered as progressive but is dependent on the age of the patient, disease severity, and access to early and effective treatment (Redding, 2009).

2.1.1 Aetiology

Despite bronchiectasis gaining increased recognition as its own disease entity, it remains a consequence of chronic and repeated environmental insults superimposed on an underlying

genetic vulnerability, or during early childhood lung development and growth (Brower et al., 2014; McCallum & Binks, 2017). Aetiology varies between children and in many cases remains unknown (Goyal et al., 2016). In New Zealand, the most common childhood aetiologies for bronchiectasis are idiopathic (45%), post infectious (23%) post oncology disease (11%) and primary immunodeficiency (9%) (Munro et al., 2011).

The strongest predictor for developing bronchiectasis during childhood is recurrent lower respiratory tract infections and associated hospitalisation within the first year of life (Singleton et al., 2014). Additional risk factors such as smoke exposure, high socioeconomic deprivation, overcrowded and damp housing, poor healthcare access and low health literacy within the family/whānau, may also contribute to development and progression of bronchiectasis (Redding et al., 2004; Singleton et al., 2014). Although ethnicity is not considered a risk factor, Indigenous children are more likely to develop bronchiectasis than non-Indigenous children (Goyal et al., 2016). In New Zealand, Māori and Pasifika children typically experience higher levels of repeated and severe lower respiratory tract infections (Byrnes & Trenholme, 2010; Simpson et al., 2018), coupled with exposure to many of the risk factors identified above (Lees et al., 2021). Therefore, it is unsurprising that Māori and Pasifika children make up the majority of New Zealand's bronchiectasis population (Telfar Barnard & Zhang, 2021).

2.1.2 Incidence of bronchiectasis in children

2.1.2.1 International incidence

Incidence of childhood bronchiectasis continues to rise in both developing and developed countries (Goyal et al., 2016). In developed countries, the average annual incidence of bronchiectasis for Caucasian children, predominantly from socially advantaged backgrounds, remains low - ranging from 0.5 per 100,000 in Finland (Säynäjäkangas et al., 1998) to 2.1 per 100,000 in the United Kingdom (Lavery et al., 2008). Compared to Indigenous and/or socially disadvantaged children living in developed countries, the incidence of bronchiectasis ranges from 15.5 per 100,000 children in Inuit of Nunavut, Canada, to 735 per 100,000 children in Aboriginal children, Central Australia (McCallum & Binks, 2017). New Zealand is positioned within this subgroup of countries, where a high incidence is observed in its Indigenous and socially disadvantaged communities, namely Māori and Pasifika peoples (McCallum & Binks, 2017).

2.1.2.2 New Zealand's incidence

New Zealand's overall incidence of bronchiectasis for children under 15 years has steadily risen from 3.7 per 100,000 in 2001/2002 (Twiss et al., 2005) to 11.8 per 100,000 in 2019 (Telfar

Barnard & Zhang, 2021) with significant ethnic disparities observed between population groups. Children from Māori and Pasifika descent are significantly overrepresented with an incidence of 19.2 per 100,000 Māori and 21.7 per 100,000 Pasifika in 2019 (Telfar Barnard & Zhang, 2021). Incidence also demonstrates a regional pattern in New Zealand, with large groups of children with bronchiectasis living in the Auckland and Gisborne regions (Twiss et al., 2005). Higher incidence in these regions is easily explainable, as they are home to large populations of Māori and Pasifika people that live in communities with high socioeconomic deprivation (Atkinson et al., 2019).

2.1.2.3 Counties Manukau's incidence

The exact incidence of children with bronchiectasis living in Counties Manukau is unknown, due to the lack of a disease registry. However, a retrospective audit of one of Counties Manukau bronchiectasis services provides a broad outline of the number and demographic makeup of children with bronchiectasis in the region. In 2019, the Kidz First bronchiectasis multidisciplinary team (MDT) clinic, reported that 96 children with bronchiectasis were enrolled in their service (Rensford, 2021). At the time of the audit, the mean age of children enrolled was 7.99 years (range 2 - 16 years), predominantly male ($n = 45$, 61.6%) and the majority identified as either Māori ($n = 19$, 26%) or Pasifika ($n = 44$, 60.3%). Over 70% of the clinic population lived in high socioeconomically deprived communities (NZDep Index 9 and 10) (Rensford, 2021). Further, 65% of those children were classified as overweight or obese (R. Matsas, personal communication, December 31st, 2019). The number of children with bronchiectasis living in Counties Manukau is estimated to be higher, as not all children attend this clinic under the current model of care; see section 2.1.3.1, although broad child demographics are thought to be similar.

2.1.3 Bronchiectasis Management

Bronchiectasis management is typically lifelong and whenever possible is provided by a specialised MDT that consists of medical, nursing, physiotherapy, and social work (Chang et al., 2018; Chang, Fortescue, et al., 2021). The aim of the MDT is to ensure that children receive developmentally appropriate, individualised, and effective treatment programmes, which are based on best practice guidelines (Chang et al., 2015; Chang et al., 2018; Chang, Fortescue, et al., 2021). Treatment objectives focus on optimising lung growth, preserving lung function and enhancing quality of life by reducing exacerbation frequency, and preventing co-morbidities. This is achieved with daily airway clearance programme and regular physical activity, typically provided by a respiratory physiotherapist, and antibiotic/inhaler therapy when required (Chang, Fortescue, et al., 2021).

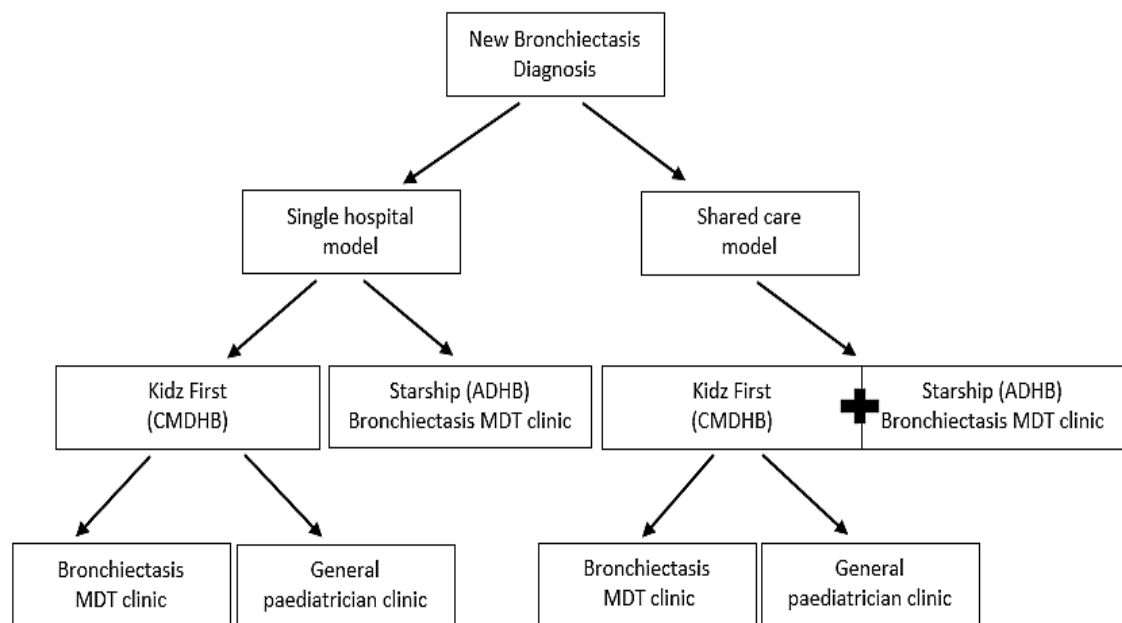
2.1.3.1 Model of care

Until recently, Counties Manukau was one of the three District Health Board's (DHB) (Auckland, Counties Manukau and Waitematā), that provide healthcare services to the wider Auckland region. In July 2021, during this study, the New Zealand government reformed the DHB system and replaced it with Te Whatu Ora – Health New Zealand. As a result, the three Auckland DHBs were combined with Northland DHB to make one large Northern Region; refer to Appendix B.

The current Te Whatu Ora – Health New Zealand reforms have not yet affected paediatric bronchiectasis service provision; therefore specialist care for children residing in Counties Manukau continues to be provided between Kidz First (Counties Manukau's local children's hospital) and Starship (Auckland children's hospital and New Zealand's tertiary children's hospital), see Figure 1.

Figure 1

Model of care for children with bronchiectasis living in Counties Manukau



Note. MDT = multidisciplinary team.

Unfortunately, there is no standardised pathway that determines which hospital children are referred to for ongoing bronchiectasis management following diagnosis. As a result, Counties Manukau children fall into an array of different services and receive varying models of care. For example, some children may be under the sole care of one hospital (Kidz First or Starship) while other children receive shared care between both hospitals. Even within Kidz First, there is no standardised pathway to determine which service a child with bronchiectasis is allocated to: bronchiectasis MDT clinic or general paediatrician clinic.

Current service providers acknowledge the inequality of services that children with bronchiectasis receive, when living in Counties Manukau (Northern Regional Bronchiectasis Meeting, personal communication, August 9th, 2021). It is hoped that with the introduction of Te Whatu Ora – Health New Zealand, standardised service pathways and a disease registry will be developed improving access to specialised bronchiectasis care for all children, regardless of where they live.

2.1.4 Disease burden

Bronchiectasis can cause heightened levels of morbidity and create numerous health and economic burdens for the individual with bronchiectasis, their family/whānau and the health system (Goeminne et al., 2019; Marchant et al., 2021; Quint & Smith, 2019). Disease burden has been well established in the adult bronchiectasis population but there is less available data in paediatrics (Goeminne et al., 2019; Quint & Smith, 2019).

Treatment burden, i.e., the burden associated with treating and managing chronic illness, is observed in children with bronchiectasis and their family/whānau caring for them (Marchant et al., 2021; Quint & Smith, 2019). Research remains novel in this field, but demonstrates similar burden themes observed in other chronic health conditions, such as daily treatment practicalities, balancing family/ whānau responsibilities, time off work, absence from early childhood care or school, advocating for their child, and concerns about quality of life and potential future (Blamires, 2020; Jepsen et al., 2018; Marchant et al., 2021).

Economic burden, specifically cost of hospital admissions, is most referred to in the literature. For the fiscal year 2012 - 2013, bronchiectasis related hospital admissions, cost the New Zealand healthcare system NZD \$5.34 million, with child admissions accounting for 18% (Bibby et al., 2015). In Australia, bronchiectasis related hospital admissions during 2014 – 2016 were estimated to cost AUD \$30,182 per child for a mean length of stay of 12.3 days. Additional costs to families were estimated at AUD \$2669.50 for loss of income and other hospital related expenses (Goyal et al., 2020). Higher cost estimates were associated with length of stay, age, and number of lobes affected with bronchiectasis (Goyal et al., 2020). Estimates were restricted to hospital admissions but, unlike Bibby et al. (2015), included ward-related resource, clinical supports, health professional salaries and wages, hospital-related overhead costs and loss of family income. Both Bibby et al. (2015) and Goyal et al. (2020) indicated significant economic burden, but failed to encapsulate the wider health-related economic burden, associated with chronic care outside of hospital admissions such as outpatient appointments, prescriptions, and transport.

Healthcare resource burden relates to the additional costs placed upon the healthcare system to manage life-long chronic illness. This may be financial but also includes demands on service provisions and health professionals. The study by Lovie-Toon et al. (2019) used monthly parent reported interviews to determine the annual health resource required for managing children (under 18 years) with bronchiectasis in Australia ($n = 59$) and New Zealand ($n = 26$). Results showed that Australian and New Zealand children, experienced a mean (standard deviation) of 3.3 (2.2) bronchiectasis exacerbations per year with 11.4% requiring hospitalisation. In any given month, half of the cohort required some form of medication and 25% required 2.4 to 4.0 days off school (Lovie-Toon et al., 2019). When compared to the general population, children with bronchiectasis had a higher rate of antibiotic prescription and sought health care services more frequently, especially specialist services (Lovie-Toon et al., 2019).

There is limited literature exploring disease burden in children with bronchiectasis, but from the available literature, it suggests that New Zealand children experience high levels of treatment burden and add significant strain to an already overstretched and under resourced health system. Future initiatives that could relieve an element of burden from any of these domains are desperately required, as the child bronchiectasis population continues to rapidly grow in New Zealand.

2.2 Measuring disease severity in children with bronchiectasis

Respiratory assessment is an on-going component of bronchiectasis management and includes a variety of outcome measures and clinical expertise to determine the impact bronchiectasis has on the child and their family/whānau (Chang et al., 2015; Chang, Fortescue, et al., 2021). Unlike the adult bronchiectasis population, no standardised outcome measures are available to evaluate disease severity and trajectory for children or capture the impact bronchiectasis has on quality of life. As such, international guidelines recommend clinicians use their clinical experience, to interpret a wide range of respiratory outcome measures in conjunction with the child's subjective history, to determine disease severity estimates (Chang et al., 2015; Chang et al., 2018; Chang, Fortescue, et al., 2021).

The following subsections briefly describe the key outcome measures most commonly referenced in the literature and clinically utilised. Outcome measures pertinent to the current study are further discussed in Chapter Four.

2.2.1 Chest high-resolution computed tomography

Chest high-resolution computed tomography (HRCT) is considered the gold standard for diagnosing bronchiectasis (Chang et al., 2015; Chang et al., 2018; Chang, Fortescue, et al., 2021). A bronchiectasis diagnosis requires evidence of enlarged broncho-arterial ratio (internal diameter of the bronchus relative to the diameter of the adjacent pulmonary artery), to demonstrate bronchial dilation (Chang et al., 2018; Goyal et al., 2016). Lack of bronchial tapering towards the lung periphery, bronchi seen at lung periphery, bronchial wall thickening or mucus plugging, and air trapping on expiration, may also be seen (Goyal et al., 2016). Findings are reported as the number of lobes affected and severity of bronchial damage (traction, cylindrical, varicose, and cystic), to indicate disease extent and severity (Chang et al., 2018; Chang et al., 2003). New Zealand data suggests that between 61 - 89% of children have bronchiectasis in three or more lobes (Edwards et al., 2003; Twiss et al., 2005; Twiss et al., 2006), much higher than many other countries (McCallum & Binks, 2017).

2.2.2 Spirometry

Spirometry is the most common pulmonary function test used for assessing lung function in bronchiectasis. Measurements used in clinical practice and research are forced expiratory volume in one second (FEV1) and forced vital capacity (FVC) (Chang et al., 2015; Chang, Fortescue, et al., 2021). Although spirometry can be less sensitive in milder disease (Chang et al., 2015), and difficult to undertake with younger children, due to developmental skills and behaviour, spirometry provides valuable information regarding disease status (Graham et al., 2019) and therefore, should be completed at least annually to assist monitoring of disease progression and functional status (Chang et al., 2015; Chang, Fortescue, et al., 2021).

New Zealand studies suggest many children with bronchiectasis have mild to moderate impairment on spirometry (Edwards et al., 2003; McCallum & Binks, 2017; Munro et al., 2011; Twiss et al., 2005; Twiss et al., 2006). One study further suggests a general decline in FEV1% predicted over four years observation, especially in Māori female children living in high socioeconomic deprivation, despite being managed in a tertiary bronchiectasis centre (Munro et al., 2011). By comparison, findings from Australian and United Kingdom studies concluded FEV1% predicted scores improved or stabilised following three to five years of medical management (Ramsey & Schultz, 2022). This suggests that children with bronchiectasis in New Zealand may develop more severe disease and suffer from poorer health outcomes compared to similar developed countries.

2.2.3 Bronchiectasis exacerbations

The frequency and severity of bronchiectasis exacerbations, (refer to Appendix C for definition), can be determined by counting the number and duration of antibiotic courses and hospital admissions required each year (Chang et al., 2015; Chang, Fortescue, et al., 2021). These simple outcome measures are particularly useful for monitoring children whose clinical picture may not match other objective findings i.e., frequent exacerbations despite minimal bronchiectasis changes on HRCT and normal spirometry. Additionally, prescription of long-term prophylactic antibiotics, such as Azithromycin, indicates a child with highly symptomatic or severe bronchiectasis that is not able to be managed with standard treatment alone (Chang, Fortescue, et al., 2021; Starship, 2022; Valery et al., 2013).

2.2.4 Exercise testing or physical activity monitoring

There are no validated exercise tests for children with bronchiectasis, yet they are used routinely in research and clinical settings. The Six Minute Walk Test (6MWT) and Incremental Shuttle Walk Test (ISWT), are simple submaximal stress tests, typically used to determine the effects an intervention has on exercise capacity (Lee et al., 2014). The 6MWT measures functional exercise capacity and the ISWT measures peak exercise capacity (Holland et al., 2014). Both tests are self-paced sub-maximal stress tests that require standardised protocols. However, although validated in children aged six to eighteen years (Kasović, Štefan, & Petrić, 2021; Lanza et al., 2015; Li et al., 2007), eliciting accurate scores can be difficult to achieve with younger children who require additional (non-standardised) support to behave and remain motivated throughout testing (Bartels et al., 2013). Although both the 6MWT and ISWT provide valuable exercise capacity information, they are unable to capture a child's physical activity levels or participation abilities throughout the day, a more accurate indicator of child health and wellbeing (Janssen & LeBlanc, 2010).

Physical activity monitoring, either by questionnaire or accelerometry is a potential solution for gaining a more in-depth understanding of a child's true physical activity performance and functional health throughout the day/week. Evaluating these parameters will be the basis of this thesis.

2.3 Physical activity in children

One of the most important indicators of child health and wellbeing, is children's ability to participate in physical activity and play (Janssen & LeBlanc, 2010). Physical activity is defined as any bodily actions produced by skeletal muscles that result in energy expenditure (Butte et al.,

2012; Caspersen et al., 1985). Physical activity is an umbrella term that encapsulates many domains: leisure, education, occupation, household, and transportation. It is categorised by intensity level: sedentary, light, moderate, and vigorous (Ainsworth et al., 2000; World Health Organization, 2018, 2020a); refer to Appendix D for definitions.

In research, physical activity is measured using metabolic equivalent of task (MET), a physiological measure used to express intensity, using the ratio between the amount of energy expended during a physical activity, compared to the body's resting metabolism (Ainsworth et al., 2000). METs are then grouped into physical activity intensity levels: sedentary = ≤ 1.5 METs; light physical activity = 1.5 - 3 METs; moderate physical activity = 3 - 6 METs; vigorous physical activity = ≥ 6 METs (Bull et al., 2020). A combined MET, moderate to vigorous physical activity or MVPA (≥ 3 METs) is the physical activity threshold required for an individual to achieve the physiological benefits associated with physical activity (Bull et al., 2020; Howell, 1996). As such, the MVPA threshold of ≥ 3 METs, is the most frequently used intensity target in research and physical activity guidelines, to ensure children achieve the aspired health benefits from physical activity participation (Sports New Zealand, 2019; World Health Organization, 2020a).

2.3.1 Benefits of physical activity

Childhood is a time of significant growth and development where regular physical activity is a critical component for optimal health and the development of healthy lifestyle habits (Australia Department of Health, 2019; Chaput et al., 2020; U.S. Department of Health and Human Services, 2018). Research extensively shows participation in regular physical activity provides many health benefits, outlined in Table 1 (Bull et al., 2020; Chaput et al., 2020; Janssen & LeBlanc, 2010; Poitras et al., 2016; World Health Organization, 2020a). The benefits achieved through physical activity, are directly related to frequency, duration, and intensity, meaning the more physical activity accumulated across the week at higher intensities (i.e., MVPA) will result in better health outcomes (U.S. Department of Health and Human Services, 2018). This is also inversely true for sedentary or low physical activity and poor health outcomes. Unfortunately, with children participating in less physical activity, non-communicable diseases, such as obesity, cardiovascular disease, are increasing. In fact, inactivity is now considered the lead contributor to global mortality for all age groups, including those with chronic disability or disease (Altenburg et al., 2016; U.S. Department of Health and Human Services, 2018; World Health Organization, 2018, 2020a).

Table 1

Benefits of physical activity for children

Domain	Benefits gained from physical activity
Physical	Improved physical fitness (cardiorespiratory and muscular fitness), cardio-metabolic health (blood pressure, insulin resistance, dyslipidaemia), bone health and reduced adiposity
Cognitive	Improved academic performance, memory, creativity, and executive functioning
Psychological	Improved mental and emotional wellbeing Reduced anxiety, stress, and depression
Social	Social skill and relationship requisition
Developmental	Promotes normal child development, growth, skill acquisition

2.3.1.1 Benefits of physical activity for children with bronchiectasis

The exact physiological and psychosocial effect physical activity has on children with bronchiectasis, is unknown and assumptions largely rely on theoretical speculation and research in similar populations (Jones et al., 2022; Lee et al., 2021). It is assumed that children with bronchiectasis achieve similar physical activity benefits as healthy children, but to date there is no evidence to support or refute this claim (Joschtel et al., 2018). It is also unknown if physical activity provides any additional disease specific benefits, such as a reduction in exacerbation frequency, a key predictor for pulmonary decline and hospitalisation (O'Grady & Grimwood, 2017), as seen following pulmonary rehabilitation in the adult bronchiectasis population (Alison et al., 2017; Holland et al., 2021). Potential insight into this question may be revealed in the near future following the completion of the proposed study by Jones et al. (2022), who plan to complete a randomised control trial investigating the effects of a pulmonary rehabilitation model on Australian children with bronchiectasis.

2.3.2 Physical activity recommendations

To achieve the health benefits associated with physical activity, WHO recommends children aged 5 - 17 years complete at least an average of 60 minutes per day of MVPA across the week. Physical activity should mostly be aerobic based, but also incorporate muscle and bone strengthening activities for at least three days a week (World Health Organization, 2020a). Recommendations are targeted at healthy and typically developing children, however when able and under medical guidance, children with chronic disability or disease, should also strive to achieve similar recommendations (Bull et al., 2020; Chaput et al., 2020; World Health Organization, 2020a).

The WHO's physical activity recommendations, provide the foundation for national policy development around the world (Bull et al., 2020), including New Zealand's Physical Activity Guidelines for Children and Young People (Ministry of Health, 2017) and Everybody Active Strategic Plan (Sports New Zealand, 2019).

2.3.2.1 Physical activity recommendations for children with bronchiectasis

Two international bronchiectasis guidelines include physical activity recommendations for children: Chronic Suppurative Lung Disease and Bronchiectasis in Children and Adults in Australia and New Zealand (Chang et al., 2015) and the European Respiratory Society Guidelines for the Management of Children and Adolescents with Bronchiectasis (Chang, Fortescue, et al., 2021). Unfortunately, due to the paucity of research in this field, both recommendations simply state children should be encouraged to participate in regular physical activity. Recommendations are non-specific and provide minimal guidance. As a result, physiotherapists provide physical activity interventions based on WHO recommendations, research extrapolated from similar child populations such as cystic fibrosis or adult bronchiectasis populations, and clinical experience (Bell et al., 2018).

2.3.2.2 Clinical application of physical activity recommendations

In the absence of practice recommendations, physiotherapists throughout New Zealand provide a range of physical activity interventions. For the most part, children and their family/whānau are encouraged to be regularly active (as per guidelines) and provided with general advice on how to achieve this (Northern Regional Paediatric Physiotherapy meeting, personal communication, November 23rd, 2021). More targeted interventions are only provided if exercise intolerance has been identified. As there are no formal pulmonary rehabilitation programmes available for children, considered gold standard treatment in the adult population (Alison et al., 2017), interventions typically consist of an individually tailored home exercise programme, occasionally with supplementary outpatient appointments (Northern Regional Paediatric Physiotherapy meeting, personal communication, November 23rd, 2021).

The ability to measure physical activity during childhood is key for monitoring general health and determining the efficacy of physical activity interventions (Duncan et al., 2020). There are no gold standard or overarching outcome measures capable of incorporating the multitudinous number of variables that influence participation and performance (Materová et al., 2022). The most common outcome measures used in child physical activity research are accelerometry and questionnaires (Marasso et al., 2021; Troiano et al., 2014).

Accelerometers are small wearable electronic devices that use sensors to measure raw accelerations to capture continuous objective physical activity data such as intensity, frequency, and duration (Actigraph, 2021; Rowlands et al., 2014). Accelerometers are considered the more reliable and valid tool for collecting physical activity data, but are unable to provide descriptive information about the mode or context physical activity that was completed (Arvidsson et al., 2019; Migueles et al., 2017). Furthermore, due to the associated costs, resources and specialised skills required to use them, accelerometers are primarily used in the research setting (Hidding et al., 2018).

Physical activity questionnaires are easy to administer, inexpensive, and provide a wide range of descriptive data that is unable to be collected on accelerometers, for example: habitual activity, swimming/cycling, activity patterns, and environmental context (Hidding et al., 2018). However, questionnaires can be less reliable when they rely on subjective insight and recall, traits that commonly result in overestimation of physical activity completed (Hidding et al., 2018; Troiano et al., 2014). Questionnaires also require a set level of reading and writing comprehension skills, which younger children may have not fully developed, thus leading to reporting errors and the need for external assistance.

Both accelerometers and questionnaires provide valuable physical activity data, as they measure different aspects of physical activity. Therefore it is recommended that researchers use both outcome measures together to achieve a comprehensive understanding of physical activity participation and performance (Hidding et al., 2018; Marasso et al., 2021; Troiano et al., 2014).

2.3.3 ActiGraph wGT3X+ accelerometer

Many different accelerometers are available for use in both clinical practice and research. For this study, the ActiGraph wGT3X+ accelerometer (ActiGraph LLC, Pensacola, FL, USA) was selected due to its overall reliability and validity (Arvidsson et al., 2019; Migueles et al., 2017; Montoye et al., 2018). For ease of reference within this thesis, the ActiGraph wGT3X+ accelerometer will be referred to as the 'accelerometer'. This accelerometer is a small wearable motion sensor, used in health research to capture physical activity in free living conditions; refer to Figure 2. The accelerometer is the equivalent size and weight of a regular watch (dimension 4.6cm x 3.3cm x 1.5cm; weight 19 grams) and uses a tri-axial (horizontal right-left (x), vertical (y), and horizontal front-back (z)) micro electromechanical system accelerometer, to capture raw accelerations and activity counts of the body segment it is attached to (Actigraph, 2021). The accelerometer has an average charge lifespan of 31 days

and is waterproof for up to 30 minutes at a depth of one meter allowing it to be continuously worn for research purposes (Actigraph, 2021).

Figure 2

ActiGraph wGT3X+ Accelerometer



Note. Image sourced from <https://actigraphcorp.com/actigraph-wgt3x-bt/>

There are no gold standard guidelines available for accelerometer use, which means the psychometric properties and results will vary between each study based on accelerometer parameters selected (Migueles et al., 2017; Montoye et al., 2018). In an attempt to reduce the variance between studies and facilitate data comparison, it is recommended the following parameters (placement, initialisation, data analysis and reporting), are evaluated against the intended population and outcome variable (i.e., MVPA) before the study commences (Arvidsson et al., 2019; Matthews et al., 2012; Montoye et al., 2018).

2.3.3.1 Placement of the accelerometer

There is much debate regarding accelerometer placement and the effect this has on results. Traditionally accelerometers were worn over the right hip on elastic belts during awake hours (Migueles et al., 2017; Montoye et al., 2018). However due to significant issues with wear compliance resulting in underestimation of physical activity and incomplete datasets, research has shifted towards wrist-based accelerometers as an alternative option (Arvidsson et al., 2019; Doherty et al., 2017; Fairclough et al., 2016; Rowlands et al., 2014; Troiano et al., 2014).

Typically, wrist-based placement has been considered a less accurate measure of energy consumption when compared to hip-based laboratory studies, but when used in free living studies, wrist-based accelerometers have many distinct advantages that outweigh its limitations (Arvidsson et al., 2019; Fairclough et al., 2016). Wrist-based accelerometers are particularly advantageous for child-based studies as they can capture light physical activity and upper body movements better than hip-based accelerometers. This feature is particularly valuable for children, as their movement is often sporadic, omnidirectional, and far more complex than just locomotion (Holfelder & Schott, 2014). Refer to Table 2 for wrist-based

accelerometer advantages for child research compared with hip-based (Arvidsson et al., 2019; Fairclough et al., 2016; Rowlands et al., 2014).

Table 2

Comparison of wrist- and hip-based accelerometer placement for child research

	Wrist Accelerometer	Hip Accelerometer
Datasets	Lower dropout rates Higher percentage of valid datasets	Higher dropout rates Lower percentage of valid datasets Requires larger sample size to accommodate for data loss
Measurement accuracy	More accurate in free living studies Better detection of light physical activity and upper limb movements Better detection of sporadic and omnidirectional movements Accurate assessment of sleep patterns	More accurate in laboratory settings Underestimates activities with little/no hip movement i.e., cycling Better detection of single directional locomotion Poor assessment of sleep patterns
Wear compliance	Worn 24-hours a day, only removed for water submersion or sports safety Easily worn in all age groups High wear compliance Reduced risk of participant selection bias	Worn during awake hours only Relies on participants to put on each day Difficult to keep on young children Poor wear compliance Increased risk of participant selection bias
Accurate placement	Worn like a watch, limited room for position error or disruption	Often positioned incorrectly, easily shifts during active play
Risk of falling off	Not easily removed, hospital band needs to be cut off	Velcro band easily comes undone
Comfort	Minimal discomfort Easy to wear, similar to a watch Wrist bands available for all wrist sizes	Uncomfortable, moves position Regularly removed by participants due to discomfort Limited band size options for overweight and obese children
Discreet	Looks like a watch, easily goes unnoticed	Looks different, might not sit well under clothing, and draw attention

2.3.3.2 Initialisation of the accelerometer

Physical activity monitoring is typically completed over a seven-day period, to achieve better reliability of captured data in most populations, and the opportunity to sample behaviour on weekday and weekend days (Bergman, 2018; Matthews et al., 2012). The inclusion of at least one weekend day is important due to differences in physical activity participation between weekdays and weekends (Brazendale et al., 2021). A 24-hour recording protocol is recommended to encompass physical activity and sleep behaviours, but a 10-hour per day

protocol is also accepted for accelerometers that need to be removed for sleeping (Matthews et al., 2012).

The accelerometer uses three axes (x, y, z) to capture raw physical activity accelerations using pre-set sample frequency and epoch length parameters (Actigraph, 2021). Sample frequency is the rate at which each axis records acceleration data, commonly set between 30 - 100Hz, with 30Hz applied more frequently to better detect light physical activity, while ignoring additional movement 'noise' of daily living (Arvidsson et al., 2019; Migueles et al., 2017). Epoch length is the interval of time raw data is collapsed into a summary metric (counts). At the end of each epoch, the sum of activity counts is calculated and assigned a physical activity intensity, therefore epoch length will significantly influence physical activity classification (Gómez-García et al., 2022). In studies using MVPA as a variable of interest, short epoch lengths are recommended to avoid MVPA counts being averaged or smoothed out into other intensity levels (Gómez-García et al., 2022; Matthews et al., 2012).

2.3.3.3 Accelerometer cut-point algorithm

Cut-point algorithms are required to group acceleration counts into physical activity intensity levels, that align with MET thresholds (i.e., 818 + counts = ≥ 3 METs = MVPA); refer to section 2.3 and Appendix D. Several cut-point algorithms have been validated in child physical activity research that have used the ActiGraph wGT3X+ accelerometer (Chandler et al., 2016; Evenson et al., 2008; Hänggi et al., 2013; Hildebrand et al., 2017; Hildebrand et al., 2014; Romanzini et al., 2014). Due to the high number of accelerometer variables (placement, sample frequency, recording criteria) that influence algorithm outcomes, physical activity results vary between algorithms even when tested on the same sample of children within a controlled environment (Migueles et al., 2017). As such, no algorithm is considered better than another and selection is once again based on the study's objectives (Matthews et al., 2012).

Only one algorithm is available for non-dominate wrist placement in children (Chandler et al., 2016). The algorithm cut-points used by Chandler et al. (2016) were originally evaluated with healthy children participating in a range of activities: colouring/crafts, walking, playground, splash pad, swimming and shuttle running. It was thought to have excellent psychometric properties for accurately classifying MVPA (Chandler et al., 2016). A recent 2022 laboratory-based study reevaluated three wrist-based cut-points using more 'lifestyle' activities (i.e., laundry tasks, sweeping). All three wrist-based cut-points, including Chandler et al. (2016), were thought to overestimate non-ambulatory activities that used significant arm or wrist movements, and underestimate MVPA if arm movements were more constrained i.e., cycling (Troost et al., 2022). The study recommended wrist-based accelerometers use functional data

analysis to process data instead. However, these processes are not typically used in health research due to the advanced programming skills and specialized software required, therefore the original process continue to be used.

2.3.3.4 Valid dataset criteria

Before undertaking the analysis, non-wear time and valid dataset criteria need to be set. There is limited consensus regarding non-wear time parameters in children but a cut-point of 60 - 90 minutes of consecutive zero counts is commonly applied in the literature (Arvidsson et al., 2019; Migueles et al., 2017). The algorithm used by Choi et al. (2011) has the highest sensitivity score for detecting non-wear time at the wrist for people aged 10 - 67 years, (Choi et al., 2012; Migueles et al., 2017). There are also no defined criteria for valid datasets but three to four days, including at least one weekend day, with a minimum of ten hours (600 minutes) per day, has been commonly used by studies reported in the literature (Arvidsson et al., 2019; Migueles et al., 2017).

The above sections outline the key considerations that need to be made when setting up accelerometers. Unfortunately due to the reality of research and normal child behaviour, researchers are often required to alter accelerometer parameters, at times away from protocol recommendations to better suit their population needs (Arvidsson et al., 2019; Matthews et al., 2012; Montoye et al., 2018). While these alterations are necessary they can affect the study's future ability to directly compare results with other studies.

2.3.4 Physical Activity Questionnaire for Children (PAQ-C)

The Physical Activity Questionnaire for Children (PAQ-C) is one of the most widely used questionnaires in research and clinical settings for children aged 8 to 14 years during school term (Marasso et al., 2021; Triantafyllidis et al., 2021). The PAQ-C is a self-administered, seven-day recall questionnaire designed to measure MVPA and collect descriptive data such as mode of physical activity completed (i.e., running, basketball, swimming) and time of day children are most active physical activity, either during school, after school, or evenings (Kowalski et al., 2004; Marasso et al., 2021). Refer to Appendix E for a copy of the PAQ-C and scoring instructions.

The PAQ-C consists of nine items, each scored on a 5-point scale, to estimate physical activity completed during the recall period. A total activity score, from one to five, is generated by calculating the mean score of the nine items. A total activity score of one, indicates low physical activity, and five indicates high physical activity (Kowalski et al., 2004). A participant who attains a mean total activity score of 2.75 or more, is considered to have achieved MVPA

recommendations for the recall period (Benítez-Porres et al., 2016). The PAQ-C has acceptable psychometric properties for reliability and validity, and is sensitive for detecting change between genders and age (Janz et al., 2008). A recent meta-analysis demonstrated a moderate association (regression correlation coefficient (r) = 0.34, 95%; confidence interval 0.29, 0.39) between the PAQ-C and accelerometer-based outcome measures, indicating that the PAQ-C needs to be used in conjunction with accelerometer data to comprehensively measure MVPA (Marasso et al., 2021).

The PAQ-C has been extensively used around the world, including New Zealand (Foley et al., 2008; Ni Mhurchu et al., 2008; Telford et al., 2021; Utter et al., 2006; Utter et al., 2007), to assess physical activity in a range of ethnic groups and health conditions (Marasso et al., 2021; Moore et al., 2007; van der Kamp et al., 2021). Although not validated in a New Zealand population, the PAQ-C demonstrates similar measurement properties in most population groups that it has been validated in, but there is some concern of psychometric variance towards the lower end of acceptability in non-Caucasian ethnic groups (Moore et al., 2007), which could be problematic for New Zealand's diverse and Indigenous populations. For example, the PAQ-C is written in English-American using terminology and sports such as recess and floor hockey. Use of English-New Zealand, validation in te reo Māori and common Pacific languages, and inclusion of national sports and cultural activities such as rugby and Kapa Haka would ensure the questionnaire was relevant and culturally appropriate.

2.4 Physical activity in children with bronchiectasis

To date, there is only one study published that has investigated physical activity levels in children with bronchiectasis, a cross-sectional study that recruited 46 children with bronchiectasis aged 4 - 14 years (mean (standard deviation) age 7.5 (2.6) years) from Queensland Children's Hospital in Brisbane, Australia (Joschtel et al., 2019). The primary outcome measure was MVPA minutes per day, captured over seven days using a hip placed ActiGraph GT3X+ accelerometer. Accelerometer data was compared against the WHO physical activity recommendations, and two Australian population-based health surveys: Queensland Preventative Health Survey (Queensland Health, 2016) and the Health Kids Queensland Survey (Abbott et al., 2008).

While the study provides the first insight into physical activity levels, the lack of participant demographics included challenges its representation of the 'typical' child with bronchiectasis and its application to a New Zealand bronchiectasis population; refer to section 2.1.2. The study by Joschtel et al. (2019) did not stipulate the inclusion of Indigenous children, and only

22% of participants were noted to reside in low-income households (AUD \$50,000). These demographic markers are important to consider, when interpreting the data against that from Kidz First bronchiectasis MDT clinics, which consists of 26% Indigenous (Māori) and 70% living in high socioeconomic deprivation (NZDep Index 9 and 10) (Rensford, 2021).

The dropout rate from the Joschtel et al.'s (2019) study was 21.7%, potentially due to the utilisation of hip-based accelerometers and produced 36 valid datasets for analysis. The mean (standard deviation) average recording time was 5.9 (1.3) days with a wear time of 728.2 (114.6) minutes per day, well over the recommended criteria (Arvidsson et al., 2019; Migueles et al., 2017). The study by Joschtel et al. (2019) reported children with bronchiectasis completed an average of 48 minutes of daily MVPA, with only two (5.6%) achieving the WHO daily MVPA recommendations compared to 42% in the Queensland Preventative Health Survey (Abbott et al., 2008). While children with bronchiectasis appeared to be less active than their peers, the degree of difference between the two groups may be overestimated due to the mismatch of physical activity constructs and outcome measures used in each study (Joschtel et al. (2019) = accelerometer and MVPA; Queensland survey = self-reported survey and minutes spent being active) (Hidding et al., 2018; Marasso et al., 2021; Troiano et al., 2014). Furthermore, the Queensland survey did not measure daily MVPA achievement as per the WHO guidelines (World Health Organization, 2020a), instead used parental questioning to estimate their child's accumulated daily physical activity participation. Consequently it is very plausible that social desirability and recall bias, commonly observed in surveys (Althubaiti, 2016), resulted in overestimation of physical activity achievement. Had Joschtel et al. (2019) included a healthy control group as its comparator, the study would have provided a more accurate comparison of daily achievement of MVPA recommendations (Ruble, 2017).

Joschtel et al.'s (2019) study fulfilled many of the recommended accelerometer reporting methods; outlined in section 2.3.3 (Arvidsson et al., 2019; Matthews et al., 2012; Montoye et al., 2018). Utilisation of the traditional hip placed accelerometer, with cut-points as used by Evenson et al. (2008) for children 5 - 8 years, was a valid option for the younger cohort (4 - 14 years; mean (standard deviation) age 7.5 (2.6) years) used by Joschtel et al. (2019), although it did risk miscalculation for older participants (Trost et al., 2011). However, the accelerometer daily wear time criteria used by Joschtel et al. (2019) was two hours shorter than the recommended 10 hours advocated by Matthews et al. (2012), potentially due to the decision to use hip placement that precludes a 24-hour wear protocol. It is unknown if the reduced wear time use, influenced overall MVPA minutes simply by reducing potential recording hours.

Lastly, Joschtel et al. (2019) did not include a physical activity questionnaire as recommended in the literature (Hidding et al., 2018; Marasso et al., 2021; Troiano et al., 2014). The absence of a questionnaire makes the results one dimensional, as accelerometer data in isolation is unable to provide a comprehensive understanding of physical activity participation and performance (Hidding et al., 2018; Marasso et al., 2021). The application of a questionnaire by Joschtel et al. (2019) would have provided contextual data to the study findings such as mode, frequency and location of physical activity completed. This additional data would provide a more in-depth insight into physical activity behaviours of children with bronchiectasis which would be valuable for development of future physical activity research initiatives.

2.5 Summary of the literature on physical activity in children with bronchiectasis

There is minimal research investigating physical activity in children with bronchiectasis. As a result, it is widely unknown how physically active children with bronchiectasis are and what impact level of physical activity may have on their future health, either directly (respiratory) or indirectly (obesity, mental health). Therefore, current recommendations are vague, provide minimal support to physiotherapists working with this population group, and are based on research extrapolated from healthy child populations, or from similar chronic health conditions such as cystic fibrosis. From the one published physical activity study (Joschtel et al., 2019), children with bronchiectasis are less active than their peers, but due to the applied study methods, it is unclear to what extent they are less active than their healthy peers and how assertive physiotherapists need to be to address these physical activity limitations. Findings from the above five narratives have been used to inform the current study design to best answer the study's question - how physically active children with bronchiectasis living in Counties Manukau are compared to their healthy peers?

Chapter 3 COVID-19 and Physical Activity Levels in Children

This additional chapter was included in this thesis to acknowledge the significant impact the COVID-19 pandemic has had on the study. The chapter will first provide an overview of the COVID-19 pandemic and the public health response before presenting New Zealand's unique experience. The consequence of lockdown mandates on children's ability to participate in physical activity will then be discussed and finally, the direct impact COVID-19 on this study will be presented.

3.1 Overview of COVID-19

COVID-19, formally known as Coronavirus disease, is a highly infectious and adaptive respiratory disease caused by the SARS-CoV-2 virus (World Health Organization, 2022b). First detected in early December 2019 in Wuhan City, China, COVID-19 quickly spread internationally triggering a Public Health Emergency of International Concern (PHEIC) on the 30th January 2020, and then a Global Pandemic on the 11th March 2020 (World Health Organization, 2022a). For the last three years, COVID-19 has remained one of the biggest threats to healthcare globally with more than 655 million infections and 6.6 million COVID-19 related deaths reported worldwide as of January 3rd 2023 (World Health Organization, 2022b). True estimates are understood to exceed recorded numbers by millions (Bergeri et al., 2021; Taylor, 2022).

The rapid spread of COVID-19 triggered unprecedented public health measures around the world that changed the normal behaviour of every human being (World Health Organization, 2022a). Public health strategies initially aimed to contain and eliminate the virus but once this became unachievable, shifted towards reducing transmission and protecting the vulnerable. Public health measures varied throughout the world but typically included hand hygiene, mask wearing, gathering restrictions, border control (international and regional), contact tracing, and lockdowns (World Health Organization, 2020b, 2021).

Lockdowns were designed as a short-term measure to break the chain of transmission, slow the spread of COVID-19, and prevent healthcare systems becoming overloaded (Atalan, 2020). Lockdown definitions and severity varied between countries but generally included stay-at-home orders, curfews and quarantine measures, which restricted people to their homes unless they needed to leave for essential reasons i.e., essential work force, food, or supply provision, seeking healthcare, or approved exercise hours (Atalan, 2020; Onyeaka et al., 2021).

Unfortunately, many lockdown measures were prolonged as the virus continued to spread uncontrollably and by April 2020, five months following first detection, approximately half the world's population were under some level of lockdown (Standford, 2020) and remained in varying states of this until December 2020 when the first COVID-19 vaccination was approved, and mass vaccination programmes were started (Oliu-Barton et al., 2022; World Health Organization, 2022a).

3.2 New Zealand's response to COVID-19 outbreak

In New Zealand, COVID-19 was first detected in Auckland on 28th February 2020 and triggered an unprecedented governmental response to protect the 'team of five million' (New Zealand Government, 2022). Refer to Appendix F for New Zealand's COVID-19 timeline. New Zealand's initial Elimination Strategy (Appendix G), utilised some of most stringent public health measures in the world (Jones, 2020). Key components included international border closure to everyone except returning citizens and residents, strict quarantine measures using dedicated facilities, and a four-tiered Alert Level Lockdown system (Ministry of Health, 2022e; New Zealand Government, 2022). The Elimination Strategy was highly effective and resulted in some of the lowest numbers of infections, hospitalisations, and deaths in the developed world while COVID-19 vaccines were developed (Jefferies et al., 2020; Wilson et al., 2021). However, the success of the Elimination Strategy was only possible due to the sacrifices the 'team of five million' made. For children, the closure of schools, community programmes and facilities were significant (Childrens Commissioner, 2020; Meissel et al., 2021). It is yet unknown what the long-term consequences of prolonged and fluctuating lockdowns will have on future educational, physical, and mental health outcomes for New Zealand children.

Following the development and implementation of COVID-19 vaccinations, in December 2021 New Zealand aligned with the rest of the world and shifted to the more sustainable Minimise and Protect Strategy (Appendix H) (Ardern, 2021; Ministry of Health, 2022e). As seen internationally, the easing of restrictions lead to COVID-19 infections surging throughout New Zealand. At the time this study was stopped in March 2022, infection rates were between 24,000 - 39,000 cases per day (Ministry of Health, 2022c). Almost three years later, like the rest of the world, COVID-19 continues to circulate, placing significant strain on people, the healthcare system, and the economy. By January 4th 2023, New Zealand had recorded 2.1 million infections and 2,331 COVID-19 associated deaths, with children (aged 0 - 19) accounting for 22.8% of total infections and four deaths (Ministry of Health, 2022b). To date,

there is no available data for the number of children with bronchiectasis in Counties Manukau, or wider New Zealand, who have contracted COVID-19.

3.2.1 Regional impact of COVID-19

Most COVID-19 outbreaks in New Zealand, particularly in the initial stages, were localised to the wider Auckland region (Auckland, Waitematā, and Counties Manukau). Between March 21st 2020 and December 1st 2021, the Auckland region was placed in lockdown five times, before shifting to the COVID-19 Protection Framework on December 2nd 2021 where Auckland remained at Red, or Orange until the Protection Framework was disestablished in April 2022.

Counties Manukau region has arguably been most impacted by COVID-19 compared with other regions, including being identified as the epicentre and subsequent catalyst for four major lockdowns (August 2020, February 2021, August 2021, and February 2022) (Forbes, 2022; Ministry of Health, 2022d). Outbreaks in Counties Manukau were largely epidemiologically explainable due to many of its population working in or attending environments, such as managed isolation and quarantine (MIQ) facilities, airport, hospitals, factories, schools, churches associated with increased risk of COVID-19 transmission. When they invariably returned to large, multigenerational, and overcrowded homes with substandard ventilation and heating (Forbes, 2022), common factors associated for rapidly spreading respiratory illness amongst individuals (Byrnes & Trenholme, 2010). These factors, in conjunction with Counties Manukau's lower health status (Lees et al., 2021; Macleod et al., 2014; Singh et al., 2021) and slower vaccination rates for COVID-19 (Forbes, 2021; Tagata Pasifika, 2022) and other scheduled immunisations (Chan et al., 2021), created the perfect vortex for widespread community transmission. It also premeditated poorer health outcomes for those that did contract COVID-19 (Forbes, 2022; Heather & Jones, 2020; Ministry of Health, 2022c; Radio New Zealand., 2021), potentially including children with bronchiectasis. This was captured in official governmental data, in which Counties Manukau was identified as one of the highest regions for COVID-19 infections and deaths (Ministry of Health, 2022c).

Frequent COVID-19 outbreaks in Counties Manukau caused fear and anxiety within its community as well as misdirected social stigma and racial abuse from wider New Zealand (Franks, 2021; Ma'ia'i, 2020; Pickering-Martin, 2021; Te Wake, 2021). Many people in Counties Manukau were frightened of contracting COVID-19, especially those with vulnerable family members such as children, elderly or disabled (Hendry-Tennent, 2021; Ministry of Health, 2021c; Radio New Zealand, 2020). Many families, out of fear, chose to uphold isolation restrictions for longer than required by the government, which was especially evident when it came to children returning to school (George, 2020; Gerritsen, 2020; Porter & Kenny, 2022;

Redstall, 2021; Woodland et al., 2021; Writes, 2022). Following the appearance of COVID-19, New Zealand's school attendance rates dropped from 72.8% in 2019 (pre COVID-19) to 50.5% in 2020 (during COVID-19) (Ministry of Education, 2022b). Two years later after numerous COVID-19 lockdowns, and another COVID-19 variant circulating school attendance further dropped to 46.1% at the start of 2022, with lower rates observed in primary school (5 - 10 years) students (45.4%), and Māori (32.8%) and Pasifika (30.4%) students. There are no specific Counties Manukau data, but school principals reported fluctuating attendance rates over the last two years (Fa'afiu, 2021; Latif, 2021; McClure, 2022).

3.3 Impact of COVID-19 restrictions on children's physical activity levels

Children contract COVID-19 just as frequently as adults but are less likely to become severely unwell, resulting in significantly lower rates of hospital admissions and COVID-19 related deaths (Russell et al., 2022; Zimmermann & Curtis, 2020). Nonetheless children's everyday lives have been substantially affected by the COVID-19 pandemic, but perhaps more so by the governmental mandates, and specifically lockdowns.

For children, lockdowns resulted in the subsequent closure of schools, organised sports and other recreational facilities and programmes, which profoundly changed their daily routines and inhibited options for achieving daily physical activity recommendations (Bailey & Scheuer, 2022; Smith et al., 2022). Prior to COVID-19, children were predominantly active during the week and during school attendance due to physical activity participation through physical education classes, active play during recess, and active transport to/from school (Bailey & Scheuer, 2022; Brazendale et al., 2021; Brazendale et al., 2017; Smith et al., 2022; Stockwell et al., 2021). Before the pandemic, physical activity levels in children aged 5 - 17 years were already low with only 27 - 33% of children internationally achieving the recommended 60 minutes of daily MVPA, across the week (Aubert et al., 2022). Now, following two years of COVID-19 restrictions, many public health professionals have serious concerns regarding the long-term impact lockdowns may have had on children's normal physical activity behaviour and their overall health and wellbeing, irrespective of contracting the COVID-19 virus itself (Amini et al., 2021; Cuschieri & Grech, 2020; Dunton et al., 2020).

3.3.1 Physical activity levels during lockdown

There is an abundance of international research that suggests most children during lockdown demonstrated a decrease in physical activity time, energy expenditure and daily MVPA minutes achieved (Paterson et al., 2021; Rahman & Chandrasekaran, 2021; Stockwell et al.,

2021). Of the few studies that used accelerometers to collect data during COVID-19 lockdowns, daily MVPA averaged between 34 - 48 minutes with 11 - 13% of children achieving MVPA recommendations (Dallolio et al., 2022; Hurter et al., 2022; ten Velde et al., 2021), significantly lower than pre-pandemic levels (27 - 33%) (Aubert et al., 2022). Lower levels of physical activity were more commonly observed in specific categories. These include: in girls, in older children who relied on organised sports for physical activity, in lower income households, single parent or multiple child families, parents working from home, elevated levels of parental anxiety regarding COVID-19, and reduced space at home i.e., apartment with no backyard (Cuschieri & Grech, 2020; Dunton et al., 2020; Guerrero et al., 2020; Paterson et al., 2021; Rahman & Chandrasekaran, 2021). A few contrasting studies (Guerrero et al., 2020; Paterson et al., 2021; Pietrobelli et al., 2020; Schmidt et al., 2020), including three from New Zealand (Meissel et al., 2021; Smith et al., 2022; Sport New Zealand, 2020c), demonstrated that some children were able to maintain physical activity levels, and in some cases to MVPA recommendations, by increasing unstructured physical activities. Children less affected by lockdown restrictions were younger children who could actively play inside the house and children whose families prioritised an active lifestyle and participated in physical activity with them (Rahman & Chandrasekaran, 2021).

In New Zealand, an increase in unstructured physical activity was observed during the first lockdown (March - April 2020) when families were actively encouraged by the government and their communities to participate in physical activity lockdown initiatives such as teddy bear hunts, free online and televised fitness classes, and getting outdoors for socially distanced family walks and bike rides (Meissel et al., 2021; Smith et al., 2022). However, like most international findings, the overall amount of time New Zealand children spent being physical active, decreased from 11.27 hours per week pre-pandemic to 8.14 hours per week during the pandemic, with greater reductions observed in older children, and those who relied on organised sports (Sport New Zealand, 2020c).

Conflicting findings are expected given the wide variation of lockdown restrictions utilised between countries and the heterogeneous research designs and methodologies applied to facilitate accelerated publications during COVID-19 (Kharel et al., 2022; Paterson et al., 2021). Due to pandemic restrictions, most studies were cross-sectional and used online child/parent reported questionnaires, many of which were non-validated researcher-constructed surveys (Paterson et al., 2021; Stockwell et al., 2021). However, despite study design limitations and the many confounding factors that influence physical activity participation, most evidence suggested that most children were less active during lockdowns (Paterson et al., 2021; Rahman & Chandrasekaran, 2021; Stockwell et al., 2021).

3.3.2 Physical activity levels following the removal of lockdown mandates

Following the development and roll out of COVID-19 vaccinations, many countries removed lockdown mandates and children slowly started to return to school and normal physical activities. Emerging evidence post lockdown suggests children's physical activity levels have not immediately returned to pre-lockdown levels, with an average of seven to eight minutes less MVPA completed per day compared to 2018 (Salway et al., 2022). There are no longitudinal studies available yet assessing the long-term impact of COVID-19 lockdowns on New Zealand children, but emerging adult studies suggest that overall physical activity levels decreased throughout the lockdown and by April 2021 remained 3.4% lower than pre-pandemic levels (Wilson et al., 2022).

3.3.3 Impact of lockdown on children with bronchiectasis

There are no physical activity studies of children with bronchiectasis during the COVID-19 pandemic, but there are a few studies inclusive of similar chronic respiratory conditions which provide some interesting insights. Generally, families with children with a chronic respiratory disease were inevitably more cautious and fearful of contracting COVID-19 (Di Cicco et al., 2021). This resulted in children living within stringent social isolation restrictions, some governmental, some family imposed, for extended periods of time even after lockdowns were lifted. In many instances, social isolation extended to avoidance of medical appointments, even during exacerbations or medical emergency, for fear of visiting facilities where COVID-19 may have been present (Di Cicco et al., 2021; Lazzerini et al., 2020). Common reasons for strict isolation included fear of COVID-19 and how this would impact their child's health if they became unwell, issues associated with mask wearing, and stigmatisation associated with coughing or sniffing in public, common respiratory symptoms experienced in this population especially during exercise (Ferraro et al., 2022; McLoone et al., 2022; Taheri et al., 2022). The long-term effects of these isolation measures is unknown, but it is speculated that children with chronic respiratory conditions who relied on physical activity as part of their disease management control prior to the pandemic, could have poorer health outcomes following two years of lockdown mandates (Khare et al., 2022). Future research, could use the findings from this study, completed mid pandemic in 2021, as a baseline for measuring the long-term effects COVID-19 lockdowns and mandates had on MVPA achievement in children with bronchiectasis.

3.3.3.1 Clinical experience of the Kidz First bronchiectasis MDT clinic

The following section is based on the anecdotal experience of the MDT specialists, inclusive of a senior paediatric physiotherapist with expertise in respiratory care, at Kidz First

bronchiectasis MDT clinic and inpatient services at Kidz First Hospital during the COVID-19 pandemic.

In the Kidz First bronchiectasis MDT clinic, children and their family/whānau reported a reduction in physical activity during lockdown (A. Ainsworth, personal communication August 29th, 2021). Families reported being too frightened to leave their homes, in fear of contracting COVID-19 from their neighbour or someone at the local shop (Choi et al., 2021; Howie, 2021; Su'a-Tavila et al., 2020). Children were kept home, away from school, sports, recreational areas, community groups and hospital/clinic appointments. Due to limited space and resources at home, many children simply remained inactive for prolonged periods of time during the day. Some families reported venturing out for walks during initial lockdowns, but this reduced as lockdowns became more frequent and fear increased with local outbreaks. Children with bronchiectasis living in Counties Manukau were particularly slow to return to school after each lockdown (S. Quinn, at Wiri Central School, and V. Leru, at Ferguson Intermediate School, personal communication November 24th, 2021). This attitude persisted despite governmental and medical recommendations to return (Russell et al., 2022) and resulted in many children with bronchiectasis being absent from school between August 2020 and April 2022. By the latter half of 2022, children slowly returned to school, but attendance remained infrequent, and a small cohort have yet to return (Kidz First bronchiectasis MDT clinic meeting, personal communication December 12th, 2021).

The consequences of the COVID-19, and its associated lockdowns, became apparent in the Kidz First bronchiectasis MDT clinic towards the end of 2021. Anecdotal experience suggests that very few children with bronchiectasis who contracted COVID-19 had more than mild symptoms, with few children requiring short hospital admissions (Kidz First bronchiectasis MDT clinic meeting, personal communication December 12th, 2021). The most frequent COVID-19 associated complaints were issues around physical activity participation, with many children reporting they had not returned to pre COVID-19 physical activities. Interestingly, children showed little indication of returning to physical activity in the future. Those that had returned often complained of breathing and musculoskeletal issues and the inability to participate in physical activity, at the same level as they did before the pandemic. Common symptoms include increased breathlessness, fear of breathlessness, increased coughing with exertion and musculoskeletal injuries such as sprains and muscle aches (Kidz First bronchiectasis MDT clinic meeting, personal communication December 12th, 2021). As a result, many children withdrew or avoided physical activities that required higher intensities such as MVPA, further adding to the perpetual cycle of inactivity and its consequential acute and chronic side effects: shortness of breath, pain, obesity, poor quality of life (World Health Organization, 2020a).

3.4 Impact of COVID-19 on the current study

This study was significantly impacted by COVID-19 and its concomitant lockdowns, restrictions, and mandates; refer to Appendix I. The study required children to engage in their usual physical activities within their community, but constant fluctuation between Alert Levels Two to Four and Protection Framework Red, prevented recruitment. Between April 2020 and March 2022 multiple attempts were made to recruit, with only one successful period of recruitment achieved between May 3rd and August 17th 2021, before being prematurely stopped by another regional lockdown on August 18th 2021. By March 2022, while still under restrictions following the August 2021 outbreak, the study was deemed no longer feasible to continue with then or in the immediate/near future due to the growing list of logistical barriers and confounding factors that would influence future datasets.

3.4.1 Barriers preventing recruitment

There were five key barriers that prevented study recruitment during the COVID-19 pandemic, and subsequently resulted in the early termination of the study.

One, following each lockdown fewer children returned to school with attendance rates still low at the beginning of 2022 (Fa'afiu, 2021; Franks & Halpin, 2021; Gerritsen, 2022). The study required children to be engaging in their usual physical activities, so they were unable to be recruited.

Two, timing of recruitment became more difficult following each lockdown. Careful consideration and census from children with bronchiectasis, their family/whānau and schools was sought to ensure they were in a position to participate in research. As a result, only one suitable recruitment period was achieved between May 2021 and August 2021 before another lockdown prematurely stopped this. By February 2022, during Auckland's longest and most severe lockdown, many families in Counties Manukau were struggling to achieve their basic day-to-day needs (Brunton, 2021; Heather & Jones, 2020; Ministry of Health, 2021c; Tokalau, 2021, 2022). Access to income, food, housing, and health services became the priority, with many older children leaving school to work so they could supplement their parent's income (Fagaiava-Muller, 2020; Latif, 2021; One News, 2020). Based on family/whānau feedback from the Kidz First bronchiectasis clinic and general consensus of the Counties Manukau community, many families were no longer able to participate in additional tasks, such as research, that did not serve the family's immediate needs.

Three, recruitment of the Control group was unable to proceed following the August 2021 outbreak as the two recruited schools needed to withdraw from the study, stating reasons related to focusing on students' health and wellbeing. When schools did re-open in 2022, strict school policies remained in place stipulating a no visitor/parent presence policy on school grounds; only teachers and students allowed (Independent Schools of New Zealand, 2022; Ministry of Education, 2022a). These rules prevented research staff from recruiting to the study even if schools were able to participate.

Four, during the pandemic all health workers were re-prioritised to essential services only. This included the lead researchers who had been allocated 20 hours (0.5 FTE) a week to conduct research specifically for the current study, being reassigned to inpatient clinical work to meet the fluctuating demands of Kidz First Hospital. The absence of the lead researcher prevented recruitment from progressing.

Finally, by 2022 the study was entering its third year of recruitment and Counties' Manukau was in Protection Framework Red and experiencing a new COVID-19 variant (Omicron) outbreak. The ongoing uncertainty of COVID-19 and the increasing number of barriers preventing recruitment made the study unfeasible to continue with.

3.4.2 Potential confounding factors

Had the above logistical barriers been successfully overcome and a second recruitment period achieved, the study would have required a much larger sample size to account for the potential confounding factors that would have occurred with recruiting participants some nine to twelve months apart.

As stated above, children have become less physically active as the pandemic has progressed, therefore any additional participants recruited, could have had significant differences in baseline measures, such as BMI or spirometry. Furthermore, MVPA results could be influenced by the difference in COVID-19 experience, duration in lockdown or having time off school. These issues would not have been localised to just children with bronchiectasis, but also the healthy control group, meaning they would no longer represent the 'normal' population for when the study first started.

3.5 Summary of COVID-19 on physical activity

The impact of COVID-19 has been significant, affecting every individual and country in a myriad of ways, and while normality is slowly returning in some countries, the long-term effects of the

COVID-19 pandemic and reduced physical activity are predicted to continue for some time yet; and in some instances may remain indefinitely. For this study, the prolonged and fluctuating lockdowns and mandates imposed by the New Zealand government to control COVID-19, became a significant barrier which made data collection and, by association, continuation of the study not viable. At the time the study was suspended indefinitely, 18 participants in the Bronchiectasis group, and 13 in the Control group had been recruited.

Chapter 4 Research Methods

This chapter outlines the research methods used, from planning and design through to statistical analysis. Firstly, the study design and the results of cultural consultation are described. The methods used for recruitment, data collection and statistical analyses are then described as per the original study outline, with notations highlighting when modifications to the methods were required due to the COVID-19 pandemic.

For clarity, Chapters Four, Five and Six will define participant groups as:

- Bronchiectasis group = participants with bronchiectasis
- Control group = healthy matched controls

4.1 Study design

To answer the study's research questions, a quantitative cross-sectional observational study was used. This study design has been successfully used in similar physical activity studies across a wide array of pathologies and countries, including the only published child bronchiectasis study (Joschtel et al., 2019). The study used a systematic approach to recruit to the Bronchiectasis group, using clinical lists of all potential participants in Kidz First and Starship, and convenient sampling, to recruit the Control group with matching variables. To reduce confounding variables that may influence physical activity outcomes, participants were matched for age, gender, and BMI (Bauman et al., 2002). The inclusion of the Control group, rather than simply comparing against national and international datasets, was used to provide a local comparison of physical activity levels within Counties Manukau during the same period thus providing a more accurate picture of current physical activity levels.

4.1.1 Inclusion criteria

Eligible participants needed to meet the following inclusion criteria:

- Aged between 7 to 12 years old.
- Reside in Counties Manukau District Health Board region, as per map in Appendix B.
- Have an appropriate level of English language to provide written and informed consent, both participant and legal guardian.

In addition to above three criteria, participants in the Bronchiectasis group also required:

- A definitive diagnosis bronchiectasis, unrelated to cystic fibrosis, on HRCT, as per the Thoracic Society of Australia and New Zealand guidelines (Chang et al., 2015); see section 2.2.1.
- Spirometry completed within six months of the study enrolment date; see section 2.2.2.
- No acute bronchiectasis exacerbations for at least 30 days before starting the study as defined by Kapur et al. (2012); refer to Appendix C.

4.1.2 Exclusion criteria

Participants were excluded if they had a physical or cognitive impairment that influenced participation in the study such as:

- Acute or chronic musculoskeletal conditions, e.g., muscle or ligament sprain, fracture, Severs disease, Osgood-Schlatters, juvenile arthritis, or chronic fatigue.
- Neurodevelopmental conditions, e.g., Trisomy 21, cerebral palsy, global developmental delay, chromosomal deletion syndromes such as cri-du-chat.
- Other lung diseases, e.g., Cystic fibrosis, chronic suppurative lung disease, bronchiolitis obliterans or poorly controlled asthma.

Due to the concomitant link between asthma and bronchiectasis (Crimi et al., 2020; Munro et al., 2011), the current study was unable to simply exclude all potential participants with asthma without forgoing a large volume of the total population with bronchiectasis. Therefore, potential participants with asthma were only excluded if:

- Asthma was the participant's primary lung disease i.e., asthma with mild and non-symptomatic bronchiectasis in one lobe.
- Partly or uncontrolled asthma as per the modified Global Initiative for Asthma (GINA) assessment for asthma symptoms in children 5 - 11 years (McNamara et al., 2020); refer to Appendix J.

4.2 Ethical considerations and participant recruitment

4.2.1 Ethics approval

Ethical approval was obtained from the Health and Disability Ethics Committee (reference: 20/CEN/88) (Appendix K). Localities' approval was obtained by the Counties Manukau Research Committee (reference: 1213) (Appendix L) and included approval from the Kidz First

Research Committee and Counties Manukau's Māori Research Committee. Locality approval was inclusive of recruitment from both Counties Manukau and Starship sites. As a result of the COVID-19 pandemic, several research extensions and study variations were required and approved between April 2020 and February 2022, (Appendix M and N).

4.2.2 Children as research participants

Special consideration was undertaken when working child participants. This included age appropriate information forms, assent forms, opportunities to ask questions and support from legal guardians and the research team to provide informed consent. Research processes for this study were guided by the ethical principles outlined by the National Ethics Advisory Committee (2019).

4.2.3 Recruitment procedures

4.2.3.1 Planned procedures

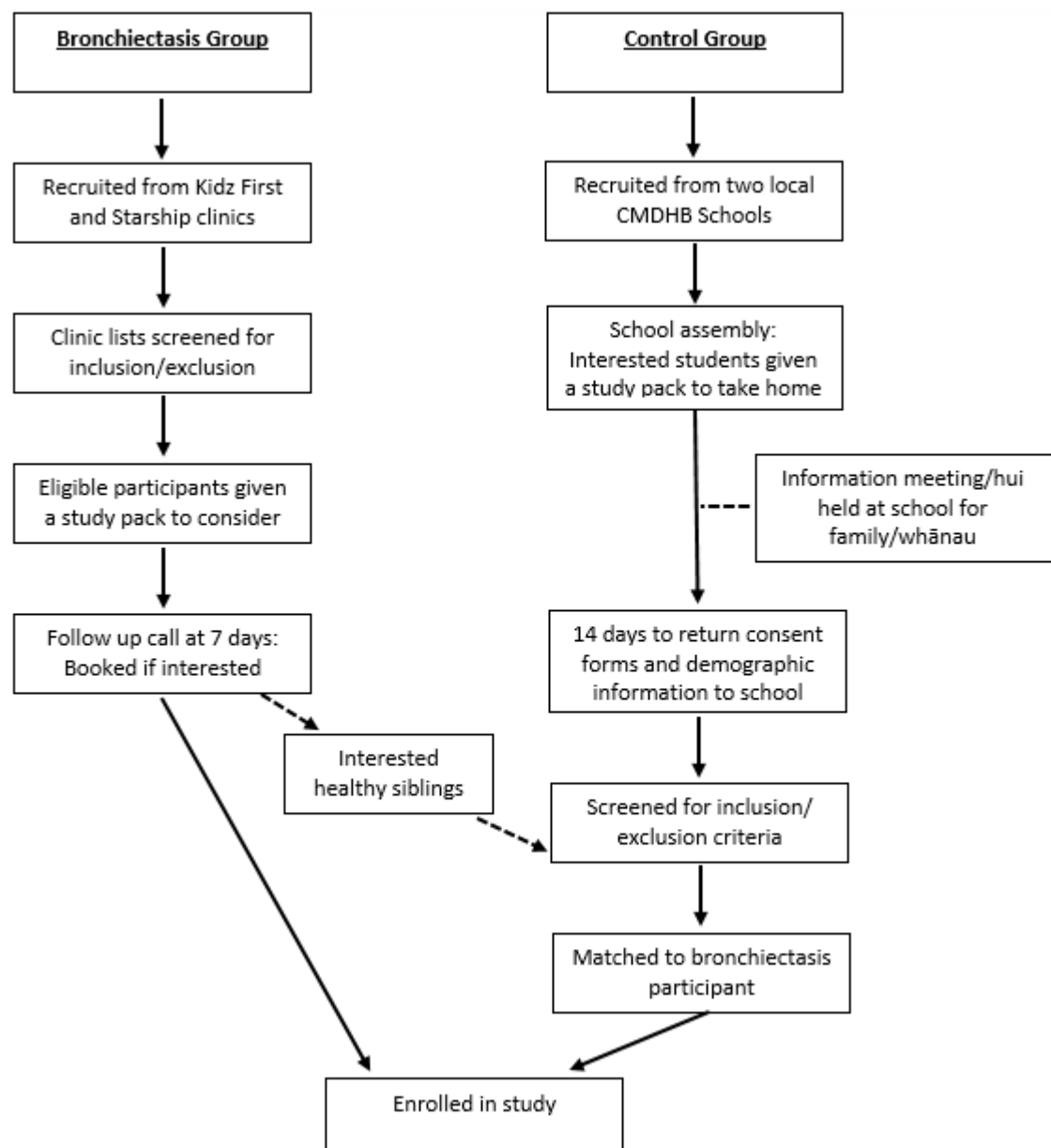
Participant groups would be recruited separately using two different pathways, see Figure 3. Participants within the Bronchiectasis group were recruited from one of three bronchiectasis clinics that care for Counties Manukau children: Kidz First bronchiectasis MDT clinic, Kidz First physiotherapy respiratory clinic, and Starship's bronchiectasis MDT clinic. The inclusion of all three clinics ensured all eligible children were provided equal opportunity to participate in the study regardless of their primary care team. To promote family/whānau participation, healthy siblings of bronchiectasis participants were also invited to participate in the study if interested and if they met the inclusion/exclusion criteria.

The Control group would be recruited from two local schools within the Counties Manukau region that already had a working relationship with the lead researcher and the bronchiectasis MDT clinic. The inclusion of these specific schools was expected to provide a more homogeneous baseline sample due to the influence local community and socioeconomic determinants can play on overall health and the development of bronchiectasis (Singleton et al., 2014; Telfar Barnard & Zhang, 2018). To ensure baseline comparability between groups, and reduce potential confounding factors at the analysis stage, the Control group would be matched to the Bronchiectasis group for age, gender and BMI prior to study enrolment using a 2:1 model. To achieve matching, small groups of approximately 20 healthy controls would be recruited at timed intervals using convenience sampling. To avoid introducing sibling fixed effects such as the effects of pre-natal smoking or alcohol consumption and additional potential confounders like, genetic endowments, or environmental influence, siblings would not be matched together (Kim & Tong, 2020).

All eligible study participants were provided a study pack to take home and discuss with family/whānau. Study packs included a study brochure, caregiver information sheet/consent form, and an age-appropriate participant information sheet/assent form (Appendix O). Due to the slight variations in recruitment procedures, potential Control group participants would also receive a participant demographic form and information meeting/hui invitation in their study pack (Appendix P).

Figure 3

Planned participant recruitment pathways



4.2.3.2 Achieved procedures

COVID-19 significantly impacted the study's ability to recruit participants (Appendix I). Recruitment was initially scheduled to start April 30th 2020, but this was cancelled due to New Zealand's first Level Four COVID-19 lockdown. Interruptions continued throughout the year, especially for Counties Manukau, the epicentre of several outbreaks (Forbes, 2022; Ministry of Health, 2022d). On May 3rd 2021, during Alert Level One, recruitment commenced. Recruitment into the Bronchiectasis group occurred first, and a few healthy siblings were recruited to the Control group. Two schools were consented to start recruitment August 24th 2021 for the Control group. Recruitment progressed with an estimated completion date of September 30th 2021, the end of school Term Three, but another national lockdown on August 18th 2021 prematurely stopped recruitment and led both schools to withdraw from the study, stating reasons related to their students' health and wellbeing. The study was unable to restart due to restrictions in Auckland that carried through to 2022.

By February 2022, during another lockdown change and a new COVID-19 variant spreading in Counties Manukau, the study was reviewed by the lead researcher and supervisors, and deemed unfeasible to continue, due to current and future logistical barriers and confounding factors that would negatively impact on any future data collected; refer to section 3.4.

4.2.4 Avoiding conflict of interest

Most participants in the Bronchiectasis group were under the long-term care of the lead researcher. To negate potential coercion, fourth year physiotherapy students, acting as research assistants during their student placement, recruited participants. When a student was not available, a member of the wider bronchiectasis team undertook this role. Recruitment processes were standardised and included initial contact in clinic, follow up phone call/text/email and study session bookings (Appendix Q). Participants' first contact with the lead researcher was at the time of enrolment and initial consent was obtained.

The lead researcher also had a working relationship with the two schools that had consented to participate in the study as the Control group. In both instances, the researchers' relationship was with the Special Education Needs Co-Ordinator (SENCO) therefore to negate potential coercion, the lead researcher met with the Head of School to discuss the study and the associated requirements of the school. Discussions included establishing clear ground rules between the researcher and hospital outreach roles to ensure professional boundaries were maintained (Appendix R).

4.2.5 Reducing health inequity and maximising recruitment and engagement

Health and socioeconomic inequities can prevent Māori and Pasifika children from participating in research (Franke et al., 2022). To help overcome this, the lead researcher sought consultation from Counties Manukau's Māori Research Review Committee and Pacific Advisory Committee to help design a culturally safe, meaningful, and accessible study as per the Principles of the Te Tiriti O Waitangi/Treaty of Waitangi and Māori Health Committee's guidelines (Came, 2013; Health Research Council of New Zealand, 2010; Hudson & Russell, 2009; Ministry of Health, 2020). To understand the specific needs and challenges of this population, Māori and Pacific leaders attended the Kidz First bronchiectasis MDT clinic, to meet the wider MDT, children with bronchiectasis and their families/whānau. Identified barriers surrounding study recruitment and engagement, were similar to previous research in this population (Franke et al., 2022; Jepsen et al., 2018) and included: study location, parking concerns, loss of income from time off work, time away from school and financial hardship.

To reduce participation burden on the family/whānau and allow equal access for all children, the study was undertaken in Counties Manukau facilities. Participants were required to complete two sessions; refer to section 4.4. For most participants, sessions were scheduled during classroom hours with the support of school staff, to reduce time out of school and off work. For the Bronchiectasis group, who required their first session at Kidz First Hospital or SuperClinic (Counties Manukau's outpatient centre), pre-paid parking vouchers were provided to negate financial barriers and a wide range of appointment times offered, including after hours and weekends, to best fit the family/whānau schedules. When appointments were not attended, participants were contacted without prejudice by the research assistant and provided the opportunity to rebook. In exceptional circumstances where a child was unable to access Kidz First, SuperClinic or school due to financial hardship, the lead researcher completed a home visit to facilitate study completion.

Community meetings/huis were identified as a necessary platform for the Control group to have the opportunity to discuss the study with the research team. Two meetings/huis for each school were planned, one before enrolment to introduce and discuss the study, and one following the study's completion to share the results. To increase accessibility, meetings/huis were scheduled at the end of the school day and led by a known school leader. The aim was to create a safe place for sharing knowledge in a culturally appropriate manner, which included traditional greetings, prayer/karakia and a koha of healthy food/kai to share. Due to COVID-19 pandemic, recruitment was forced to stop before community meetings/huis took place.

4.2.6 Mitigating risk

There were minimal risks involved with participating in the study due to its observational design. Skin irritation or friction from the vinyl wrist strap of the accelerometer was identified as a potential risk. To mitigate irritation, participants were shown how to apply, wear and remove the accelerometer safely as well as how to manage skin irritation if it occurred. A supporting handout was provided (Appendix S).

Potential safety risks to researchers during home visiting was negated through adherence to the study's offsite safety protocol (Appendix T), based on Counties Manukau's community/home based visiting policy (Counties Manukau Health, 2013).

4.3 Outcome measures

4.3.1 Baseline demographic and disease severity markers

Baseline demographic markers for age, gender, ethnicity, non-dominant hand, height, weight, BMI, and socioeconomic deprivation were collected for all participants (Appendix U). Demographic data was obtained to inform participant profiles of Counties Manukau children and additionally ensure accurate participant matching during analysis. Height (cm) was measured to the nearest centimetre using a SECA portable stadiometer (Capes Medical, New Zealand) with shoes removed. Weight (kg) was measured to the nearest 0.1kg on calibrated Salter scales (Capes Medical, New Zealand) with shoes and jackets removed. BMI was calculated using the formula $BMI = \text{kgs} / (\text{m}^2)$ and then grouped into categories: underweight $BMI \leq 18.4$; healthy $BMI 18.5 - 24.9$; overweight $BMI 25.0 - 29.9$; obese $BMI \geq 30$ (New Zealand Guidelines Group, 2012). Socioeconomic deprivation was measured using the 2018 NZDep Index, an area-based measure for population deprivation based on the national census (Atkinson et al., 2019) (Refer to Glossary).

For the Bronchiectasis group, additional baseline information was collected as disease severity markers, specifically aetiology, age at time of diagnosis, number of affected lobes (1 - 5), spirometry, oxygen or non-invasive ventilation use, and total number of antibiotics courses and hospital admissions in the last year. Aetiology was identified in the participant's clinic notes, and in cases where aetiology was unable to be classified, they were grouped as idiopathic (Goyal et al., 2016). If a participant had more than one HRCT, the original report was used for establishing the age of diagnosis and the most recent report was used for calculating the number of lobes affected by bronchiectasis. If the HRCT report was unclear, or the exact number of lobes with bronchiectasis was not recorded or unusual terminology was used,

original scans were reviewed by the Respiratory Fellow aligned with the Kidz First bronchiectasis MDT clinic, who had experience with HRCT interpretation. Spirometry was completed by qualified spirometry technicians at either Counties Manukau or Starship Hospital on an EasyOne Spirometer (NDD Medical Technologies, USA) using the American Thoracic Society and European Respiratory Society Task Force Guidelines for acceptable and repeatable results (Graham et al., 2019). Spirometry Z scores and predicted percentages were recorded for forced expiratory volume in one second (FEV1% predicted), forced vital capacity (FVC) and FEV1/FVC ratios. For analysis, FEV1% predicted was grouped into severity categories: normal $\geq 100\%$; mild 80 - 99%; moderate 50 - 79%; severe $\leq 49\%$ (Jat, 2013). Standard and COVID-specific infection control measures were adhered to in keeping with Counties Manukau's spirometry policy. Total number of antibiotics courses and hospital admissions were accessed via the hospital database (Clinical Portal) and confirmed with the participant and their legal guardian.

4.3.2 Primary outcome measure

The primary outcome measure evaluated in this study was physical activity; in particular, the number of minutes participants spent each day, completing MVPA. As discussed in Chapter Two, this study used the ActiGraph wGT3X+ accelerometer (ActiGraph LLC, Pensacola, FL, USA), recognised as a reliable and valid accelerometer for recording physical activity levels in children (Arvidsson et al., 2019; Migueles et al., 2017; Montoye et al., 2018). The accelerometer parameters, as described below, were selected based on the literature review findings and then tailored to meet the specific needs of the study and its participants as recommended by Arvidsson et al., (2019) and Mathews et al., (2012)

4.3.2.1 Accelerometer placement

Based on the literature review in Chapter Two, anticipated wear compliance, and targeted outcome measure (MVPA), non-dominant wrist placement was selected using hospital bands to attach the accelerometer. The non-dominant wrist was selected to reduce misclassification of upper extremity movement during sedentary or light physical activity tasks such as writing, colouring, playing on devices, as recommended by Chandler et al. (2018). Hospital bands were selected to promote 24-hour wear compliance.

4.3.2.2 Initialisation of accelerometer

Accelerometers were initialised using the ActiLife software (v6.11.9, ActiGraph, Pensacola, FL, USA). All three accelerometer axes (x, y, z) were activated, and sampling rate was set at 30 Hertz to detect lighter physical activity movements typically completed by children (Arvidsson et al., 2019). Epoch lengths were set as five-second intervals, as pre-determined by cut-points

referenced by Chandler et al. (2016), that were used to categorise accelerations into intensity categories. Accelerometers were set to record at 0000 hours on Day One. No end recording time was set to ensure the accelerometer kept recording until it was removed (Matthews et al., 2012). Refer to Appendix V for the standardised initialisation procedure used for setting up the accelerometer.

4.3.2.3 Application and wear instructions

The accelerometer was applied to each participant's non-dominant wrist using a single-use vinyl strap; see Figure 4. Participants were asked to wear the accelerometer 24-hours a day, for seven consecutive days (Bergman, 2018; Matthews et al., 2012), only removing for prolonged water submersion activities, in the bath or swimming as per manufacture instructions (Actigraph, 2021). If the accelerometer came off for any reason, participants were asked to put it back on as soon as they could do so safely. Each participant was provided with three replacement straps, letters for their school/coach(s) outlining the study requirements (Appendix W) and an accelerometer instruction handout with contact details (Appendix S).

Figure 4

Accelerometer application



4.3.2.4 Accelerometer data preparation

At the end of the study, data was downloaded and processed on the ActiLife software (v6.11.9, ActiGraph, Pensacola, FL, USA). Activity counts recorded by the accelerometer were classified into intensity subgroups using the protocol cited by Chandler et al. (2016). The vector magnitude (square root of the sum of three axes) cut-points were used to better capture the dynamic movement patterns of children, refer to Table 3.

Table 3

Chandler et al's. (2016) Vector magnitude cut-points for classifying physical activity intensity

	Intensity Category	Counts per 5 seconds
Vector magnitude	Sedentary (≤ 1.5 METs)	< 305
	Light (1.5 – 3 METs)	306 – 817
	Moderate (3 – 6 METs)	818 – 1968
	Vigorous (≥ 6 METs)	1969 +
	MVPA (≥ 3 METs)	818 +

Note. METs = metabolic equivalent of task; MVPA = moderate to vigorous physical activity.

Non-wear time was defined as per the algorithm cited by Choi et al. (2011) with default settings: 90 or more consecutive minutes of zero counts, with an allowance of two minutes for sedentary activity. The protocol cited by Choi et al. (2011), was chosen as it was available on the ActiLife software (v6.11.9, ActiGraph, Pensacola, FL, USA) programme and had been applied successfully in the child bronchiectasis study by Joschtel et al. (2019). Daily wear time was calculated by subtracting non-wear time from the total number of minutes recorded that day (Choi et al., 2011). As per recommendations, a valid day was set at a minimum of ten hours (600 minutes) wear time (Arvidsson et al., 2019; Matthews et al., 2012). Therefore, to be included in the final analyses, participants needed to have accelerometer data for at least three valid days (10 hours), including at least one weekend day.

4.3.3 Secondary outcome measure

As identified in Chapter Two, the study used the Physical Activity Questionnaire for Children (PAQ-C) (Appendix E), recognised as a reliable and valid questionnaire for measuring MVPA, activity mode and the time of day/week children participated in physical activity (Kowalski et al., 2004; Wang et al., 2016). As in the study by Gobbi et al. (2016), additional sports were added to Item One to better represent the studied population. For this study, athletics, rugby, rugby league, touch rugby, netball, cricket, tennis, and gymnastics were added. An additional question was, Item Eleven, "Did you remove the accelerometer during the study period?" This question was not included in PAQ-C scoring, only recorded under additional comments to assist wear compliance calculations during accelerometer data analysis. The PAQ-C was scored by the lead researcher using the PAQ-C manual (Kowalski et al., 2004). A cut off total activity score of 2.75 was used to measure MVPA achievement during the recall period as derived by Benítez-Porres et al. (2016).

4.4 Study procedures

Each participant was required to complete two sessions, eight days apart; refer to Table 4. All participants underwent the same standardised pathway (Appendix X), except for Session One where the location varied between groups. The Bronchiectasis group completed Session One at Kidz First Hospital or the SuperClinic to allow baseline respiratory measure i.e., spirometry, while the Control group completed Session One at school.

Table 4

Study procedures – Day Zero to Eight

	Location	Procedures
Day Zero	Bronchiectasis group = Kidz First Hospital or SuperClinic Control group = School	<u>Session One</u> - Consent / assent forms completed - Baseline measures completed - Accelerometers initialised and applied - Supporting handouts provided - Day 8 follow-up organised
Day One	Community	Accelerometer - Starts recording at 0000 hours (automatic)
Day Three or Four	Electronic	Study message sent to participant - Check in message
Day Seven	Electronic	Study message sent to participant - Collection time/day reminder
Day Eight	School Home if required	<u>Session Two</u> - Accelerometer collected: - Recording stopped - Downloaded into software - PAQ-C completed - Thank you card and koha given

Note. PAQ-C = Physical Activity Questionnaire for Children.

4.4.1 Day Zero

Day Zero, Session One, represented the beginning of active participation. Following consent/assent procedures, baseline measures were taken, and the accelerometer was initialised and fitted as per section 4.3.2. Consent and assent forms were read through by the lead researcher with the participant and their legal guardian. Questions were encouraged and additional time was offered to the participant if they wished to discuss the study further with their legal guardian. Accelerometers were set to start recording Day One at 0000 hours. Day Zero, day of application, was not recorded as participants received their accelerometers at various times throughout the day. Day Zero also served as an adaption period for the participants to become comfortable with the accelerometer and avoid initial surges of activity

post application (Matthews et al., 2012). Lastly, a follow-up time and location were organised with the participant and their school for accelerometer collection on Day Eight.

4.4.2 Day One to Seven

To promote compliance, participating families received two study reminder messages via their preferred method of text, phone, or email. On Day Three or Four, weekday dependent, timed messages reminded the participant to keep wearing the accelerometer and asked if they had any concerns. On Day Seven, messages reminded participants to keep wearing their accelerometer, and confirmed the collection time and location for the following day.

4.4.3 Day Eight

Day Eight, Session Two, marked the end of active participation. The lead researcher or research assistant removed the accelerometer and completed the PAQ-C with participants. Accelerometers were carefully cleaned using alcohol wipes and stored until data was downloaded. The PAQ-C was self-administered in a quiet space. Reading, writing and comprehension assistance were provided by the research team as required to facilitate questionnaire completion. Questionnaires and study packs were checked for completeness before the participant finished the study. A koha consisting of a \$10 Warehouse voucher and thank you card was provided in appreciation for their time and participation. A final thank-you message was also sent to the legal guardian marking the end of the study.

4.4.4 Privacy and data storage

The study upheld the data storage, governance and management policies as recommended by Counties Manukau's Research Office and New Zealand's Ethics Advisory Committee (National Ethics Advisory Committee, 2019). Each participant was assigned a unique research identification code to anonymise their data following collection. Data was entered into the study's spreadsheet using research identification codes and key-coding methods (Appendix Y). All participants' electronic data files were kept secure in password-protected files and original hardcopies were locked in an office cabinet, only accessible to the research team. When sent for data processing, participant data was encrypted and key coded with all identifiable data removed, before transferred via secure networks.

4.4.5 Blinding

To increase study rigour and reduce subconscious bias, the lead researcher, who continued to have a patient-therapist relationship with many of the participants, was blinded to participant data wherever possible. The lead researcher collected baseline measures and graded the PAQ-

C, but otherwise was blinded to the other outcome measures i.e., MVPA results. The research assistant was responsible for entering the data into the spreadsheet. Only when the study had finished and all participant data was entered, was the lead researcher able to view the coded result spreadsheet to undertake the statistical analysis.

4.5 Statistical analysis

As previously stated, the statistical analysis was adapted due to COVID-19 prematurely terminating recruitment and data collection. This subsection will first describe the original statistical analysis plan, and then the modified plan used to analyse results from the limited datasets that were available.

4.5.1 Original statistical plan

4.5.1.1 Sample size calculation

There is only one study (Joschtel et al., 2019) investigating physical activity levels in children with bronchiectasis, using similar methods as described in this study. For this study, sample size calculations were based on estimates from Joschtel et al., (2019) and other similar studies using children with other chronic illnesses (Aznar et al., 2014; Mackintosh et al., 2018; Melo et al., 2018; Voss et al., 2017; Zijlstra et al., 2017). Based on conservative estimates, assuming normality and equal variance, and at 95% confidence level, equivalent to Type I error 5%, with 80% power which is equivalent to a Type II error 20%, to detect ten minutes per day MVPA difference between the Bronchiectasis and Control group (one-sided test), 30 participants with bronchiectasis and 60 healthy matched controls, were required. P-values would be set at 0.05 or less to be considered statistically significant.

4.5.1.2 The original statistical analysis plan

Data would be analysed using IBM SPSS for windows. Descriptive statistics would have been presented for all patient demographics, PAQ-C scores, and outcome variables. Comparison of MVPA minutes would be completed using generalised linear mixed models, with random effects for healthy matches, with fitting link and distribution. Covariates including age, gender, body mass index, ethnicity, would be adjusted for, if found significant, creating stepwise model building. Logistic regression with random effects would be used to test if the Bronchiectasis group met physical activity recommendations at the same level as the Control group. Subgroup analysis would also use generalised linear models to test if demographic or disease severity markers were associated with the number of MVPA minutes recorded.

4.5.2 Modified statistical plan adapting to the final samples

4.5.2.1 Limited sample size

Following cessation of the study in February 2022, the desired sample size had not been achieved, with just 18 of 30 participants recruited to the Bronchiectasis group, and 13 of the 60 participants to the Control group. Following review of the available datasets, with the biostatistician and supervision team, it was agreed that a modified analysis, albeit descriptive due to insufficient power, could be undertaken and provide valuable results to the research field.

4.5.2.2 Modified statistical analysis plan

The modified statistical plan was conducted using SAS version 9.4 (SAS Institute Inc., NC, USA) and included the descriptive analyses and part of the original planned inferential analysis. Descriptive analyses were presented for patient demographics and outcome variables (MVPA minutes, PAQ-C scores). Patient demographics and outcomes were also presented by each weekday. Inferential analyses included binary analysis using ANOVA and Kruskal Wallis for continuous variables, and Chi square test for categorical variables. Generalised linear mixed model was used to compare MVPA minutes for the Bronchiectasis and Control group and adjusted for weekday, and interaction of group and weekday. The generalised linear mixed models with random effects for the Control group, were fitted with Gaussian distribution. Logistic regression and subgroup analysis were not conducted due to the smaller samples. Pearson and Spearman correlation coefficients were used to evaluate the associations between MVPA and continuous variables (i.e., BMI, NZDep Index). Cumulative density plots were used to visualize the empirical distribution of MVPA by gender. Pearson and Spearman regression correlation coefficient (r) < 0.34 indicates a weak association, 0.35 - 0.66 indicate a moderate association and > 0.67 indicates a strong association. P-values for all statistical tests were set at 0.05 or less, to be considered statistically significant.

4.6 Summary of methods

The COVID-19 pandemic significantly impacted recruitment and the study therefore was unable to achieve its desired sample size of 90 participants, consequently under powering the research and preventing the original statistical analysis to be completed. However, numerous steps were made to ensure the study still collected high quality data and the modified statistical analysis would provide valuable data and results that would contribute to the field of paediatric bronchiectasis research.

Chapter 5 Results

This chapter outlines the results of the study by answering the following research questions:

1. How physically active are children aged 7 to 12 years with bronchiectasis living in the Counties Manukau compared to healthy matched controls?
2. Do children with bronchiectasis achieve daily MVPA recommendations, as outlined by the WHO?
3. Is there an association between MVPA and demographic or disease severity markers in children with bronchiectasis?
4. What mode of physical activity are children with bronchiectasis engaging in? And when are they most likely to engage in these activities?

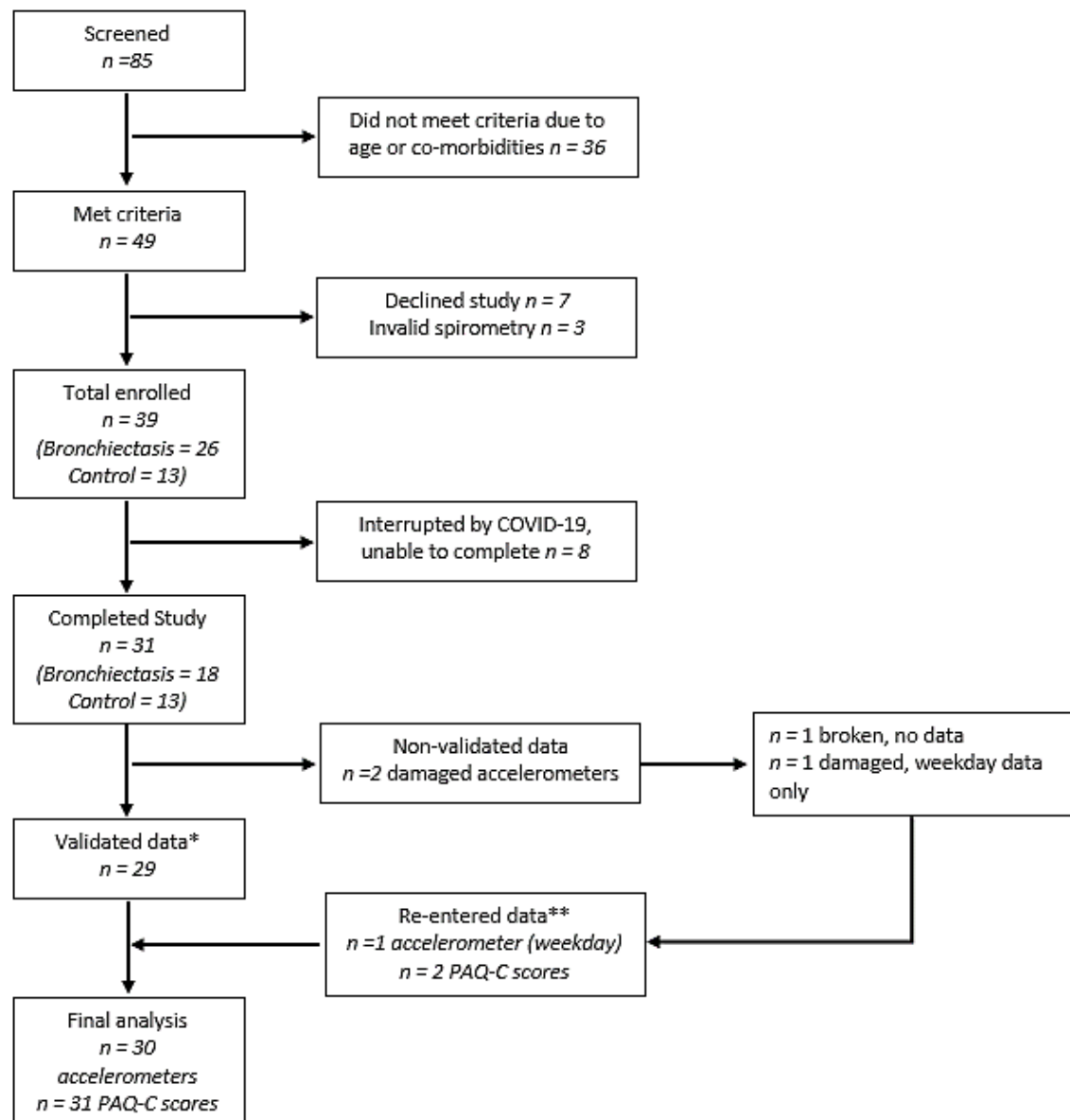
As previously outlined, the COVID-19 pandemic significantly affected the study's methods and by association the results. The study was unable to achieve its desired sample size and was consequently underpowered. As such, the results section is largely descriptive and illustrates trends that are clinically important for clinicians and researchers working in this field.

5.1 Recruitment

Recruitment took place between May 3rd 2021 and August 17th 2021 during Alert Level One restrictions. In total, 85 children were screened against the eligibility criteria. Forty-nine children met these criteria and were approached to participate in the study. Thirty-nine children consented, 26 in the Bronchiectasis group and 13 in the Control group. During active recruitment, the study was suddenly suspended on August 18th 2021, preventing eight participants with bronchiectasis from completing the study, and preventing recruitment starting at the consented schools on August 24th 2021 for the Control group. Due to ongoing COVID-19 influences, the study was terminated February 2022 with 18 participants in the Bronchiectasis group, and 13 participants in the Control group. Participants in the Control group only consisted of healthy siblings of bronchiectasis participants as the study was suspended before schools were able to participate. Figure 5 provides an overview of achieved recruitment procedures.

Figure 5

Flow diagram detailing achieved recruitment numbers



Note. PAQ-C = Physical Activity Questionnaire for Children; * Validated dataset = 600 minutes per day, for three or more days, including one weekend day; ** Partial datasets re-entered for analysis.

Twenty-nine participants (93.5%) provided the minimum requirement of three valid accelerometer monitoring days, including one valid weekend day. Two participants had invalid accelerometer datasets. The accelerometer of one participant from the Bronchiectasis group sustained water damage on Day Four and did not include weekend data. The accelerometer of one participant from the Control group was heavily damaged preventing any data retrieval. Thirty-one participants (100%) completed the PAQ-C. After consideration, all available data was included in the analysis with the justification that the additional data, even if considered invalid as per the study's original criteria, would not change the modified analysis and would be valuable to the new descriptive results.

5.2 Participant demographics

There were no significant differences in participant demographics between the Bronchiectasis and Control group, see Table 5.

Table 5
Participant demographics

	Bronchiectasis <i>n</i> = 18		Control <i>n</i> = 13		p-value
Age at enrolment					
Mean (SD)	10.8	(1.2)	10.1	(1.9)	0.221
Median (IQR)	10.7	(10.2-11.6)	10.4	(8.4-11.3)	
Gender					
Female	10	(55.6%)	3	(23.1%)	0.071
Male	8	(44.4%)	10	(76.9%)	
Ethnicity					
Asian	1	(5.6%)	0	(0)	0.369
European	0	(0)	0	(0)	
Indian	2	(11.1%)	0	(0)	
Māori	7	(38.9%)	4	(30.8%)	
Pasifika	8	(44.4%)	9	(69.2%)	
Body Mass Index (BMI)					
Mean (SD)	23.96	(7.8)	23.58	(5.6)	> 0.95 ‡
Median (IQR)	24.32	(19.1-26.4)	23.12	(19.0-28.6)	
BMI group					
< 18.4 (underweight)	3	(16.7%)	2	(15.4%)	0.462
18.5 - 24.9 (healthy)	7	(38.9%)	7	(53.8%)	
25.0 - 29.9 (overweight)	7	(38.9%)	2	(15.4%)	
30 > (obese)	1	(5.6%)	2	(15.4%)	
NZ Deprivation Index					
Mean (SD)	8.2	(2.1)	8.1	(2.3)	0.655 ‡
Median (IQR)	9	(6-10)	10	(5-10)	
NZ Dep group					
1-2	0	(0)	0	(0)	0.462
3-4	0	(0)	0	(0)	
5-6	5	(27.8%)	4	(30.7%)	
7-8	2	(11.1%)	0	(0)	
9-10	11	(61.1%)	9	(69.2%)	

Note. SD = standard deviation; IQR = interquartile range; BMI = body mass index; NZ = New Zealand.

Statistics: Data presented as mean (SD), median (IQR 25-75) or counts (%). P = value is calculated by ANOVA for numerical covariates or Kruskai Wallis test and chi-square test (‡) for categorical covariates.

The mean (standard deviation) age was 10.8 (1.2) years for the Bronchiectasis group and 10.1 (1.9) years for the Control group. Both groups predominantly consisted of participants from Māori and Pasifika ethnicities, living in communities with high deprivation level (NZDep Index 9 and 10). Mean BMI was within healthy limits for both groups.

Disease severity markers for the Bronchiectasis group are presented in Table 6. The Bronchiectasis group consisted of 18 participants, 60% of the originally intended sample size. Disease aetiology for all participants was reported as post infectious. The mean number of lobes affected with bronchiectasis was three, and the number of antibiotics courses was three for the twelve months prior to the study. One child was receiving prophylactic antibiotics before and during the study. Fifteen participants (83.3%) FEV1% predicted scores were classified as normal or mild impairment. Thirteen participants (72.2%) had no hospital admissions within the twelve months prior to the study.

Table 6

Disease severity markers for the Bronchiectasis group

Bronchiectasis <i>n</i> = 18		
Number of lobes with bronchiectasis		
Mean (SD)	3.1 ± 1.2	
Median (IQR)	3	(1-5)
FEV1% predicted (severity)		
≥ 100 % (normal)	10	(55.6 %)
80-99 % (mild)	5	(27.8 %)
50-79 % (moderate)	3	(16.7 %)
≤ 49 % (severe)	0	(0 %)
Antibiotics course per year		
Mean (SD)	3 ± 3.2	
Median (IQR)	2.5	(0-13)
Hospital admissions per year		
0	13	(72.2 %)
1	4	(22.2 %)
2	1	(5.6 %)

Note. FEV1 % = forced expiratory volume over one second percentage predicted; SD = standard deviation; IQR = interquartile range.

Statistics: Data presented as mean (SD), median (IQR 25-75) or counts (%).

5.3 Accelerometer results

5.3.1 MVPA achieved between groups

The mean (standard deviation) number of valid accelerometer monitoring days for the entire sample was 6.6 (1.1) days, with a daily wear time of 1332.7 (262) minutes. MVPA minutes completed each day, accounting for incomplete datasets, was 74.8 (27.5) minutes for the Bronchiectasis group and 100.8 (38.2) minutes for the Control group, see Table 7. Generalised linear mixed models demonstrated the Bronchiectasis group on average completed 31.63 ($p = 0.034$) less minutes of MVPA per day than the Control group, regardless of the day of the week.

Table 7

Total number of MVPA minutes completed per day for each group

	Bronchiectasis $n = 18$		Control $n = 13$	
Mean (SD)	74.8	(27.5)	100.8	(38.2)
Median (IQR)	74.8	(56.2–85.9)	86.9	(80.5–110.1)

Note. MVPA = Moderate to vigorous physical activity; SD = standard deviation; IQR = interquartile range.

Statistics: Data presented as mean (SD) or median (IQR 25-75).

Table 8 and Figure 6 display the mean (standard deviation) number of MVPA minutes completed by participants each day. When viewed by day, the Bronchiectasis group completed less MVPA minutes per day, for all days of the week, compared to the Control group. Both groups completed significantly more MVPA minutes on Monday ($p = 0.031$) and Tuesday ($p = 0.041$) but the overall trend of the Bronchiectasis group completing less MVPA minutes than the Control group remained. Significantly higher ($p = 0.002$) MVPA minutes were also evident during weekdays compared to weekend days. Generalised linear mixed models demonstrated a significant difference between the Bronchiectasis and Control group but a non-significant interaction ($p = 0.56$) between days of the week and MVPA minutes completed, indicating participants were more active on Monday, Tuesday, Wednesday, and Friday regardless of the group they belonged to.

Table 8

Total minutes of MVPA completed each day of the week

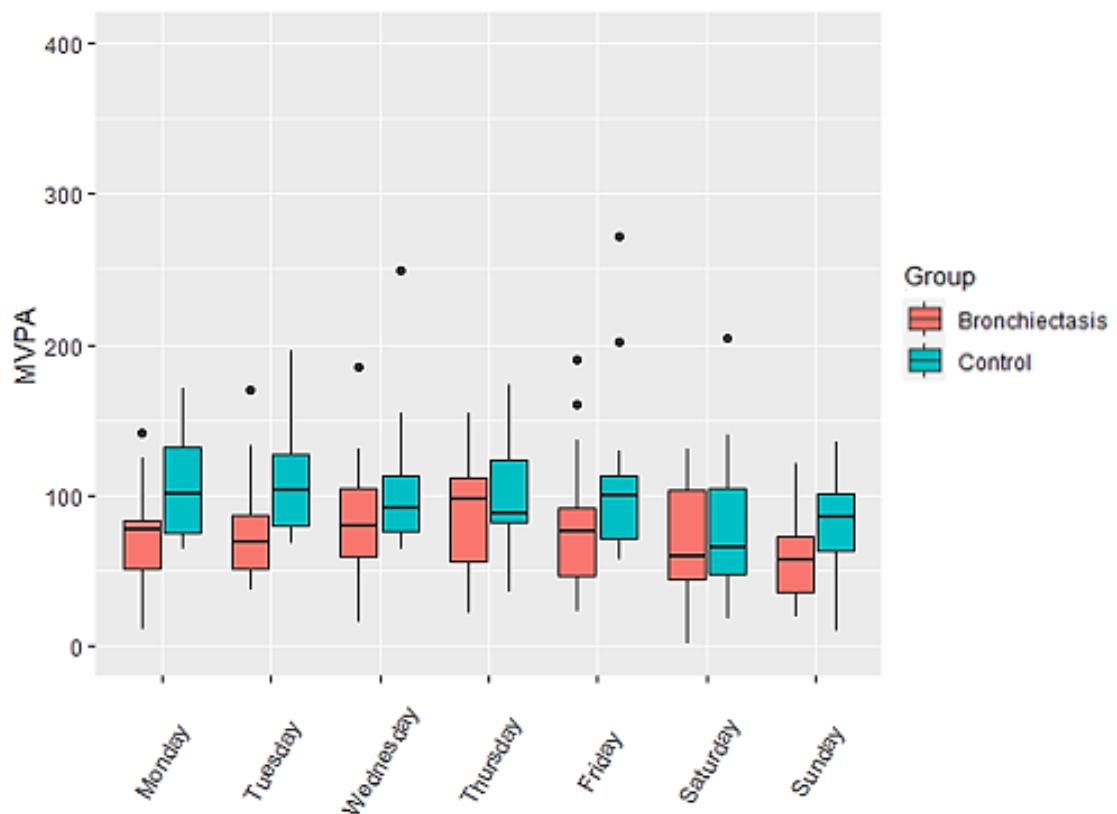
Day	Bronchiectasis		Control		P-value
Monday	72.36	(35.68)	104.61	(36.72)	0.031*
Tuesday	79.02	(35.79)	109.55	(38.09)	0.041*
Wednesday	79.37	(42.55)	108.87	(53.08)	0.111
Thursday	88.12	(37.3)	97.9	(41.23)	0.505
Friday	80.44	(44.66)	113.73	(62.91)	0.150
Saturday	67.01	(37.7)	83.5	(52.56)	0.333
Sunday	59.69	(29.81)	82.29	(38.4)	0.105

Note. MVPA = Moderate to vigorous physical activity.

Statistics: Data presented as mean (standard deviation); significant at $p < 0.05$ *

Figure 6

Box and Whisker Plot of MVPA completed each day of the week



Note. MVPA = Moderate to vigorous physical activity.

5.3.2 MVPA recommendations achieved between groups

On average, 62.3% of the Bronchiectasis group and 86.4% of the Control group achieved at least 60 minutes of daily MVPA across the week. Table 9 illustrates the number of participants each day that achieved daily MVPA recommendations. The mean (standard deviation) number

of days MVPA recommendations were achieved during the seven-day recording period was 4.2 (2.3) days for the Bronchiectasis group and 5.7 (1.4) days for the Control group. There were no statistical differences between groups for the percentage of participants that achieved 60 minutes of MVPA per day. However, the Bronchiectasis group consistently demonstrated a lower percentage of participants achieving daily MVPA recommendations per day, across different weekdays.

Table 9

Number of participants who achieved 60 minutes of MVPA per day

Day	Bronchiectasis		Control		P-value
Monday	n=10	(62%)	n=11	(100%)	0.054
Tuesday	n=12	(71%)	n=11	(100%)	0.125
Wednesday	n=13	(72%)	n=11	(100%)	0.126
Thursday	n=12	(67%)	n=10	(83%)	0.419
Friday	n=12	(67%)	n=11	(92%)	0.193
Saturday	n=8	(50%)	n=8	(80%)	0.218
Sunday	n=8	(47%)	n=6	(50%)	0.876

Note. MVPA = Moderate to vigorous physical activity.

Statistics: *n* = the number of participants who contribute accelerometer data for that day; P-value calculated using Fisher exact test, significant at < 0.05 *

5.3.3 Association between MVPA and demographic markers

Pearson and Spearman correlations analysis indicated there were weak to moderate associations between MVPA minutes and two demographic markers (BMI, NZDep Index,). Gender, age, and ethnicity were unable to be calculated within the correlation analyses due to the sample size being too small to make a conclusive statement for these tests.

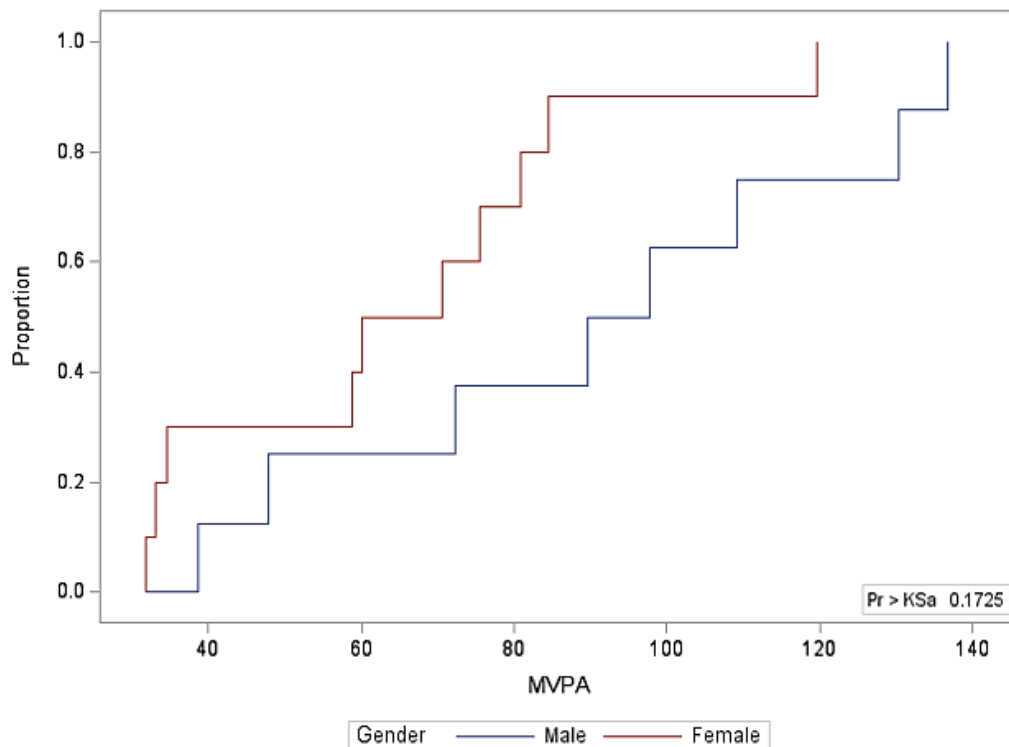
A weak negative association was found between BMI and MVPA minutes, regression correlation coefficient (*r*) ranged between -0.01 to -0.36 across different weekdays, but was not significant (*p* valued ranged 0.23 to 0.96 across different weekdays). Despite the weak associations, the negative sign of the correlation coefficient indicates a higher BMI associated with lower MVPA minutes.

A moderate negative association between NZDep Index and MVPA minutes, regression correlation coefficient (*r*) ranged between -0.01 to -0.45, but was not significant (*p* value ranged 0.04 to 0.85 across different weekdays). The negative sign of the moderate correlation coefficient indicates a higher NZDep Index associated with lower MVPA minutes.

There were no clear associations between gender and MVPA minutes. However empirical distribution of MVPA compared between boy and girl using a cumulative density graph demonstrated boys consistently completed more MVPA minutes than girls across different weekdays. Although p values were non-significant (p value ranged 0.17 to 0.56) across all days suggesting no gender associations, the study sample size was too small to make a conclusive statement for this test. Figure 7 provides an example of MVPA minutes between genders using a cumulative density graph.

Figure 7

Example of empirical distribution for MVPA and gender for one weekday



Note. MVPA = Moderate to vigorous physical activity.

5.3.4 Association between MVPA and disease severity markers

The mean MVPA level in participants with FEV1% predicted 50 - 79% were all lower than participants with FEV1% predicted $\geq 80\%$ across all weekdays, although all the hypothesis tests were not significant due to small sample size (Appendix Z).

The results between MVPA and other disease severity markers presented similar visible findings. Participants with three or more lobes affected with bronchiectasis or having a recent hospital admission recorded fewer MVPA minutes (Appendix Z), although none of the results tested significant using statistical tests likely due to the small sample size.

Despite these non-significant results, visualisation of trends within the analyses indicated fewer MVPA minutes were observed in children with an FEV1 less than 80% predicted, three or more lobes affected with bronchiectasis on HRCT, and a recent hospitalisation.

5.3.5 Non-recorded physical activity

Six participants in the Bronchiectasis group and seven participants in the Control group reported removing their device for more than 30 minutes. Table 10 lists the reasons accelerometers were not worn during recording period. The most common reasons were wrist band breakage and organised sports games (rugby and netball), that required accelerometer removal for safety regulations. Typically, accelerometers were removed for approximately 30 to 60 minutes per game, mostly on a Saturday, which likely included periods of MVPA. However, as participants did not record the length of time their accelerometer was removed, this information was not entered into the final analysis. As a result, it is unknown if this additional time would have affected overall MVPA trends seen between groups and weekdays versus weekends.

Table 10

List of reasons accelerometers were not worn during the recording period

Reason for Device Removal	Bronchiectasis	Control
Device wrist band broke	1x replaced after a few hours 2x not replaced for remainder of study	2x replaced after a few hours 1x not replaced for remainder of study
Sports practice or game (Due to game safety regulations)	1x participant, over 3 sports events, approximately 45 minutes duration each	4x participants, over 7 sports events, approximately 30-60 minutes duration each
Unknown reason or time	2	0

Note. Data extracted from Physical Activity Questionnaire–Child (PAQ-C) questionnaire, Item 11.

5.4 PAQ-C results

5.4.1 MVPA achievement

The PAQ-C was completed by all study participants. There was no significant difference ($p = 0.724$) in overall PAQ-C total activity scores between the Bronchiectasis and Control group. The mean PAQ-C total activity score for both the Bronchiectasis (2.59) and Control (2.68) groups, were below Benítez-Porres et al. (2016) cut-off value of 2.75 for MVPA achievement.

5.4.2 Physical activity mode

Participants in both groups engaged in a wide range of physical activities, with greater participation in leisure activities and non-organised school yard games compared to organised sports, refer to Table 11. While not formally recorded, many participants described playing backyard or playground basketball or touch rugby rather than with formal school or club teams outside of school hours. There were consistent patterns illustrating that the Bronchiectasis group had lower participation in team sports games compared to the Control group.

Table 11

Mode of Physical Activity Completed by Study Participants

Physical Activity Mode	Bronchiectasis <i>n</i> = 18 (%)		Control <i>n</i> = 13 (%)	
PAQ-C Total Activity Score	2.59	(0.68)	2.68	(0.72)
Leisure Activities				
Running / jogging	17	(94.4%)	13	(100%)
Walking	14	(77.8%)	7	(53.8%)
Tag	11	(61.1%)	9	(69.2%)
Skiping	7	(38.9%)	5	(38.5%)
Aerobics	6	(33.3%)	3	(23.1%)
Dancing	6	(33.3%)	7	(53.8%)
Bike ridding	2	(11.1%)	1	(7.7%)
Skating	2	(11.1%)	0	(0%)
Swimming	2	(11.1%)	0	(0%)
Ice Skating	1	(5.6%)	1	(7.7%)
Skiing	0	(0%)	1	(7.7%)
Sport Games				
Basketball	8	(44.4%)	7	(53.8%)
Volleyball	6	(33.3%)	6	(46.2%)
Rugby	5	(27.8%)	6	(46.2%)
Touch Rugby	5	(27.8%)	5	(38.5%)
Athletics	4	(22.2%)	4	(30.8%)
Soccer	4	(22.2%)	6	(46.2%)
Netball	3	(16.7%)	4	(30.8%)
League	2	(11.1%)	3	(23.1%)
Badminton	1	(5.6%)	1	(7.7%)
Hockey	1	(5.6%)	1	(7.7%)
Softball	0	(0%)	2	(15.4%)
Cultural Activities				
Kapa Haka (Māori dance group)	2	(11.1%)	2	(15.4%)
Mau Rakau (Māori martial arts)	1	(5.6%)	0	(0%)

Note. Data extracted from PAQ-C questionnaire, Item One.

Statistics: Data presented as mean (standard deviation) and counts (%).

5.4.3 Time of day children engage in physical activity

Table 12 illustrates the time-of-day participants engaged in physical activity as recorded in the PAQ-C. Most participants, across both groups, completed physical activity during school hours, specifically morning tea, lunch and in physical education classes, compared to outside of school hours. There was no significant difference between groups for time of day children participated in physical activity.

Table 12

Time-of-day participants engaged in physical activity

Time of Day	Bronchiectasis n= 18		Control n= 13	
Physical education class	14	(77.8%)	10	(76.9%)
Morning tea	16	(88.9%)	12	(92.3%)
Lunch	16	(88.9%)	11	(84.6%)
After school	13	(72.2%)	8	(61.5%)
Evening	13	(72.2%)	8	(61.5%)

Note. Data extracted from PAQ-C questionnaire.

Statistics: Data presented as counts (%).

5.5 Summary of results

The findings of this study provide a unique view of physical activity for children with bronchiectasis living in Counties Manukau. However, these results must be viewed cautiously and within the limitations caused by COVID-19 disruptions. The study did not achieve its desired sample size which meant the study was underpowered and unable to determine, with certainty, if the results are significantly meaningful.

Mindful of the above limitations, the results suggested that children with bronchiectasis, aged 7 to 12 years living in Counties Manukau, completed less MVPA minutes than their healthy peers. On average, children with bronchiectasis completed 31.63 less minutes of MVPA per day and achieved daily MVPA recommendations less often. Trends also suggested fewer MVPA minutes were completed by children with more severe bronchiectasis, compared to those with milder disease. Regardless of group, children living in Counties Manukau were most active at school during the week and were more likely to participate in leisure activities and non-organised sports or games.

Chapter 6 Discussion

This is the second study to examine physical activity levels in children with bronchiectasis, and the first study completed in a New Zealand population. Findings of this study show that children with bronchiectasis completed less minutes of MVPA and subsequently achieved daily MVPA recommendations less often, than their healthy peers. Furthermore, this was the first study to investigate associations between MVPA achievement and demographic and disease severity markers, mode of physical activity completed, and the time-of-day children with bronchiectasis were most active.

This chapter discusses the findings within the context of available literature and specifically the research questions and the hypotheses:

1. How physically active are children aged 7 to 12 years with bronchiectasis living in Counties Manukau compared to healthy matched controls?

Hypothesis: Children with bronchiectasis will be less active than their healthy matched controls.

2. Do children with bronchiectasis achieve daily MVPA recommendations, as outlined by the WHO?

Hypothesis: Children with bronchiectasis will achieve daily MVPA recommendations but less frequently than their healthy peers.

3. Is there an association between MVPA and demographic or disease severity markers in children with bronchiectasis?

Hypothesis: Lower MVPA minutes will be associated with increased BMI, reduced lung function ($\leq 80\%$ FEV1 predicted) and recent hospital admissions. Boys will be more active than girls.

4. What mode of physical activities are children with bronchiectasis engaging in and when do they engage in these activities?

Hypothesis: Children with bronchiectasis will engage in a wide range of activities, with a bias towards inexpensive and informal school and backyard games/activity. Children with bronchiectasis will participate in less physical education classes at school, but like their peers, will be more active during the week compared to the weekend.

Of the following four sections, the first two sections examine daily MVPA minutes completed between children with bronchiectasis compared to their healthy peers, and outline levels of achievement of daily MVPA recommendations. This is then followed by demographic and disease severity markers associated with MVPA achievement, and finally mode of physical activity and time of day/week children are most active.

6.1 MVPA minutes achieved per day for children with bronchiectasis compared to their healthy peers

The primary aim of this study was to establish how physically active children with bronchiectasis are compared to their healthy peers. It was hypothesised that children with bronchiectasis would be less active than their healthy peers. The study proved this hypothesis to be true, as children with bronchiectasis completed an average of 31.63 less minutes of MVPA per day, than their healthy peers. As there were no statistically significant demographic differences identified between the Bronchiectasis and Control group that could explain the variation in MVPA minutes, the differences observed between groups therefore must be due to the presence of bronchiectasis.

The current study's findings were consistent and comparable with the study by Joschtel et al. (2019), the only other published child bronchiectasis physical activity study, with both studies concluding that children with bronchiectasis achieve less MVPA minutes than their healthy peers. However, the studies differed significantly regarding the volume of MVPA minutes achieved each day. Findings from the current study indicated children with bronchiectasis completed an average of 74.8 minutes of MVPA per day compared to the finding reported by Joschtel et al. (2019), at 48.6 minutes of MVPA per day. This discrepancy in MVPA minutes will be in part due to differences in baseline participant demographics and the accelerometer methods implemented by the two studies.

6.1.1 Influence of baseline participant demographics on daily MVPA minutes

Participant demographics for age, inclusion of an Indigenous population, BMI and disease severity varied between the current study and that of Joschtel et al. (2019), and potentially accounted for some of the variation observed in MVPA minutes achieved between the studies.

The literature suggests that age influences physical activity participation and MVPA achievement during childhood (Biddle et al., 2011; Button et al., 2020). Children are most active up until they reach adolescents when a decline in physical activity is commonly observed. Children with bronchiectasis in the current study were older than Joschtel et al.

(2019) participants, at 10.8 years versus 7.7 years respectively. According to Sport New Zealand's (2020a) survey, a government funded agency who completed a cross-sectional survey of 4,799 healthy New Zealand children aged 5 - 17 years, it was identified that physical activity levels peaked between 12 - 14 years. Based on these findings, it is possible that the current study achieved higher MVPA minutes simply because participants were older, and nearer to peak physical activity age, than the participants in Joschtel et al. (2019) study.

Research in healthy New Zealand and Australian children shows that Indigenous (Māori and Aboriginal respectively) children are more active, and more likely to achieve MVPA recommendations than non-Indigenous children (Australian Institute of Health and Welfare, 2018; Sport New Zealand, 2020a). In the current study, 38.9% of participants identified as Māori, slightly higher than Counties Manukau's typical child bronchiectasis population of 26% Māori (Rensford, 2021). By comparison, the study by Joschtel et al. (2019) did not explicitly state the inclusion of an Indigenous (Aboriginal) population, a weakness given that Aboriginal children have the highest prevalence of bronchiectasis in Australia (McCallum & Binks, 2017). As a result, it is possible that the difference in daily MVPA minutes between the current study and Joschtel et al. (2019), was also inadvertently influenced by the number of Indigenous children recruited to each study.

BMI is also known to effect daily MVPA minutes in children and therefore needs to be adjusted for during analysis, in physical activity research when BMI is not the primary outcome measure being investigated (Jago et al., 2020). The current study included BMI as a baseline measure with the plan to match participants for BMI during analysis, to remove its influence on MVPA results. Accounting for BMI was particularly important and potentially unique to the current study. This was due to the elevated prevalence of obesity (37.9%) reported in the Kidz First bronchiectasis MDT clinic (R. Matsas, personal communication, December 31st, 2019), and Counties Manukau region (18.6%) (Healthy Auckland Together, 2019), compared to lower estimates observed in wider New Zealand (12.7%) (Ministry of Health, 2021a) and internationally (12% overweight or obese) (Ritchie & Roser, 2017). The most likely explanation for the increased number of obese children in the bronchiectasis clinic, is due to the disproportionate effect obesity has on Māori and Pacifica children (Ministry of Health, 2021a), who make up the majority of children with bronchiectasis in Counties Manukau (Rensford, 2021). Interestingly, despite the higher prevalence of obesity in Counties Manukau, participants recruited in the current study predominantly fell within normal healthy BMI limits (Bronchiectasis group BMI = 24.32; Control group BMI = 23.12). It is unclear if this was due to the small sample size or if a natural research bias was at play, where the study topic attracted more active children with lower BMI due to their propensity towards physical activity.

Regardless, MVPA minutes recorded in the current study may have been further elevated as a result of a 'healthier' study cohort, and potentially not truly representative of the typical Counties Manukau bronchiectasis population.

Lastly, comparisons between the current study and that of Joschtel et al. (2019), in respect to participant disease severity and its role on MVPA, are difficult to establish as each study applied different outcomes to measure baseline disease severity. The current study recruited more children with mild to moderate disease severity, as indicated by the fewer lobes affected with bronchiectasis, normal to mild impairment on spirometry, and low rates of antibiotics and hospital admissions in the year proceeding the study. Compared to the study by Joschtel et al. (2019) which recorded the number of doctors' visits in the last twelve months and current medications. Interpretation of these outcome measures is difficult as Joschtel et al. (2019) failed to specify if the doctors' visits included all bronchiectasis related appointments, i.e., specialists' appointments, or were limited to general practice appointments to manage bronchiectasis exacerbations. Additionally, Joschtel et al. (2019) reported 38.9% of their cohort were using antibiotics during the study, but did not explicitly document if this were due to current exacerbations, or if they were prophylactic antibiotics, indicative of greater disease severity due to the need for routine antibiotics to maintain daily health status. Either way, the use of antibiotics during the study may have negatively influenced the number of MVPA minutes achieved. As such, without comparable outcome measures it is difficult to know to what extent disease severity influenced MVPA achievement. It is possible that the participants in the current study were healthier, due to predominantly mild to moderate disease, and favourably contributed to the higher MVPA minutes observed in this study compared to Joschtel et al. (2019) study.

Overall, the current study included more participant demographic and disease specific outcome measures, than Joschtel et al. (2019) study. These baseline measures (age, inclusion of Indigenous children, BMI and disease severity) facilitated a more accurate understanding of MVPA achievement for children with bronchiectasis, compared to their healthy peers, and identified several plausible explanations that may have accounted for some of the variation in MVPA minutes between the current study and Joschtel et al. (2019).

6.1.2 Influence of accelerometer protocols on MVPA results

It has been well established that differences in accelerometer initialisation and data processing protocols, such as cut-points, do influence MVPA output even when tested simultaneously in a laboratory setting (Migueles et al., 2017). Therefore, the difference in MVPA minutes observed between Joschtel et al. (2019) and the current study would have occurred, in part, by the

differing accelerometer wear-site and cut-point applied. Both studies used the ActiGraph wGT3X+ accelerometer but Joschtel et al. (2019) utilised hip-based placement with cut-points as referenced by Evenson et al. (2008), while the current study opted for wrist-based placement and cut-points as referenced by Chandler et al. (2016). Application of the wrist-based placement and a 24-hour wear time protocol was selected, based on the current study's need to improve wear compliance and reduce selection bias (Fairclough et al., 2016; McLellan et al., 2020b). The decision had the desired effect, with 94.5% ($n = 29/31$), of participants providing valid datasets, compared to 78.2% ($n = 36/46$) reported by Joschtel et al. (2019). It is unknown to what extent this decision affected the difference in MVPA minutes observed between studies, but it could be speculated that a 24-hour wear time protocol had the potential to accumulate more MVPA minutes than Joschtel et al.'s (2019) awake-time protocol of at least eight hours per day. Additionally, the discomfort of wearing a hip-based accelerometer may have influenced normal physical activity participation, such as reducing vigorous running or jumping activities, due to concerns of the elastic waist band riding up or twisting and becoming uncomfortable. The literature is conflicted regarding the best wear-site, with arguments for both positions recording too much or too little activity. So unless two studies use the exact same accelerometer protocols for wear-site, cut-points, and valid dataset criteria, a definitive comparison between two studies cannot occur.

6.2 Achievement of daily MVPA recommendations

In addition to establishing daily minutes of MVPA, the study also aimed to establish if children with bronchiectasis achieved daily MVPA recommendations, as outlined by the WHO (World Health Organization, 2020a). It was hypothesised that some children with bronchiectasis would achieve daily MVPA recommendations, but less frequently than their healthy peers. This hypothesis was proven to be true. The study found children with bronchiectasis achieved daily recommendations of at least 60 minutes of MVPA per day across the week, less often than their healthy peers. These findings were once again consistent with Joschtel et al. (2019), however the percentage of children achieving daily MVPA recommendations varied significantly between studies. The current study reported 62.3% of the Bronchiectasis group and 86.4% Control group achieved MVPA recommendations, significantly higher than Joschtel et al. (2019) findings of 5.6% for their Bronchiectasis groups and 42% for their comparator group.

6.2.1 Influence of the comparator method used for comparing MVPA

While both studies agreed that children with bronchiectasis achieved MVPA recommendations less frequently than their healthy peers, the extent of disparity differed substantially. Joschtel et al. (2019) reported a large between-group difference for achieved daily MVPA recommendations (5.6% Bronchiectasis; 42% Comparator group), but used the Queensland Preventative Health Survey (Queensland Health, 2016) as the comparator instead of the recommended control group (Ruble, 2017). MVPA results found in the Queensland Preventative Health Survey may have been miscalculated due to the methodology used. For example, this survey relied on parental recall and insight to estimate their child's daily physical activity participation. Not only is this methodology vulnerable to social desirability and recall bias (Althubaiti, 2016), but it also relies on the assumption parents can accurately account for their child's physical activity throughout the entire day, inclusive of hours the child is not with them, such as at school (Koning et al., 2018; Sumonja & Jevtic, 2019). Furthermore, the Queensland Preventative Health Survey incorrectly calculated MVPA achievement by totalling the overall number of minutes spent being physical activity each day, rather than counting only minutes of physical activity that reached a level of MVPA, as per the WHO definition of at least 60 minutes of MVPA per day (World Health Organization, 2020a). As a result, the survey would have presented a higher percentage of children achieving recommendations, than there actually were.

A strength of the current study was the decision to use a control group to allow direct between-group analyses of the Bronchiectasis and Control group. This decision was further validated as no other child bronchiectasis, cystic fibrosis or healthy New Zealand studies have used wrist-based accelerometers and therefore comparisons to previous research was not possible. Compared to Joschtel et al. (2019), the current study identified a smaller between-group difference for achievement of daily MVPA recommendations (62.3% Bronchiectasis; 86.4% Control). The inclusion of a control group was postulated to provide a more sensitive and accurate representation of MVPA differences between children with bronchiectasis and their healthy peers at that point in time, meaning the results in the current study are more representative of between-group differences than the Joschtel et al. (2019) findings which did not use a control group for their comparator.

Comparing the current study's findings to wider New Zealand physical activity studies is difficult due to the variation in research methods applied between studies; however within these limitations some conclusions can be roughly extrapolated. The New Zealand based Neighbourhoods for Active Kids study (Oliver et al., 2016) is the most comparable normative

dataset to the current study, in terms of participant demographics (children aged 8 - 12 years, specific inclusion of Māori and Pasifika, Auckland-based recruitment); and measurement of MVPA (hip-based ActiGraph wGT3X+ accelerometers). However, despite similar study methods, the Neighbourhood for Active Kids study reported 38% of children ($n = 1102$) achieved daily MVPA recommendations (Smith et al., 2018), significantly lower than the findings of the current study (62.3% Bronchiectasis group; 86.4% Control group). The difference in MVPA minutes observed is likely a result of the vastly different time periods the studies were undertaken; 2015 - 2016 versus 2021. New Zealand's Physical Activity Report Card (Wilson et al., 2023), a nationwide survey of children aged 5 - 17 years that contributes to the Global Matrix Physical Activity Report Card of 57 Countries (Aubert et al., 2022), reported that the percentage of children achieving daily MVPA recommendations has increased from 20 - 26% in 2016 to 54 - 59% in 2019 (Wilson et al., 2023). This is significantly higher than the global average of 27 - 33%, which has remained stagnant during this same time period (Aubert et al., 2018; Aubert et al., 2022). While the New Zealand's Physical Activity Report Card (Wilson et al., 2023) results are exclusively survey based and inclusive of a wider age range, the findings clearly indicate a significant improvement in daily achievement of MVPA over time, which is likely being demonstrated in the results observed between the Neighbourhood for Active Kids study (Smith et al., 2018) and the current study.

Interpreting the current study's results against any normative physical activity datasets, New Zealand or international, needs to be undertaken cautiously as they were all completed prior to the COVID-19 pandemic and unlikely to represent physical activity levels for children today. Global research shows that during COVID-19, particularly while in lockdown, children's normal physical activity behaviours were significantly impacted (Paterson et al., 2021; Rahman & Chandrasekaran, 2021; Stockwell et al., 2021). Furthermore, it is speculated that many children have yet to return to pre COVID-19 physical activity levels (Salway et al., 2022); refer to section 3.3. The current study was completed May 2021 to August 2021, mid pandemic and in-between New Zealand's strict lockdown measures. This vastly different environment would likely have influenced achievement of daily MVPA recommendations in the current study, but without nation-wide normative data pre- and post- the COVID-19 pandemic, it is unclear to what extent this may be. What the study has achieved, via use of a healthy control group, is capture a unique cross-sectional snapshot of physical activity levels of children from Counties Manukau during the COVID-19 pandemic that could provide valuable information for future studies.

6.2.2 MVPA achievement as per the PAQ-C

The PAQ-C, used in the current study, also found that children with bronchiectasis were less active than their healthy peers. The mean total activity score for the Bronchiectasis group was 2.59 compared to the Control group's 2.68, but unlike the accelerometer data, the PAQ-C suggested that neither group achieved daily MVPA recommendations for the week surveyed, as measured by the total activity score cut-off value of 2.75 (Benítez-Porres et al., 2016). Cautious interpretation of these values is required as the Benítez-Porres et al. (2016) cut-off value have not yet been validated in a child population, despite being widely used in child research, including New Zealand child studies (Foley et al., 2008; Ni Mhurchu et al., 2008; Telford et al., 2021; Utter et al., 2006; Utter et al., 2007). Furthermore, while the PAQ-C provides very useful physical activity data, regarding mode and time of day children are active, it is a less accurate measure of MVPA minutes and should be used in conjunction with an accelerometer (Marasso et al., 2021), as performed in the current study.

6.2.3 Overall summary of MVPA achievement in children with bronchiectasis

Despite the discrepancy in MVPA minutes and methods used, both Joschtel et al. (2019) and the current study, concur that children with bronchiectasis are less active, and achieve daily MVPA recommendations less frequently, than their healthy peers. The clinical significance of this aligned conclusion should encourage physiotherapists to embed physical activity assessment and early intervention into routine bronchiectasis management. Physical activity needs to be viewed as an integral component of daily management, similar to airway clearance, in order for children with bronchiectasis to maximise the health benefits associated with regular physical activity. Bronchiectasis guidelines could better support physiotherapists by changing their brief statement that simply encourages 'regular activity' (Chang et al., 2015; Chang, Fortescue, et al., 2021), to at least include the current WHO recommendations in order to give some clarity regarding physical activity recommendations. At least until further disease specific research is completed.

6.3 Association between MVPA and demographic or disease severity markers

This was the first study to investigate whether there was an association between MVPA and demographic or disease severity markers in children with bronchiectasis. The study hypothesised that lower MVPA minutes would be associated with increased BMI, reduced lung function, and recent hospital admissions. Boys would also be more active than girls. The

study's hypothesis was proven partly true. The study found weak to moderate, although non-significant, associations between MVPA and demographic markers (BMI, and socioeconomic deprivation) but not MVPA and disease severity markers (FEV1% predicated, number of lobes with bronchiectasis, antibiotic courses and hospital admissions).

6.3.1 Demographic markers

The study found non-significant associations between lower MVPA minutes achieved per day and increased BMI scores (weak association; $r = -0.01$ to -0.36) and high socioeconomic deprivation (moderate association; $r = -0.01$ to -0.45). Both of these associations were negative, suggesting that children with bronchiectasis achieved less MVPA minutes per day when they had a higher BMI and greater socioeconomic deprivation.

The inverse relationship between low MVPA achievement and increasing BMI in children is well established (Baran et al., 2020; Elmesmari et al., 2018; Jago et al., 2020), including in a New Zealand population (Anderson et al., 2017). Therefore the weak association between MVPA and BMI achieved in the current study, is likely an underestimation for children with bronchiectasis. This may have occurred from the small sample size and the bias towards normal BMI scores in the participants recruited. A recent New Zealand based, cross-sectional study investigating physical activity behaviours in 130 obese, $BMI \geq 30$, children (4 - 16 years, 45% Māori, 29% living in high deprivation) found only 18.5% achieved daily recommendations of 60 minutes of MVPA per day, as recorded on hip-based accelerometers. Based on these findings and similar international studies (Baran et al., 2020; Elmesmari et al., 2018; Jago et al., 2020), it could be assumed that increased BMI would have similar effects on MVPA achievement for children with bronchiectasis. Therefore increased BMI, with a background of bronchiectasis, should be used as an indicator for physiotherapists to provide proactive physical activity assessment and initiate appropriate interventions to increase physical activity in conjunction with lifestyle and diet modifications.

The negative association identified between MVPA minutes and high socioeconomic deprivation, observed in the current study, partly conflicts with some New Zealand research reports. The Sport New Zealand (2019, 2020a) physical activity reports, suggest socioeconomic deprivation does not influence weekly participation or time spent being active for children aged 5 - 11 years. Instead it only influenced the mode of physical activity children participate in, while the New Zealand 2022 Report Card, and other international Report Cards, reported lower MVPA minutes from children living in communities with higher socioeconomic deprivation (Aubert et al., 2022; Wilson et al., 2023). Future research would benefit from

investigating this association further, as the findings obtained in the current study may be a result of the sample size and heavy bias of children living in NZDep Index 9 and 10.

In the current study, and that by Joschtel et al. (2019), boys consistently exhibited more MVPA minutes than girls, albeit not statistically significant enough to produce an association between MVPA and gender. The gender gap associated with MVPA achievement has been extensively published in many child populations (Farooq et al., 2020; McLellan et al., 2020a; Smith et al., 2018; Sport New Zealand, 2020a, 2020c; World Health Organization, 2020a). Results vary between studies, but boys are either more active or equally active as girls. The most recent normative data for New Zealand, showed girls aged 5 - 17 years spend on average of 96 fewer minutes per week being physically active than boys (Sport New Zealand, 2020a). Girls, particularly those from high socioeconomic deprivation, participate in fewer organised physical activities and sports, especially activities that include higher MVPA requirements (Sport New Zealand, 2019, 2020a). Based on the probability that girls with bronchiectasis are less physically active than boys, as identified in the current study, Joschtel et al. (2019) and normative New Zealand data (Sport New Zealand, 2019, 2020a), additional focus may need to be placed on supporting girls into physical activities. This would include organised sport teams, not only to improve MVPA achievement but to also gain other valuable health benefits such as development of social relationships, improved mental health and quality of life (President's Council on Sports Fitness & Nutrition Science Board, 2020).

There were insufficient numbers in the current study to determine associations between MVPA and age and ethnicity. However, based on healthy child New Zealand (Sport New Zealand, 2020a) and international (Biddle et al., 2011; Button et al., 2020) research that demonstrates a decline in MVPA minutes with increasing age, it can be assumed that had the sample size been larger or included a wider age range, an association between MVPA and age may have also been present in the current study. Further research investigating this association in children with bronchiectasis, would provide valuable insight into whether or not bronchiectasis is associated with a premature decline in daily MVPA minutes compared to healthy children, and thereby require an earlier and proactive treatment approach. Lastly, as previously discussed in section 6.1.1, Māori children are typically more active than non-Māori children (Sport New Zealand, 2020a), yet a strong association was not identified in the current study. Further investigation using a bigger sample size is required to examine whether Māori children with bronchiectasis are more active than another ethnic group or if this association has been subdued due to other factors may influence physical activity participation for Māori children, such as high socioeconomic deprivation or more severe levels of disease. Examination

of Pacifica children's MVPA levels would also be useful given they account for more than 60% of Counties Manukau's bronchiectasis child population (Rensford, 2021).

6.3.2 Disease severity markers

There were no significant associations found between MVPA and disease severity. This is possibly due to the Bronchiectasis group largely consisting of children with mild to moderate disease severity, the small sample size, or limitations of the outcome measures used to assess disease severity. However, there were some trends observed in the raw data that suggested fewer MVPA minutes were completed by children with low FEV1% predicted scores, three or more lobes affected with bronchiectasis on HRCT, and hospitalisations within the last twelve months.

Joschtel et al.'s (2019) study did not include an association analyses and therefore cannot be compared to the current study. When viewing the wider literature, there are a few child cystic fibrosis studies that have investigated the association between FEV1% predicted and MVPA minutes (Bianchim, McNarry, Holland, et al., 2022; Giannakoulakos et al., 2022; Kinaupenne et al., 2022). Unfortunately, findings are conflicting and inconclusive regarding the existence of a potential association. Similar results were also reported in an adult bronchiectasis study that investigated daily MVPA using hip-based ActiGraph wGT3X+ accelerometers which found FEV1% predicted, did not correlate with MVPA minutes (Bradley et al., 2015). However, unlike the child bronchiectasis population, the adult population has a validated disease severity outcome measure: Bronchiectasis Severity Index (BSI) (Chalmers et al., 2014). Interestingly, although the study by Bradley et al. (2015) reported that disease severity, as graded by the BSI, did not correlate with daily achievement of MVPA recommendations, it did find that adults with moderate to severe disease (BSI score ≥ 5) generally completed significantly less MVPA minutes per day than those with milder disease (BSI score ≤ 4) (Bradley et al., 2015).

Due to limitations within the current study, such as sample size, the existence of any potential associations between MVPA and disease severity were unable to be determined. Additional research is required to explore this further. However before this is undertaken, there needs to be a level of standardisation for measuring disease severity in children. It is unlikely that a universal paediatric based disease severity scale, similar to the BSI used in adults, can be created due to the natural challenges that age and developmental skills have on outcome measure accuracy, i.e., spirometry in young and cognitively impaired children. Thereby it is up to the bronchiectasis guideline committees, and future researchers, to provide greater consensus regarding which outcome measures should be used to best quantify disease severity.

6.3.3 Summary of associations between MVPA and demographic or disease severity markers

The current study, supported by wider literature, identified key demographic and disease severity markers that could assist physiotherapists to identify children at greatest risk of low MVPA achievement. Monitoring of demographic and disease severity markers, could provide a method to proactively identify children at higher risk of poor MVPA achievement. Early conversations between physiotherapists, children with bronchiectasis, and their family/whānau regarding the importance of physical activity participation, coupled with physical activity intervention or enrolment into community physical activity initiatives, could lead to preventing additional co-morbidities like obesity and poor mental health, and the consequential health burdens (i.e., financial, treatment and resource) on the child and wider health system.

6.4 Mode of physical activity and time of day/week children are most active

The last study aim was to explore the mode of physical activity which children with bronchiectasis are engaging in and to discover when they engage in these activities. The study hypothesised that children with bronchiectasis would engage in a wide range of activities, with a bias towards inexpensive and informal school and backyard games/activity. They would also participate in less physical education classes at school, but like their peers, would be more active during the week, compared to the weekend. This last hypothesis was also proven partly true. Children with bronchiectasis, similar to their healthy peers, did engage in a wide range of activities with a bias towards inexpensive and informal school and backyard games/activity. But, the study did not identify differences in participation of physical education classes, instead found children with bronchiectasis engaged in fewer team sports than their healthy peers. Lastly, as hypothesised, children with bronchiectasis were more active during the week at school compared to afterschool and on the weekend.

6.4.1 Mode of physical activity that children with bronchiectasis engage in

This study was the first to investigate the mode of physical activity children with bronchiectasis engage in. Children from both the Bronchiectasis and Control group engaged in a wide range of physical activities with greatest participation in leisure activities and non-organised school yard games (i.e., tag, running, dancing), compared to organised team sports games (i.e., basketball, rugby, soccer). These findings are consistent with Sports New Zealand's (2019, 2020a)

normative physical activity data for healthy children with similar age, ethnicity and socioeconomic deprivation demographics as the cohort recruited in the current study. The study also identified that children with bronchiectasis participate in fewer team sports, both school yard based and organised, compared to healthier children. Explanations could be specific to bronchiectasis, or a result of COVID-19 and socioeconomic deprivation.

A qualitative study by Blamires (2020), *“A pretty normal life with bronchiectasis”*, identified running as one of the key factors that makes participation in sport difficult for young New Zealanders with bronchiectasis. All 15 participants interviewed, aged 13 - 23 years, disclosed that their bronchiectasis made running harder than normal, triggering symptoms like coughing and fatigue, which at times precluded them from participating completely. For some, the ongoing illness and disruption led to withdrawing from sports all together (Blamires, 2020). Although those interviewed were older than participants in the current study, the findings in Blamires’ (2020) study matched anecdotal reports heard in the Kidz First bronchiectasis MDT clinic. This could explain the results found in the current study, as ‘running’ is a key component of most sports games.

The ongoing influence COVID-19 has had, and continues to have, on children in Counties Manukau, particularly those with bronchiectasis, may also be partly responsible for lower team sports observed in the current study. Although recruitment took place during Alert Level 1 between COVID-19 outbreaks, many organised sports and school environments had not returned to pre-pandemic status, despite relaxing restrictions, thus potentially reducing opportunities for engagement to occur. Furthermore, children may have chosen to participate in ‘safer and socially distanced activities’ due to ongoing COVID-19 fears, or simply felt they were unable to return to sports, due to decreases in physical fitness following lockdowns. Without longitudinal, New Zealand based COVID-19 studies, these theories are speculative and based on clinical observations and feedback from children with bronchiectasis and their family/whānau, who attend the Kidz First bronchiectasis MDT clinic. Regardless of the reasons, the consequence of children not participating in team based sports extend further than just the physical benefits of exercise. Team based sports also provide important social development opportunities and mental health benefits that all children, including those with bronchiectasis, can benefit from (Bull et al., 2020; Chaput et al., 2020; Janssen & LeBlanc, 2010; Poitras et al., 2016; World Health Organization, 2020a). Future initiatives to better engage children with bronchiectasis into team sports would result in significant benefits for both their physical health, mental health and overall quality of life.

Socioeconomic deprivation is thought to significantly influence mode of physical activity children are able to participate in New Zealand (Sport New Zealand, 2019, 2020a). Sport New Zealand's spotlight on socioeconomic deprivation, reported that participation in organised sport programmes declines steeply for children living in higher deprivation, due to cost and transport barriers associated with economic hardship (Sport New Zealand, 2019, 2020a). As a result of deprivation, rather than child preference, mode of physical activity typically consists of more informal leisure activities and non-organised schoolyard games, such as running/jogging, netball, rugby, and Kapa haka (Sport New Zealand, 2019). Similar findings have been demonstrated in the current study, which is not overly surprising, given over 70% of participants live in communities with high socioeconomic deprivation.

6.4.2 Time of day and week children with bronchiectasis are most active

6.4.2.1 Time of day

Results from the PAQ-C in the current study indicated that children in the Bronchiectasis and Control groups were most active at school during morning tea, lunch, and physical education classes than after school or in the evenings. These findings are consistent with patterns documented in other New Zealand and international studies (Brooke et al., 2016; Clemens & Lincoln, 2018; Díaz-Quesada et al., 2022; Sport New Zealand, 2019). New Zealand data also shows children living in communities with high deprivation, like Counties Manukau, are more active at school, compared to children living in communities with less deprivation (Sport New Zealand, 2019, 2020a). This is likely why mode of activity in the current study identified higher levels of school yard games and other informal activities compared to organised sports, which are most often completed outside of school hours.

6.4.2.2 Weekday versus weekend day

The current study is the first to report MVPA data for children with bronchiectasis for each day, across the week allowing between-day analyses to be completed. The current study found that all participants, regardless of their group, were more active on weekdays than weekends. This weekday/weekend pattern is already well established in the literature for most child populations (Brazendale et al., 2021; Brooke et al., 2016; Fairclough et al., 2015; Zhang et al., 2019), including Joschtel et al.'s, (2019) child bronchiectasis study.

The increased volume of MVPA completed on weekdays, during school months, has been observed internationally but is more pronounced in European Countries and Australia (Brazendale et al., 2021). Longitudinal evidence suggests that children aged 8 - 12 years develop weekly cycles of MVPA because of the five-day school/work week. For example, MVPA

gradually increases from Monday to Friday before significantly dropping off over the weekend (Telford et al., 2013). Explanations for this pattern are based on general weekend behaviour patterns. Saturday, commonly associated with organised sports and formal activities programmes, may demonstrate a small burst of MVPA but is then largely followed by sedentary behaviour. Sunday, commonly associated with the day of rest from a cultural and religious perspective, together with family time or household chores, produces the lowest level of MVPA, as activities are not overly physical (Brazendale et al., 2021; Brazendale et al., 2017; Telford et al., 2013). While children with bronchiectasis, in the current study, were more active on weekdays, the gradual increase of MVPA minutes from Monday to Friday was not overtly demonstrated, likely due to the limited sample size available, rather than a change in typical patterns. The substantial decrease in MVPA minutes over the weekend, especially Sunday, was evident in the current study. In addition to the unstructured weekend day, that is commonly observed with increased sedentary behaviour (Brazendale et al., 2017; Watson, 2018), the reduction in MVPA minutes may also be due to the high number of families in Counties Manukau, particularly Pacifika, that observe Sunday as a day for church, family, and rest (Pacific Community, 2020).

Understanding physical activity patterns for children with bronchiectasis is vital for future interventions. While school-based interventions appear to be the most pragmatic option based on the findings of the current study, many studies have failed to improve MVPA levels using this approach (Love et al., 2019). This failure is largely due to sustainability issues such as competing time pressures and curriculum requirements, weather, available facilities, and failure to engage the children at greatest need (i.e., children with increased BMI, adolescents, and girls) (Love et al., 2019; Malden & Doi, 2019). As such, it may be more beneficial for interventions to focus on weekend days to capture additional opportunities for MVPA on days that have more capacity for change than the busy school days (Brazendale et al., 2021; Brooke et al., 2016; Fairclough et al., 2015). For the population in the current study, weekend initiatives would require the inclusion of the wider family/whānau into physical activity programmes as well to increase long-term uptake.

6.5 Summarisation of discussion

The study achieved its research aims, and proved many of its hypotheses true. Children with bronchiectasis achieve fewer minutes of daily MVPA and subsequently achieved daily MVPA recommendations less often than their healthy peers. Moreover, this was the first research to identify potential associations between MVPA and participant demographics and raw data

trends between MVPA and disease severity markers. The study also identified the most common modes of activity and time of day children with bronchiectasis were most likely to engage in these. Although the study was limited by sample size due to COVID-19, the findings still provide valuable insight into current physical activity levels, for children with bronchiectasis living in Counties Manukau. The results found in this study have the capability of better supporting clinicians working with this population, as well as providing fundamental data for future intervention and community-led initiatives, to improve physical activity levels in children with bronchiectasis.

Chapter 7 Thesis Closure

The study has identified that children with bronchiectasis in Counties Manukau are less active than their healthy peers, and has identified new information that will better support clinicians and researchers working with this population in the future. Therefore, the last chapter of this thesis presents the clinical significance of the findings, the study's limitations, and future research recommendations before concluding with an overall summary.

7.1 Clinical significance

Findings from the current study suggest that, when compared to their healthy peers, children with bronchiectasis are less physically active and participate in fewer organised physical activities. These findings are clinically significant, especially for physiotherapists, working with the Counties Manukau child bronchiectasis population.

7.1.1 Clinical assessment of physical activity participation

Greater emphasis needs to be placed on physical activity assessment within routine bronchiectasis care. Regular in-depth physical activity assessment would improve monitoring of physical activity participation and proactively identify if and when more intensive physical activity interventions were required. If resource limitations prevented routine assessment of all children in the clinical setting, then findings from this study could assist physiotherapists to identify children at higher risk of lower daily MVPA achievement and facilitate preventative interventions; for example children with low FEV1% predicted, girls, or elevated BMI.

Application of the PAQ-C, used in the current study, could be easily applied to the clinical setting in Counties Manukau. The PAQ-C could quickly identify children who complete insufficient activity and would benefit from a more in-depth physical activity assessment and interventions. The PAQ-C also provides valuable insight into activities the child was already completing, thus creating a platform on which to build interventions. If integrated into practice, it is recommended that the PAQ-C is adapted and validated in a New Zealand population to ensure it was inclusive of national and cultural activities unique to New Zealand. For example, Item One on the PAQ-C could be adapted to include the same physical activities listed in the well-established Active NZ survey (Sport New Zealand, 2020a, 2020b). Although a useful tool, the PAQ-C did not appear to conclude the same level of physical activity, from our study, when compared to the accelerometer data. Based on this, the current study recommends the PAQ-C is used as an investigatory or monitoring tool for identifying mode of

activity and general daily/weekly physical activity patterns, rather than for MVPA measurement.

In some situations, accelerometers could be implemented as either an assessment measure or activity incentive to increase physical activity participation within the community. However, application of accelerometers is time consuming, expensive, requires specialised skills to interpret the data and provides little bio-feedback to the user (Hidding et al., 2018). Perhaps more pragmatic accelerometer-like options such as pedometers, simple Fitbits or already installed activity counters on phones or watches could be used. While these devices are less formal, and associated with poorer psychometric properties, they may provide sufficient visual motivation for children to self-monitor and regulate their physical activity behaviour appropriately (Kasparian & Badawy, 2022; Koorts et al., 2020). Unfortunately, private purchase of accelerometer-like device may not be a realistic option for many children living in high socioeconomic deprivation, such as Counties Manukau. However, devices could be provided in physical activity initiatives, such as the Healthiest Schools Initiative (AIA, 2018), or as part of a physiotherapy-based intervention or research initiative (Creaser et al., 2021; Ferguson et al., 2022).

The outcome measures used in the current study provides two potential objective measures suitable for improving physical activity assessments of children with bronchiectasis. Further psychometric testing and consideration regarding their application is needed before being applied clinically, to ensure they are appropriate for the targeted population.

7.1.2 Clinical intervention for increasing physical active participation

The current study clearly illustrated that many children with bronchiectasis are insufficiently active and would benefit from increasing their daily physical activity levels. Traditional physical activity interventions have targeted children with overt exercise capacity deficits that effect participation in day-to-day life typically via outpatient- or home- based exercise blocks. While the majority of children with bronchiectasis who are ‘generally just less active’ receive generic physical activity advice (Northern Regional Paediatric Physiotherapy meeting, personal communication, November 23rd, 2021). Based on the findings of the current study, the literature review, and current community programmes available in Counties Manukau, two achievable interventions could be implemented into current physiotherapy practice for children with bronchiectasis. Interventions include maximising the physical activity opportunities already available, and identifying and supporting opportunities for increased physical activity over the weekend.

7.1.2.1 Maximising current physical activity opportunities

Children's biggest weekly physical 'occupation' is during school attendance, therefore it seems reasonable that maximisation of physical activity opportunities starts there. Although this study identified that children with bronchiectasis were most active at school, anecdotal reports from the Kidz First bronchiectasis MDT clinic indicate many children with bronchiectasis, do not participate in physical education classes regularly (A. Ainsworth, personal communication August 29th, 2021). Parents commonly report that they stop their child from participating, due to fear of causing increased coughing, breathlessness and fatigue. In New Zealand, school physical education programmes are mandatory for all children aged 5 - 15 years (Ministry of Education, 2006). But unlike other countries that have time-based requirements (Hills et al., 2015; UNESCO, 2014), New Zealand has no minimal requirements for time spent being active each day/week or physical activity curriculum to develop key motor skills (Mizdrak et al., 2021). Consequently, there is minimal consistency between schools providing physical education programmes. While some schools are able to provide multiple physical activity opportunities, inequities are observed between schools, particularly for those based in communities with high socioeconomic deprivation, such as Counties Manukau, where physical activity resources and facilities are limited and compete against academic requirements (Mizdrak et al., 2021). These inequalities are likely contributing to the declining levels of physical activity completed at school, where only 54 - 59% of New Zealand children in 2019, pre COVID-19 pandemic, engaged in regular physical education classes (Wilson et al., 2023). To help improve inequities, many schools rely on governmental programmes, such as the Healthy Active Learning Initiative (Robertson et al., 2021) or local fundraising committees such as the Counties Manukau KiwiSport Local Fund (Aktive, 2020), to support physical activity opportunities and resources within their school.

As a minimum, children with bronchiectasis would benefit from actively participating, to the best of their ability, in school physical education classes. Maximisation of available school opportunities is particularly important, given the current study showed that children with bronchiectasis are most active during school time. To facilitate this, and overcome the aforementioned fears, physiotherapists may need to provide hands-on support, in addition to education, to show key family/whānau members and teachers how their child can safely exercise at school. At Counties Manukau, this hands-on approach could be easily incorporated into the PACES (Physiotherapy Airway Clearance in Education Settings) programme. The PACES programme is a physiotherapy led, community initiative that supports children with severe bronchiectasis and social barriers that prevent adequate bronchiectasis management at home. The programme assists children to complete their airway clearance programme at school

under the guidance of a trained teacher aide. Anecdotal evidence has shown the PACES programme increases adherence to airway clearance and improves health outcomes by reducing exacerbations (A. Trenholme, personal communication, January 10th, 2022). A physical activity education/support component could be easily incorporated into the PACES programme for enrolled children to lift physical activity at school and dispel family/whānau and teacher fears. The addition of a physical activity monitoring and intervention package to the PACES programme would result in a well-rounded and integrated physiotherapy approach to daily bronchiectasis management, as recommended in bronchiectasis guidelines (Chang et al., 2015; Chang, Fortescue, et al., 2021).

7.1.2.2. Identify physical activity opportunities during the weekend.

When current physical activity options are maximised, the next step would be to identify opportunities to improve physical activity behaviours on the weekend. In keeping with national strategies (Ministry of Health, 2017), simple measures such as reducing screen/T.V. time, and improving sleep hygiene, could be used as an achievable starting point for children or family/whānau, who are reluctant or fearful of increasing MVPA levels straight away. Small changes in these areas has been found to positively impact physical activity behaviour and acquisition of associated health benefits (Altenburg et al., 2016; Australia Department of Health, 2019). For those more willing to actively increase their physical activity levels, available weekend sports and community programmes could be trialled, with the inclusion of the wider family/whānau to increase uptake. Further qualitative culturally responsive research would be recommended to explore plausible options that best suit the Counties Manukau community; see section 7.3.

Physiotherapists are well placed to provide developmentally appropriate physical activity assessments and interventions within the context of the healthcare and education system (Simpson et al., 2019). Any improvements, even small ones, gained from increasing physical activity participation, will result in improvements in physical, cognitive, and psychological health domains and prevent development of avoidable co-morbidities such as obesity and chronic heart disease (Bull et al., 2020; Chaput et al., 2020; Janssen & LeBlanc, 2010; Poitras et al., 2016; World Health Organization, 2020a). Furthermore, sustained physical activity behaviours achieved during childhood, have been found to predict future physical activity behaviours in adulthood (Cleland et al., 2012; Telama, 2009). Therefore, enhancement of positive physical activity during childhood is vital for reducing the future health burden on the individual with bronchiectasis and for the health system. However to achieve this, inclusion of family/whānau is required if long term changes in childhood behaviours are to be successful.

The added benefit of including family/whānau members is that the family unit, by association, will also achieve improve health outcomes from being more active.

7.2 Limitations

When considering the results of this study, several limitations are acknowledged. First and most significantly, was the impact the COVID-19 pandemic had on study recruitment, achieved sample size, and therefore the type and scope of statistical analyses undertaken. As a result, the study was under powered and unable to detect significant effects. However, the findings discussed are valuable and provide a unique insight into the physical activity behaviours of children with bronchiectasis living in Counties Manukau, particularly given this is the first research conducted in this important area.

Participants were recruited from a single DHB (Counties Manukau) and although significant effort was made to ensure a wide range of children were recruited from the region, results cannot be considered representative and generalisable for all children with bronchiectasis, not even for this specific region of Auckland. It is also plausible that a more active and healthy sample of participants were recruited to the study, because of a natural research bias, and may be responsible for higher MVPA minute recordings. Moreover, without baseline activity data collected for the week prior to wearing the device, it is possible physical activity levels were influenced by simply wearing the accelerometer (Motl et al., 2012). However, other similar physical activity studies in children have not completed baseline recordings, likely due to accelerometer adherence issues this would create. In this regard, the current study was completed under the same context and precepts, as the majority of research in this field. Furthermore, the stand-down period between accelerometer application and Day One recording, in addition to the high number of valid days recorded (mean of 6.6. days), would have provided sufficient data to neutralise any surges of physical activity that may have occurred following the initial application of the accelerometer (Matthews et al., 2012).

The application of accelerometers to objectively measure physical activity, is a strength of the study, although the decision to use the less familiar wrist-site and cut-points, as reported by Chandler et al. (2016), reduced the study's ability to compare findings directly with similar studies. Additionally, these Chandler et al. (2016) cut-points were developed for healthy children, without validation in chronic respiratory diseases. Therefore it is possible the cut-points may not accurately calculate MVPA due to pathophysiological differences associated with bronchiectasis, such as increased metabolic or ventilatory demand (Mackintosh et al., 2018). Validation of the newly developed cystic fibrosis cut-points (Bianchim, McNarry, Evans,

et al., 2022) against a bronchiectasis population, could provide a more accurate measure of physical activity levels for children with a similar chronic respiratory condition. Furthermore, a recent study suggested that wrist-based placement is associated with an over estimation of MVPA minutes (Troost et al., 2022), which could potentially contribute to the difference in MVPA minutes recorded between the current study and Joschtel et al. (2019). However, the utilisation of a control group in the current study excluded potential concerns surrounding over estimation of MVPA from wrist-based accelerometers as both groups were assessed using the same methods and analysis. This meant the between group-analysis could accurately illustrate differences in MVPA minutes between the Bronchiectasis and Control groups, as per the study's primary aim.

The PAQ-C relies on recall and reading comprehension in English and therefore is at risk of recall and social desirability bias (Helmerhorst et al., 2012; Janz et al., 2008; Triantafyllidis et al., 2021), especially in young children where English is their second language or for those that required external reading assistance to complete the PAQ-C. In addition, the PAQ-C does not provide minutes of MVPA completed, instead giving an overall physical activity score that must reach a threshold, to be considered sufficiently active for MVPA achievement (Benítez-Porres et al., 2016). Accepting its limitations, the PAQ-C was successfully used in this study to gain greater detail regarding mode and time-of-day physical activity. This in conjunction with accelerometer data, was recommended in the literature as best practice (Hidding et al., 2018; Marasso et al., 2021; Troiano et al., 2014). Further, the combination of outcome measures provided a more in-depth perspective of physical activity for children with bronchiectasis, which may well contribute towards future physical activity initiatives and research.

The study applied the original and more commonly used WHO MVPA recommendations of achieving at least 60 minutes of MVPA per day, across the week (World Health Organization, 2020a). This was instead of the adapted recommendations, which state that children should accumulate an average of 60 minutes of MVPA activity per day, across the week (Bull et al., 2020). This slight variation in definition could mean the average number of days children with bronchiectasis achieved MVPA recommendations in the current study, was under-reported. The decision to apply the original MVPA recommendations in this study, was rationalised by its continued use in similar physical activity studies, and the associated ease of completion between study comparisons, when the same MVPA definitions were applied.

The national datasets currently available for baseline physical activity comparison in children are: Active New Zealand 2019 Participation Report (Sport New Zealand, 2020a), Neighbourhood for Active Kids study (Oliver et al., 2016; Smith et al., 2018), and New Zealand's

2022 Report Card (Wilson et al., 2023). They were all completed prior to the COVID-19 pandemic (2019). By contrast the current study was completed 15 - 18 months into the pandemic and in between lockdowns during 2021. Given the significant negative effect COVID-19 and its associated lockdowns has had on children's normal physical activity behaviour (Paterson et al., 2021; Rahman & Chandrasekaran, 2021; Stockwell et al., 2021), it is unlikely that the pre COVID-19 datasets were representative of normal child physical activity levels, at the time the current study was conducted. The inclusion of a healthy control group in the current study could have overcome this issue, had study numbers not been limited by COVID-19. The inclusion of a healthy control group would have provided a snapshot of physical activity levels of children in Counties Manukau, at the time the study was undertaken (mid pandemic), thus achieving a more accurate between-group analysis of MVPA achievement for that time.

Lastly, the study focused solely on time spent in MVPA each day. The study acknowledges that the behaviours required for achieving physical activity health benefits are far more complex than MVPA alone, as balanced sedentary behaviour and good sleep patterns are also required (Ministry of Health, 2017; Tremblay et al., 2016). It was beyond the scope of this study to include all the physical activity outcomes and therefore results need to be interpreted accordingly. For example, even if a child with bronchiectasis completed 60 minutes of MVPA but then spent the rest of the day/night sedentarily playing videogames and went without adequate sleep, the child will still be at an increased risk for cardio-metabolic complications (Carson et al., 2016). Nonetheless, the findings from the current study provides useful data regarding current MVPA achievement, clearly indicating that children with bronchiectasis, like most New Zealand children, require additional support for increasing their daily physical activity levels. Future research is required to investigate the interaction between all three domains - physical activity, sedentary behaviour, and sleep - for children with bronchiectasis. Also there is a need to identify targeted behaviour modifications including adherence to age-appropriate screen time regulations that would have the greatest influence on improving health outcomes.

Accepting these limitations, the current study has provided valuable information to the child bronchiectasis field. Not only has it further highlighted that children with bronchiectasis are less active than their healthy peers, but it has also provided the first insight into MVPA behaviour for each day of the week, potential demographic and disease specific correlations that may lead to poorer MVPA achievement, and modes of activity children are participating in. The results provide an exciting platform for future researchers to build New Zealand-specific, physical activity initiatives for children with bronchiectasis.

7.3 Future research recommendations

This study has provided new insight into physical activity levels of children aged 7 to 12 years living in Counties Manukau. Furthermore, it has created a good foundation for further physical activity research to build upon. Future researchers can either continue to build on the current study or work towards identifying physical activity interventions or initiatives to increase physical activity levels for children with bronchiectasis.

7.3.1 Evolution of the current study protocol

As the study was prematurely stopped due to COVID-19, future researchers could aim to repeat the study as per the original study protocol, with an adequate sample size and statistical power, to establish physical activity levels of children with bronchiectasis living in Counties Manukau. However, since the original study protocol was written in 2019 and the New Zealand health system has experienced significant service and priority changes following COVID-19 and health restructure to Te Whatu Ora – Health New Zealand, adaptations to some of the recruitment strategies and outcome measures applied, would be recommended to ensure the study remained relevant to the new health context.

Recruitment strategy would need to align within the new Te Whatu Ora – Health New Zealand framework and health priorities, therefore extending participant recruitment to the entire Northern Region of Te Whatu Ora (Appendix B) would be recommended. This would encompass child bronchiectasis services from Northland, Auckland, Waitematā and Counties Manukau regions. This would result in a larger and more diverse sample which was more representative of the unique child bronchiectasis population of New Zealand. The larger sample size would also facilitate a more in-depth assessment of physical activity participation and could include the influence of rural and urban settings, including service delivery, equity of service access while remaining cognisant of regional economic deprivation.

As previously highlighted, the national datasets currently available for baseline comparison (Oliver et al., 2016; Smith et al., 2018; Sport New Zealand, 2020a; Wilson et al., 2023), were completed before the COVID-19 pandemic and are unlikely to represent future physical activity behaviours. To overcome outdated normative datasets, and to ensure an accurate and comparable baseline group, the inclusion of a Northern Regional healthy control group is strongly recommended. Outcome measures should be extended to include all physical activity intensity levels - mild, moderate, vigorous and MVPA - as well as sedentary behaviour and sleep patterns as per New Zealand's physical activity guidelines (Ministry of Health, 2017). To achieve this, accelerometer processing methods such as valid dataset criteria and cut-point

algorithms will also need to be modified to facilitate the additional outcome measures. Increasing the valid dataset criteria from three to four days, inclusive of at least one weekend day, would provide a more thorough representation of physical activity levels over the seven-day assessment period. It would also support a shift in MVPA recommendations from 'at least 60 minutes per day', to 'an accumulated average of 60 minutes per day'. Extending Chandler et al. (2016) cut-point algorithms to include all physical activity intensity counts, would also be required to process the newly added outcome measures.

These adaptations would improve the protocol, if the current study were to be repeated. However the current study, and that of Joschtel et al. (2019), have both illustrated that children with bronchiectasis are less active than their peers. For that reason future research needs to shift towards intervention studies that focus on increasing physical activity participation to improve overall health outcomes and disease prevention trajectory.

7.3.2 New initiative research

Current bronchiectasis management guidelines are insufficient, briefly stating that children should be encouraged to participate in regular physical activity (Chang et al., 2015; Chang, Fortescue, et al., 2021). To improve the current body of evidence in this field, three avenues are suggested and described below in the subsequent sections: validation of key physical activity outcome measures for children with bronchiectasis; investigation into the therapeutic benefits children with bronchiectasis achieve when participating in regular physical activity; and exploration of physical activity interventions and initiatives to improve physical activity engagement.

7.3.2.1 Validation of outcome measures

To ensure outcome measures are accurately capturing physical activity levels in children with bronchiectasis, further psychometric testing is required. Ideally, outcome measures would be validated within a bronchiectasis population, especially among those that are more likely to be influenced by disease i.e., accelerometry cut-points. The study by Bianchim, McNarry, Barker, et al. (2022) provided accelerometer cut-points for children with cystic fibrosis. Due to the similarity between the two conditions, future research could test these cut-points against a child bronchiectasis population. Other more generic health outcome measures, such as the PAQ-C, would be better validated against a New Zealand population with children of different ages and languages to facilitate future comparison between other national studies.

Like most physical activity research in child populations, there is a great need for a more robust reporting of methods of data collection and analysis so that strengths and limitations

can be better understood and future work can be replicated to ensure repeatability and utility in the future. Current guidance is limited to general principles (Arvidsson et al., 2019; Matthews et al., 2012; Montoye et al., 2018) and although some progress has been made over the last decade, further work in this area is much needed to standardise physical activity research processes, especially for children with chronic respiratory disease such as bronchiectasis, cystic fibrosis and asthma.

7.3.2.2 Therapeutic benefits of physical activity for children with bronchiectasis

Larger studies, for example prospective cohort studies or randomised controlled trials, are needed to determine the short- and long-term effects physical activity has on clinical outcomes for children with bronchiectasis. Outcomes could include: frequency of exacerbations, antibiotic courses and hospitalisations, functional exercise capacity, muscle strength and quality of life. Findings from the current study could aid in the design of such research, for example the mode of activity children with bronchiectasis most commonly participate in, could be used as the basis of a physical activity intervention.

At present, a multi-centre, randomised control trial is underway in Australia to establish whether therapeutic exercise decreases exacerbation frequency in children with bronchiectasis (Jones et al., 2022). Children aged 4 - 13 years will partake in the novel eight-week play-based therapeutic exercise programme. The authors hypothesise that participants will have significantly less acute exacerbations in the 12 months following the programme compared to the wait-listed controls. A systematic review by Ward et al. (2021) exploring exercise as an alternative to airway clearance techniques in a cystic fibrosis population, indicated that exercise improves ease of expectoration compared with rest and may have some short term benefits. A duplicate study to Jones et al. (2022) could be completed in New Zealand using a multicentre approach across the four child bronchiectasis centres within the Northern region of Te Whatu Ora - Health New Zealand. To improve the uptake and adherence of a paediatric pulmonary rehabilitation programme in the New Zealand context, involvement of the wider family/whānau should be considered. A possible option could include a weekend class that included siblings and other extended family/whānau to participate in the programme, alongside the child with bronchiectasis, with the aim of up-skilling families/whānau to take ownership of their own physical activity in the future. This would improve weekend physical activity levels for the child with bronchiectasis, already identified as an area of concern in the current study, provide an opportunity for the wider family/whānau to benefit from being more active and support family/whānau physical activity independence.

7.3.2.3 Child and family/whānau centred physical activity interventions and initiatives

Before undertaking an intervention study, in-depth qualitative studies are recommended to better understand the specific physical activity needs of children with bronchiectasis living in Counties Manukau. The first set of interviews should be completed with children who have bronchiectasis and their family/whānau, to explore current and future physical activity needs. Interview themes should examine facilitators and barriers that influence participation in physical activity, in-depth questions around mode of physical activity, and exploration of the types of physical activity programmes children and family/whānau are interested in participating in. Exploration of potential family/whānau led physical activity initiatives would provide a novel, and perhaps more sustainable, community-based opportunities for children with bronchiectasis to lead a more active lifestyle, without reliance on physiotherapists or other health services.

The next stage of interviews should be completed with key stakeholders such as the bronchiectasis MDT specialists, schools/teachers, Ministry of Education, and other non-governmental agencies such as Sports New Zealand. Interviews questions should aim to identify and access physical activity interventions, community initiatives or other available supports that could be offered to children with bronchiectasis to enable a more active lifestyle. The direction of questions with stakeholders would focus on exploring avenues deemed most important by children and family/whānau, during the first set of interviews. The findings gained from these qualitative interviews, in conjunction with the current study results and available literature, would then shape the development of physical activity interventions that were meaningful and population specific, ideally resulting in better programme uptake and long-term health outcomes.

Based on the qualitative findings, future research could continue to follow traditional pathways that target interventions towards children with poor exercise tolerance and physical activity capacity. This could include investigating the effectiveness of interventions, such as the aforementioned PACES or pulmonary rehabilitation programmes. However, the literature in healthy child populations suggests that school-based interventions only improve health outcomes for the duration of the intervention and don't necessarily transfer into the home setting (Love et al., 2019). Additionally Jones et al. (2022) is already completing a multi-centre randomised control trial investigating the effects of a paediatric pulmonary rehabilitation programme. Instead, future research could investigate if less traditional physical activity interventions, such as a weekend programme, or participation in community-led physical activity initiative, could provide a new and more sustainable option for children with bronchiectasis.

Research shows children, including those with bronchiectasis, are less physically active on weekends and engage in more sedentary behaviours (Brazendale et al., 2021; Zhang et al., 2019). Based on the theory that any small change in physical activity will positively contribute to health benefits (Altenburg et al., 2016), a weekend intervention that increases MVPA minutes would improve overall health outcomes for children with bronchiectasis. Two weekend based avenues that could be explored using already available community programmes within Counties Manukau, are weekend school or club sports programmes like netball or rugby, and family/whānau-based physical activity programmes like Active Families (Ministry of Health, 2022a), Green Prescription (Ministry of Health, 2021b) or Brown Buttabean Motivation (Brown Buttabean Motivation, 2022). Future research could investigate if participation in regular weekend physical activity improved overall achievement of MVPA minutes across the week, and what short- and long-term effects this had on physical health outcomes and quality of life for children with bronchiectasis. If financial barriers needed to be overcome, future interventions could partner with community initiatives such as Sports New Zealand 'Active Me – Kia Tū' programme, which provides financial assistance, up to NZD\$300 per child, for two years, towards sports uniforms, equipment and registration fees (Sport New Zealand, 2023).

Lastly, longitudinal research has shown that weekend MVPA declines more rapidly than weekday MVPA as age increases (Brazendale et al., 2021). Therefore, interventions targeted at children aged 9 - 18 years, are recommended, as positive health behaviours developed during childhood, lead to improve physical activity behaviours in adulthood (Telama et al., 2005). In attempting to curb the steep decline in physical activity observed in New Zealand children from 14 years of age (Sport New Zealand, 2020a), initiatives targeted at children with bronchiectasis during primary school years (5 - 12 years), may be most beneficial for achieving positive health behaviours that transfers into adolescence and then adulthood. As mentioned previously, family/whānau will need to be integrated into future interventions or initiatives in order to achieve sustainable physical activity outcomes for this younger population group.

This study, the study by Joschtel et al., (2019) and the limited bronchiectasis guidelines (Chang et al., 2015; Chang, Fortescue, et al., 2021), have all illustrated the significant knowledge gaps surrounding physical activity participation, and its associate health benefits, for children with bronchiectasis. Due to the increasing prevalence of the issue and its unique complexities both demographic and disease specific, it is vital researchers invest in bronchiectasis specific physical activity research as outlined above, rather than relying on clinicians to continue providing interventions based on evidence extrapolated from similar population groups.

7.4 Conclusion

This is the second study to examine physical activity levels in children with bronchiectasis, and the first study completed in a New Zealand population. Findings from this study provide important new information that enhance the current knowledge surrounding physical activity levels for children with bronchiectasis that will assist clinicians working with these populations.

The study showed that children with bronchiectasis completed less minutes of MVPA and subsequently achieved daily MVPA recommendations less often than their healthy peers. Based on these findings, routine physical activity assessment needs to be better incorporated into standardised bronchiectasis management, to avert children succumbing to preventable co-morbidities associated with inactivity that further negatively impacts the trajectory of their bronchiectasis. The study's findings should also challenge clinicians to consider undertaking a more generalised approach towards improving physical activity participation for all children with bronchiectasis, rather than the more traditional approach of focusing on those with explicit exercise capability issues.

This was the first study to investigate associations between MVPA achievement and demographic and disease severity markers. Three demographic markers (BMI, high socioeconomic deprivation, gender) and three disease severity markers (low FEV1% predicted, three or more lobes with bronchiectasis, recent hospital admission), were found to be associated with lower MVPA minute achievement. These findings will better enable physiotherapists to identify and monitor children at increased risk of not achieving daily MVPA recommendations and undertake early and targeted physical activity interventions. This more proactive approach has the potential to improve child health outcomes and reduce future health burdens for the individual and wider healthcare system. Furthermore, the ability to easily identify children with the greatest healthcare needs, is a significantly valuable tool for any busy physiotherapy service, where regular assessment for every child with bronchiectasis may not be a feasible option.

The study provided original evidence regarding minutes of MVPA achieved each day, across the week. Children with bronchiectasis living in Counties Manukau are most active during the week while at school, and therefore participated in more informal school yard games. Subsequently, this meant they were significantly less active over the weekend and participated in fewer organised sports. These findings provide valuable information to clinicians and future researchers wanting to implement effective and population specific physical activity interventions and initiatives.

While this study provides valuable insight into current physical activity levels for children with bronchiectasis living in Counties Manukau, further research now needs to be undertaken to address these physical activity insufficiencies. Investigation into a family/whānau, weekend-based physical activity intervention, using already established community programmes, could provide a novel and exciting way to increase weekend physical activity levels for children with bronchiectasis, while also instilling positive physical activity behaviours for the wider family/whānau unit. Application of a community-based intervention that only requires support to be set up, would also avoid placing additional strain on current bronchiectasis MDT and physiotherapy services while also achieving improved outcomes for children with bronchiectasis.

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Glossary

Term	Meaning
Accelerometer	Refers to the ActiGraph wGT3X+ accelerometer (ActiGraph LLC, Pensacola, FL, USA) used in the study.
Alert Level	A four tier approach used in New Zealand's Elimination Strategy that outlined the public health and social measures that country was required to follow (Appendix G).
Body Mass Index (BMI)	BMI is calculated using the formula $BMI = \text{kgs} / (\text{m}^2)$. Grouped into categories: underweight BMI ≤ 18.4 ; healthy BMI 18.5 - 24.9; overweight BMI 25.0 - 29.9; obese BMI ≥ 30 (New Zealand Guidelines Group, 2012).
Bronchiectasis	A chronic respiratory disease characterised by a chronic wet cough, sputum production and abnormal and permanent dilation of the bronchial walls (Chang, Fortescue, et al., 2021).
Children	For this thesis, the term child or children is defined as five to twelve years old. The thesis will state the age of the child population if the literature differs to the definition used in this study.
Counties Manukau District Health Board (CMDHB)	Health board allocated to the Counties Manukau region.
COVID-19	A highly infectious respiratory disease caused by the SARS-CoV-2 virus.
Cut-point algorithms	Group acceleration counts into physical activity intensity levels that align with MET thresholds. This study uses Chandler et al. (2016) cut-points.
District Health Board (DHB)	New Zealand's National Health Service that provided health funding and service provisions through 20 different DHB's until July 2022 when it was replaced by Te Whatu Ora – Health New Zealand (Appendix B).
Elimination strategy	New Zealand initial COVID-19 response that focused on maintaining zero COVID-19 cases. A keep it out, find it and stamp it out approach was undertaken (Ministry of Health, 2022e).
Epoch length	The interval of time raw accelerometer data is collapsed into a summary metric (acceleration counts).
Forced vital capacity (FVC)	The total amount of air that can be forcibly exhaled in one breath, measured using spirometry.
Forced expiratory volume in one second (FEV1)	The volume of air exhaled in the first second on a forced exhalation breath, measured using spirometry. For the study, FEV1 was presented as FEV1% predicted and grouped into severity categories: normal $\geq 100\%$; mild 80 - 99%; moderate 50 - 79%; severe $\leq 49\%$ (Jat, 2013).
High-resolution computed	Uses thin cross-sectional x-ray scans to produce a detailed

tomography (HRCT)	image from inside the body and used to identify pathology. A HRCT of the chest is gold standard for diagnosing bronchiectasis.
Kapa haka	Māori term for performing arts. Kapa haka involves traditional Māori song, dance and chanting.
Kidz First Hospital	Counties Manukau's paediatric hospital.
Lockdown	Government mandate used during the COVID-19 pandemic which required people to stay at home in order to break the chain of transmission and slow the spread of COVID-19.
Māori	Indigenous population of New Zealand.
Metabolic equivalent of task (MET)	A physiological measure expressing the intensity of a physical activity; see Appendix D for MET threshold categorisation.
Minimise and Protect strategy	New Zealand second COVID-19 phase, where the aim was to protect those at most risk of disease and poor outcomes, and minimised the spread of COVID-19 in order to protect the health system (Ministry of Health, 2022e).
Mode of physical activity	Refers to the type of activity a child is completing i.e., swimming, running, netball.
Moderate to vigorous physical activity (MVPA)	A category of physical activity intensity that consistently demonstrated improved health benefits when achieved. MVPA utilises an intensity of ≥ 3 METS.
Multidisciplinary team (MDT)	A group of health professionals from different disciplines that work together to provide comprehensive healthcare services. In a paediatric bronchiectasis clinic the MDT typically consists of respiratory paediatricians, nursing, physiotherapy, social work, and spirometry technicians.
New Zealand Deprivation Index (NZDep Index)	An area-based measure of socioeconomic deprivation. It uses a 1-10 scale to represent the mean deprivation of an area, with a score of 1 representing the least deprived areas, and 10 the most deprived areas (Atkinson et al., 2019; Lees et al., 2021)
Sample frequency	The rate each axis on an accelerometer records acceleration of the body part it is connect to.
Sedentary behaviour	Any waking behaviour that utilises minimal energy consumption (≤ 1.5 METs) while sitting, reclining, or lying.
Spirometry	Measures lung function, specifically the volume and speed that air can be inhaled or exhaled. FEV1 and FVC (see above) are common outcome measures used to determine lung function impairment.
Starship Hospital	Auckland children's hospital, and New Zealand's tertiary children's hospital.
SuperClinic	Counties Manukau outpatient healthcare centre, location of the Kidz First bronchiectasis MDT clinic.
Te Whatu Ora – Health New Zealand	New Zealand's new National Health Service that replaced the District Health Board system in July 2022. Provides health funding and service provisions through 12 regional areas (Appendix B).

**World Health
Organization (WHO)**

International body responsible for health guidelines to aid national governmental bodies.

**World Health
Organization's physical
activity recommendations**

Children aged five to seventeen years should complete at least an average of 60 minutes per day of MVPA, across the week. Physical activity should mostly be aerobic based, but also incorporate muscle and bone strengthening activities for at least three days a week (World Health Organization, 2020a).

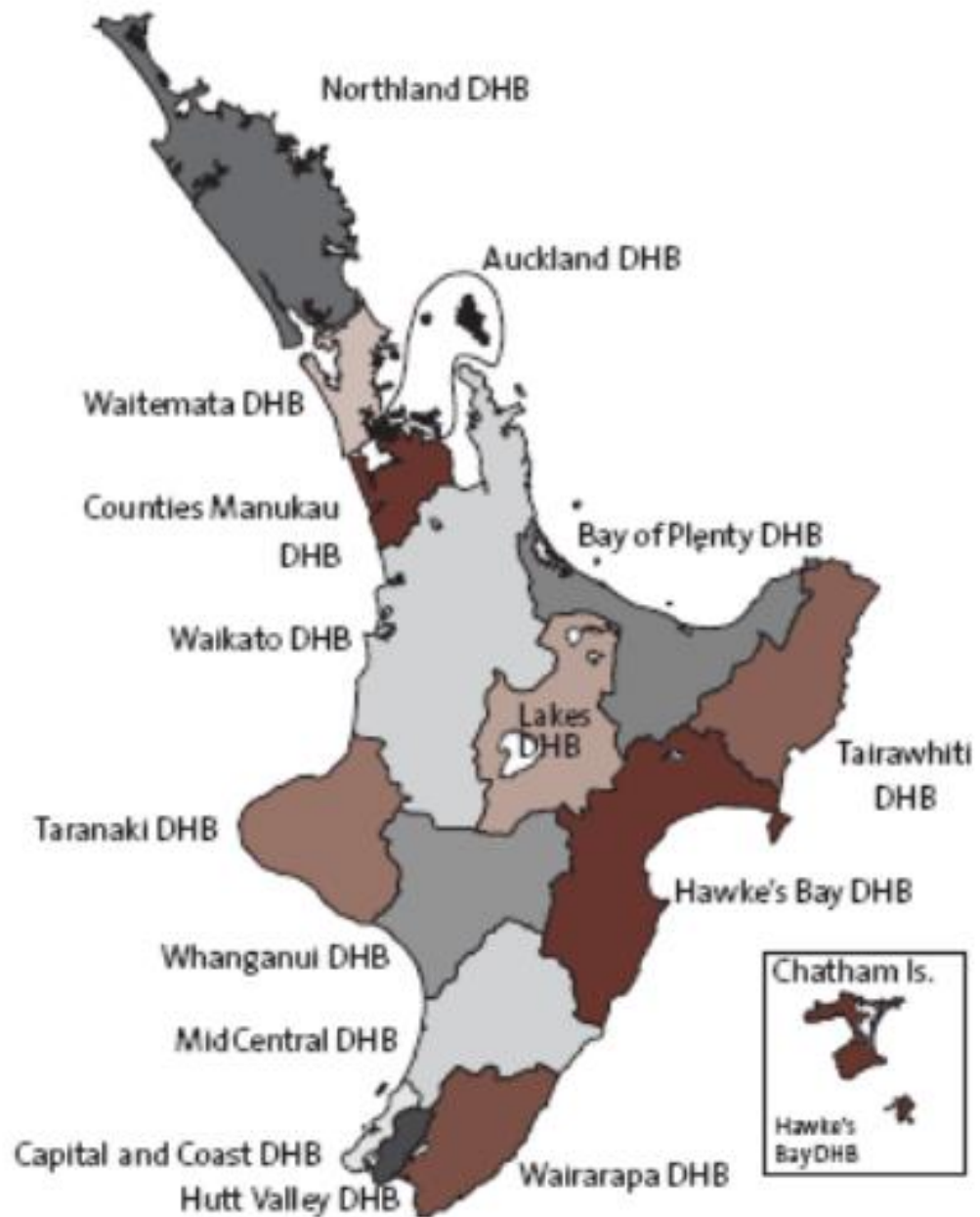
Appendices

Appendix A: Methodological approach applied to the search literature

- **Literature searches** were completed between March 2020 and January 2023.
- **Journal articles** were accessed from EBSCOhost (CINAHL, Medline and SPORTDiscus), Scopus, Science Direct via Ovid, PEDro, and Cochrane via Wiley.
- **Search terms** included, but were not limited to, bronchiectasis, non-cystic fibrosis bronchiectasis, primary ciliary dyskinesia; child*, paediatric, adolescen*, youth, school age; physical activity, daily activity, exercis*; acceleromet*, ActiGraph, cut-point. Boolean operators were used on search terms.
- **Studies were limited** to full text and published in English.
- **Studies were screened** by title and abstract to determine if appropriate for inclusion. Grey literature searches were completed on the selected articles reference lists, as well as governmental websites (Ministry of Health, Statistics New Zealand, Sports New Zealand, and Counties Manukau Health) and respiratory foundations and societies (Thoracic Society of Australia and New Zealand, European respiratory Society, Starship guidelines and Asthma and Respiratory Foundation).
- **Studies were included** in the literature review if they included children aged 5-17 years with bronchiectasis and assessed physical activity levels, specifically MVPA using an accelerometer.

Appendix B: District Health Board (DHB) and Te Whatu Ora – Health New Zealand regions

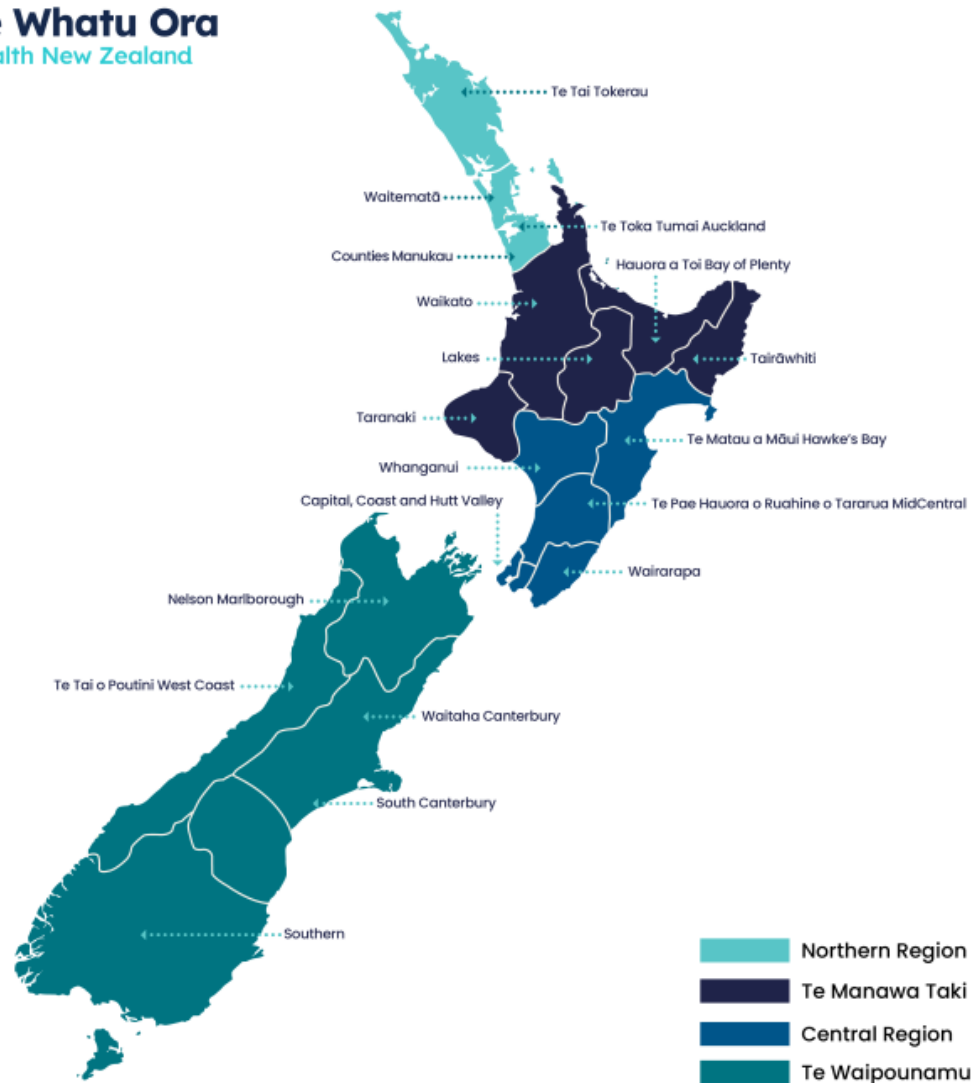
Map of District Health Boards in the North Island



Note. Map retrieved from: https://oag.parliament.nz/2009/copy_of_2007-08/part5.htm

Map of Te Whatu Ora – Health New Zealand Regions

Te Whatu Ora
Health New Zealand



Note. Map retrieved from: <https://careers.tewhatauora.govt.nz/nursing-in-nz>

Appendix C: Bronchiectasis exacerbation definition

Community criteria for identifying bronchiectasis exacerbations in children with bronchiectasis as per Kapur et al. (2012). The criteria were deemed to have a sensitivity of 95%, specificity of 75%, calculated area under the curve (AUC) of 0.84, $P < 0.001$, positive predictive value (PPV) of 78.5%, and negative predictive value (NPV) of 93.75%.

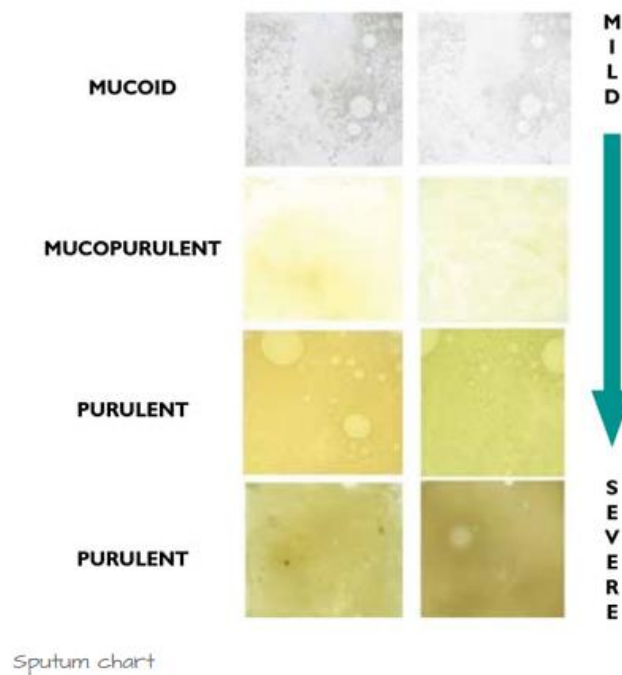
A positive exacerbation requires one major criterion PLUS and two minor criterions:

Major Criteria

- Significant increase in cough frequency over 72 hours
- Wet cough for 72 hours

Minor Criteria

- Sputum colour ≥ 3 on Bronko Test (See image below)
- Parent/child perceived breathlessness
- Chest pain
- Crepitations or crackles on auscultation
- Wheeze
- Hypoxia



Note. Image sourced from <https://mylungsmylife.org/topics/group-1/how-to-clear-your-chest/about-sputum/>

Appendix D: Definitions for common terms used physical activity research

Domains of Physical Activity:

- Leisure time – Non-essential physical activity; includes exercise, organised sports, and recreational activities i.e., walking, gardening, fishing.
- Education – Physical activity completed during school or at other educational institutions i.e., playgrounds, and physical education classes.
- Occupation – Physical activity completed during work i.e., manual labour, and stairs.
- Household – Physical activity completed during domestic duties i.e., cleaning, cooking and childcare.
- Transportation – Physical activity completed getting to and from a place i.e., walking, cycling and non-motorised wheeling such as scooters, skateboards, wheelchairs.

Physical Activity Intensities:

- **Metabolic equivalent of task (MET):** is a physiological measure expressing the intensity of a physical activity. One MET is the energy equivalent expended by an individual while seated at rest. The higher the intensity, the more energy is expended resulting in a higher MET score.
- **Sedentary:** Any waking behaviour that utilises less than 1.5 METs while sitting, reclining, or lying. This includes driving, desk-based office work and watching T.V.
- **Light intensity physical activity:** Physical activity that requires light in intensity and between 1.5 and 3 METs. This can include slow walking, showering, or other incidental activity that does not result in a substantial increase in heart or respiratory rate
- **Moderate intensity physical activity:** Physical activity that is moderately intense and between 3 to 6 METs. On a relative scale of 0-10 it is a 5 or 6.
- **Vigorous intensity physical activity:** Physical activity that is of high intensity and performed at 6 or more METs. On a relative scale of 0-10 it is a 7 or 8.
- **Moderate to vigorous physical activity (MVPA):** Combined physical activity intensity performed at 3 or more METs. On a relative scale of 0-10 it is a 6 or more. Used as a target for physical activity research and recommendations.

Appendix E: Physical Activity Questionnaire – Child (PAQ-C): Questionnaire and scoring instructions

1. Physical activity in your spare time: Have you done any of the following activities in the past 7 days (last week)? If yes, how many times? (Mark only one circle per row.)

	No	1-2	3-4	5-6	7 or more
Skipping	☐	☐	☐	☐	☐
Rowing / canoeing	☐	☐	☐	☐	☐
In-line skating	☐	☐	☐	☐	☐
Tag	☐	☐	☐	☐	☐
Walking for exercise	☐	☐	☐	☐	☐
Bicycling	☐	☐	☐	☐	☐
Jogging / running	☐	☐	☐	☐	☐
Aerobics	☐	☐	☐	☐	☐
Swimming	☐	☐	☐	☐	☐
Baseball / softball / t-ball	☐	☐	☐	☐	☐
Dance	☐	☐	☐	☐	☐
Football (American)	☐	☐	☐	☐	☐
Badminton	☐	☐	☐	☐	☐
Skateboarding	☐	☐	☐	☐	☐
Soccer	☐	☐	☐	☐	☐
Street hockey	☐	☐	☐	☐	☐
Volleyball	☐	☐	☐	☐	☐
Floor hockey	☐	☐	☐	☐	☐
Basketball	☐	☐	☐	☐	☐
Ice skating	☐	☐	☐	☐	☐
Cross-country skiing	☐	☐	☐	☐	☐
Ice hockey/ringette	☐	☐	☐	☐	☐
Athletics	☐	☐	☐	☐	☐
Rugby	☐	☐	☐	☐	☐
League	☐	☐	☐	☐	☐
Touch rugby	☐	☐	☐	☐	☐
Netball	☐	☐	☐	☐	☐
Cricket	☐	☐	☐	☐	☐
Tennis	☐	☐	☐	☐	☐
Gymnastics	☐	☐	☐	☐	☐
Other:	☐	☐	☐	☐	☐
.....	☐	☐	☐	☐	☐
.....	☐	☐	☐	☐	☐
.....	☐	☐	☐	☐	☐

2. In the last 7 days, during your physical education (PE) classes, how often were you very active (playing hard, running, jumping, throwing)? (Check one)

I don't do PE	☐
Hardly ever	☐
Sometimes	☐
Quite often	☐
Always	☐

3. In the last 7 days, what did you do most of the time at recess (morning tea)? (Check one)

Sat down (talking, reading, doing schoolwork)	☐
Stood around or walked around	☐
Ran or played a little bit	☐
Ran around and played quite a bit	☐
Ran and played hard most of the time	☐

4. In the last 7 days, what did you normally do at lunch (besides eating lunch)? (Check one)

Sat down (talking, reading, doing schoolwork)	☐
Stood around or walked around	☐
Ran or played a little bit	☐
Ran around and played quite a bit	☐
Ran and played hard most of the time	☐

5. In the last 7 days, on how many days right after school, did you do sports, dance, or play games in which you were very active? (Check one)

None	☐
1 time last week	☐
2 or 3 times last week	☐
4 times last week	☐
5 times last week	☐

6. In the last 7 days, on how many evenings did you do sports, dance, or play games in which you were very active? (Check one)

None	☐
1 time last week	☐
2 or 3 times last week	☐
4 or 5 times last week	☐
6 or 7 times last week	☐

7. On the last weekend, how many times did you do sports, dance, or play games in which you were very active? (Check one)

None	☐
1 time	☐
2 - 3 times	☐
4 - 5 times	☐
6 or more times	☐

8. Which one of the following describes you best for the last 7 days? Read all five statements before deciding on the one answer that describes you.

All or most of my free time was spent doing things that involve little physical effort		☐
B. I sometimes (1 — 2 times last week) did physical things in my free time (e.g., played sports, went running, swimming, bike riding, did aerobics)		☐
C. I often (3 — 4 times last week) did physical things in my free time		☐
D. I quite often (5 — 6 times last week) did physical things in my free time		☐
E. I very often (7 or more times last week) did physical things in my free time		☐

9. Mark how often you did physical activity (like playing sports, games, doing dance, or any other physical activity) for each day last week.

	None	Little bit	Medium	Often	Very often
Monday	☐	☐	☐	☐	☐
Tuesday	☐	☐	☐	☐	☐
Wednesday	☐	☐	☐	☐	☐
Thursday	☐	☐	☐	☐	☐
Friday	☐	☐	☐	☐	☐
Saturday	☐	☐	☐	☐	☐
Sunday	☐	☐	☐	☐	☐

10. Were you sick last week, or did anything prevent you from doing your normal physical activities? (Check one)

Yes	☐
No	☐

If yes, what prevented you? _____

11. Did you remove the device during the study period

Yes	☐
No	☐

If yes, when (day and time)? _____

Scoring the PAQ-C – For researchers only:

For researchers only									
Question	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
Score									

Total Score: _____

Mean Score: _____ PAQ-C Activity Rating: _____

Overall process - Find an activity score between 1 and 5 for each item (excluding item 10)

Five Steps:

1) Item 1 (*Spare time activity*)

- Take the mean of all activities ("no" activity being a 1, "7 times or more" being a 5) on the activity checklist to form a composite score for item 1.

2) Items 2 to 8 (*PE, recess, lunch, right after school, evening, weekends, and describes you best*)

- The answers for each item start from the lowest activity response and progress to the highest activity response
- Simply use the reported value that is checked off for each item (the lowest activity response being a 1 and the highest activity response being a 5).

3) Item 9

- Take the mean of all days of the week ("none" being a 1, "very often" being a 5) to form a composite score for item 9.

4) Item 10

- Can be used to identify students who had unusual activity during the previous week, but this question is **NOT** used as part of the summary activity score.

5) How to calculate the final PAQ-C activity summary score 6

- Once you have a value from 1 to 5 for each of the 9 items (items 1 to 9) used in the physical activity composite score, you simply take the mean of these 9 items, which results in the final PAQ-C activity summary score.
- A score of 1 indicates low physical activity, whereas a score of 5 indicates high physical activity

Reference: Kowalski, K., Crocker, P., & Donen, R. (2004). The physical activity questionnaire for older children (PAQ-C) and adolescents (PAQ-A) manual. University of Saskatchewan.

Appendix F: New Zealand's COVID-19 timeline

Year 2019

29 December - Chinese authorities advise the World Health Organization of an unknown pneumonia from an unknown cause, originating in Wuhan, Hubei province.

Year 2020

7 January - China isolates a novel coronavirus - SARS-CoV-2 (COVID-19).

13 January - First lab-confirmed case outside China identified, in Thailand.

30 January - WHO declares the epidemic a global health emergency.

3 February - New Zealand temporarily bans entry of foreigners from, or who have travelled through, mainland China. Government-chartered plane flies to evacuate New Zealanders from Wuhan.

28 February - [New Zealand's first \(in Auckland\) confirmed case of COVID-19.](#)

14 March - All passengers arriving in New Zealand, except 17 Pacific Island countries/territories, must self-isolate for 14 days.

16 March - Government bans non-essential outdoor gatherings of >500 people; schools and universities exempt.

19 March - Government bans indoor events with >100 people: exemptions for workplaces, schools, supermarkets, and public transport. [Border closed to all but New Zealand citizens /permanent residents.](#)

OUTBREAK ONE:

21 March - [The Government introduces the 4-tiered Alert Level system \(Appendix G\).](#) New Zealand is at **Alert Level 2** with 52 confirmed cases and four probable cases.

23 March - New Zealand moves to **Alert Level 3 effective immediately** following 102 confirmed cases and evidence of community transmission in Auckland and Wairarapa.

25 March - **Alert Level 4** with 205 confirmed cases. A State of National Emergency declared.

29 March - [New Zealand's first COVID-19 death.](#)

27 April - New Zealand steps down to **Alert Level 3.**

13 May - Outbreak considered controlled, New Zealand steps down to **Alert Level 2.**

8 June - No active cases of COVID-19, New Zealand steps down to **Alert Level 1.** Total number of confirmed cases 1504

OUTBREAK TWO:

11 August - [Four new cases in the Auckland community](#) with no known source of transmission. 102 days since the last community

12 August - [Auckland moves into Alert Level 3](#) (first region-based lockdown); wider New Zealand goes into Alert Level 2.

30 August - Auckland steps down to Alert Level 2, informally called "level 2.5" due to smaller gathering size allowances.

21 September - All New Zealand, except Auckland, moves to Alert Level 1.

23 September - Auckland steps down to Alert Level 2 (without restrictions).

7th October - Auckland steps down to Alert Level 1 with the rest of New Zealand.

Year 2021

OUTBREAK THREE:

14 February - Three community cases detected in Counties Manukau Auckland (Papatoetoe High School). Auckland moves to Alert Level 3, wider New Zealand moves to Alert Level 2.

17 February - Auckland steps down to Alert Level 2, with specific restrictions for the Papatoetoe High School community, wider New Zealand moves to Alert Level 1.

19 February - New Zealand's first vaccination against COVID-19 (Pfizer-BioNTech vaccine).

22 February - Auckland, except Papatoetoe High School community, steps down to Alert Level 1 with the rest of New Zealand

OUTBREAK FOUR:

28 February - Auckland moves into Alert Level 3, wider New Zealand moves to Alert Level 2.

7 March - Auckland steps down to Alert Level 2, wider New Zealand steps down to Alert Level 1.

12 March - Auckland steps down to Alert Level 1, wider New Zealand steps down to Alert Level 1.

25 March - COVID-19 transmission detected in Auckland's managed isolation facilities.

8 April - First transmission to a border-related worker detected at an Auckland isolation facility.

11 April - Temporary ban comes on travellers, including New Zealand citizens and residents, coming from India, until 28 April.

19 April - Trans-Tasman quarantine-free travel bubble starts.

23 April - Government announces travel restrictions from countries in the new "very-high-risk" category, defined as more than 50 cases of COVID-19 per 1000 arrivals: India, Brazil, Papua New Guinea, and Pakistan meet the threshold.

24 April - Quarantine-free travel between Western Australia and New Zealand has been suspended.

28 April - New Zealand resumes quarantine-free travel with Western Australia.

1 May - Direct flights from Western Australia paused for 24 hours

6 May - Quarantine-free travel "paused" for three days with New South Wales.

25 May - Quarantine-free travel with Victoria paused.

8 June - [New Zealand reaches approximately 1 million COVID-19 vaccine doses administered to adults aged 16 years and over.](#)

23 June - Wellington region put into Alert Level 2; the rest of New Zealand remains at Alert Level 1.

26 June - Travel bubble with Australia paused until 29 June, because of multiple outbreaks in Australia.

29 June - Wellington steps down to Alert Level 1, all New Zealand now at Alert Level 1.

30 July - [A Middlemore Hospital health worker at Counties Manukau](#) is in precautionary quarantine after a minor PPE protocol breach during management of a COVID-19 case.

OUTBREAK FIVE:

17 August - [All New Zealand moves to Alert Level 4 lockdown](#) following a community case detected in Auckland Northshore with no known links.

19 August - Positive case of nurse working at Auckland Hospital.

20 August - Waitematā DHB closed Short Stay Surgical Unit following in-hospital transmission to a patient. [Children aged 12-15 now eligible for vaccination with Pfizer-BioNTech COVID-19 vaccine.](#)

22 August - Businesses and events are required to use the COVID-19 Tracer App or manual record

31 August - [Auckland and Northland remain at Alert Level 4](#), wider New Zealand south of the Auckland border step down to Alert Level 3, [creating the Auckland boundary. Largest cluster associated with Mangere Assembly of God Church.](#)

2 September - Northland steps down to Alert Level 3, [Auckland remains isolated and in Alert Level 4.](#)

7 September - All New Zealand, except Auckland, steps down to Alert Level 2 with new mask and sign-in/app-scan requirements, a reduction in group sizes and an expansion of social distancing.

20 September - The northern Hauraki area moves to an Alert Level 4 for people who have worked, lived, or visited there since 8 September

21 September - Upper Hauraki and [Auckland steps down to Alert Level 3.](#)

25 September - Upper Hauraki steps down to Alert Level 2

2 October - [Middlemore Hospital \(Counties Manuka\) reported a possible COVID-19 exposure event.](#)

3 October - Alert Level 3 restrictions for Raglan, Hamilton City, Ngaruawahia, Huntly and Te Kauwhata.

4 October - Hospital transmission reported at Auckland and Northshore hospitals.

5 October - [Alert Level 3 restrictions ease slightly in Auckland](#) allowing outdoor gatherings of two households with a maximum of 10 people, early childhood centres can open with bubbles of 10, and people can travel around the Auckland region for outdoor recreation.

7 October - Alert Level 3 expansion to the Waikato region - includes Waitomo, Waipa, and Otorohanga Districts.

8 October - Northland moves to Alert Level 3, [Auckland and parts of Waikato remain at Alert Level 3 with eased restrictions](#), the rest of New Zealand remains at Alert Level 2.

13 October - [My COVID Record website launched.](#)

16 October - Super Saturday achieves 130,002 COVID-19 vaccine doses administered nationally. In Auckland 85 per cent of eligible people have now had one dose.

19 October - Northland steps down to Alert Level 2, **Auckland and parts of Waikato remain at Alert Level 3 with eased restrictions.** Wider New Zealand remains at Alert Level 2.

27 October – Alert Level 3 step down model introduced. Parts of Waikato and **Auckland step down to Alert Level 3-Step 1.**

2 November - Parts of Waikato only step down to Alert Level 3-Step 2. Upper Northland moves to Alert Level 3. **Auckland remains on Alert Level 3-Step 1.** Wider New Zealand remain at Alert Level 2.

9 November - **Auckland steps down to Alert Level 3-Step 2.**

11 November – Upper Northland steps down to Alert Level 2. **Auckland and parts of Waikato remain at Alert Level 3-Step 2.** Wider New Zealand remain at Alert Level 2.

14 November - [Vaccination rate of eligible people: 90% \(first dose\); 81% \(second dose\).](#) Managed isolation period (MIQ) for international travellers decreases from 14 days to 7 days followed by isolation at home until day 9 test is negative.

16 November - Parts of Waikato step down to Alert Level 3-Step 2.

17 November - [Auckland and Waikato students in years 1-10 return to face-to-face learning at school.](#)

19 November - Auckland DHB the first to achieve 90% of eligible population fully vaccinated.

2 December - [Alert Level system replaced by COVID-19 Protection Framework \(Appendix H\)](#) - **Auckland moves to Red.**

14 December - Auckland's isolation boundary lifted.

16 December - Omicron: first case reported in New Zealand, in managed isolation in Christchurch

30 December - **Auckland steps down to Protection Framework Level Orange to join the remainder of New Zealand.** Only Northland remains at level Red.

Year 2022

17 January - [Vaccination rate of eligible people: 95% \(first dose\); 93% \(second dose\).](#) The paediatric Pfizer vaccine is now available for children aged 5–11 years.

20 January - Northland joins wider New Zealand at **COVID-19 Protection Framework Level Orange.**

OUTBREAK SIX:

23 January - First confirmed Omicron community case. **All New Zealand moves to COVID-19 Protection Framework Level Red.**

26 January - [Government introduced Omicron phases for Protection Framework Level Red.](#) Phase 1: Focus on stamping out small outbreaks, with PCR testing and 14-day isolation period. Phase 2: Focus on slowing the spread and protecting those most at risk of getting seriously ill. Contact tracing switches to online self-assessments, isolation period drops to 10 days. Phase 3: Focus on safely

managing COVID-19 at home with rapid antigen tests (RATs) and isolation for positive tests and household contacts.

31 January - Omicron is now the dominant variant of COVID-19 in New Zealand

3 February - New mandatory mask rules: Medical masks public facing workers and on public transport.

11 February - 43% of children aged 5-11 have had one dose; 56% of eligible population have had a booster dose.

16 February - All of New Zealand moves to Phase 2 of the Omicron plan.

24 February - All of New Zealand moves Phase 3 of the Government's Omicron plan comes.

27 February – International borders open for fully vaccinated New Zealanders and other eligible travellers returning to New Zealand from Australia. Instead of MIQ, they will self-isolate for 7 days.

1 March - Novovax vaccine approved in New Zealand for those 18 and older.

2 March – Fully vaccinated New Zealanders and other eligible people entering from Australia do not have to isolate but do need to fulfil testing requirements - negative pre-departure test, negative RAT results on arrival and on day 5/6 and self-isolate if tested positive.

4 March – Fully vaccinated New Zealanders and others with Immigration eligibility can enter from anywhere in the world and do not need to isolate.

11 March - Household contact isolation period to reduce from 10 to 7 days. 53.1% of children aged 5-11 have had one dose; 72.7% of people eligible for a booster dose have received it.

16 March - Fully vaccinated Australians will be able to travel to New Zealand isolation-free.

18 March - No MIQ or self-isolation for unvaccinated New Zealand citizens and those eligible to travel to New Zealand. Minimum vaccination requirements will apply to non-New Zealand citizens.

25 March – Changes to the COVID-19 Protection Framework Level Red. Indoor gathering limits increased from 100 to 200 people. No limitations on outdoor gatherings in any traffic light setting. No more contract tracing requirements for business and organisations.

Timeline ended in conjunction with end of study

Appendix G: Elimination Strategy for New Zealand: COVID-19 Alert Levels

Alert Level	Risk Assessment	Measures Applied Locally or Nationally
Level 1: Prepare		
The disease is contained in New Zealand	COVID-19 uncontrolled overseas Potential for sporadic imported cases Potential for isolated local transmission	Border entry measures applied to minimise risk of importing COVID-19 cases All educational providers, businesses, facilities, and workplaces open Contact tracing and record keeping No movement or gathering restrictions
Level 2: Reduce		
Low risk of community transmission within applied area	Limited community transmission Active clusters in more than one region	Entry borders measured maximised Limit non-essential travel around New Zealand Must wear a face mask in public if >12 years Gatherings restricted to 100 people with mandatory record keeping and social distancing Education and businesses open with additional health measures in place Physical distancing required at all times - public transport, work and event facilities and hospitality venues High risk individuals encouraged to remain home Level 2.5 = mandatory masks in all indoor settings, gatherings limited to 10 people
Level 3: Restrict		
Medium risk of community transmission. Active but managed clusters	Multiple cases of community transmission Multiple active clusters in multiple regions	Entry borders measured maximised Travel restricted to local only, strict inter-regional travel restrictions Stay home using alternative ways of working. If unable to work from home can return to work if they can safely operate under Alert Level 3 restrictions Must wear a face mask in public if >12 years Some educational facilities open for essential workers children Public venues closed No mass gatherings allowed – maximum of 10 people with physical distancing and record keeping Virtual primary care consultations Non-acute (elective) services and procedures in hospitals deferred and healthcare staff reprioritised Step 3.1 = < 10 people can meet outside, early childcare centres open, travel through Auckland region without stopping Step 3.2 = < 25 people can meet outside, public facilities and retail open with mask use and distancing

Level 4: Lockdown		
Likely the disease is not contained	Sustained and intensive community transmission Widespread outbreaks	Entry borders measured maximised Travel severely restricted - Stay home in your household bubble Must wear a face mask in public if >12 years Only essential travel allowed All education facilities closed Only essential business (supermarkets, pharmacy, petrol stations) and lifeline utilities (hospitals, fire, police) open No gathering allowed; all public facilities closed Major reprioritisation of healthcare services Rationing of supplies and requisitioning of facilities

Note. Last updated 27th October 2021.

Reference: <https://covid19.govt.nz/assets/resources/tables/COVID-19-Alert-Levels-summary-table.pdf>;

<https://www.dia.govt.nz/Local-Government-COVID-19-Response-Update-Wednesday-6-October-2021>

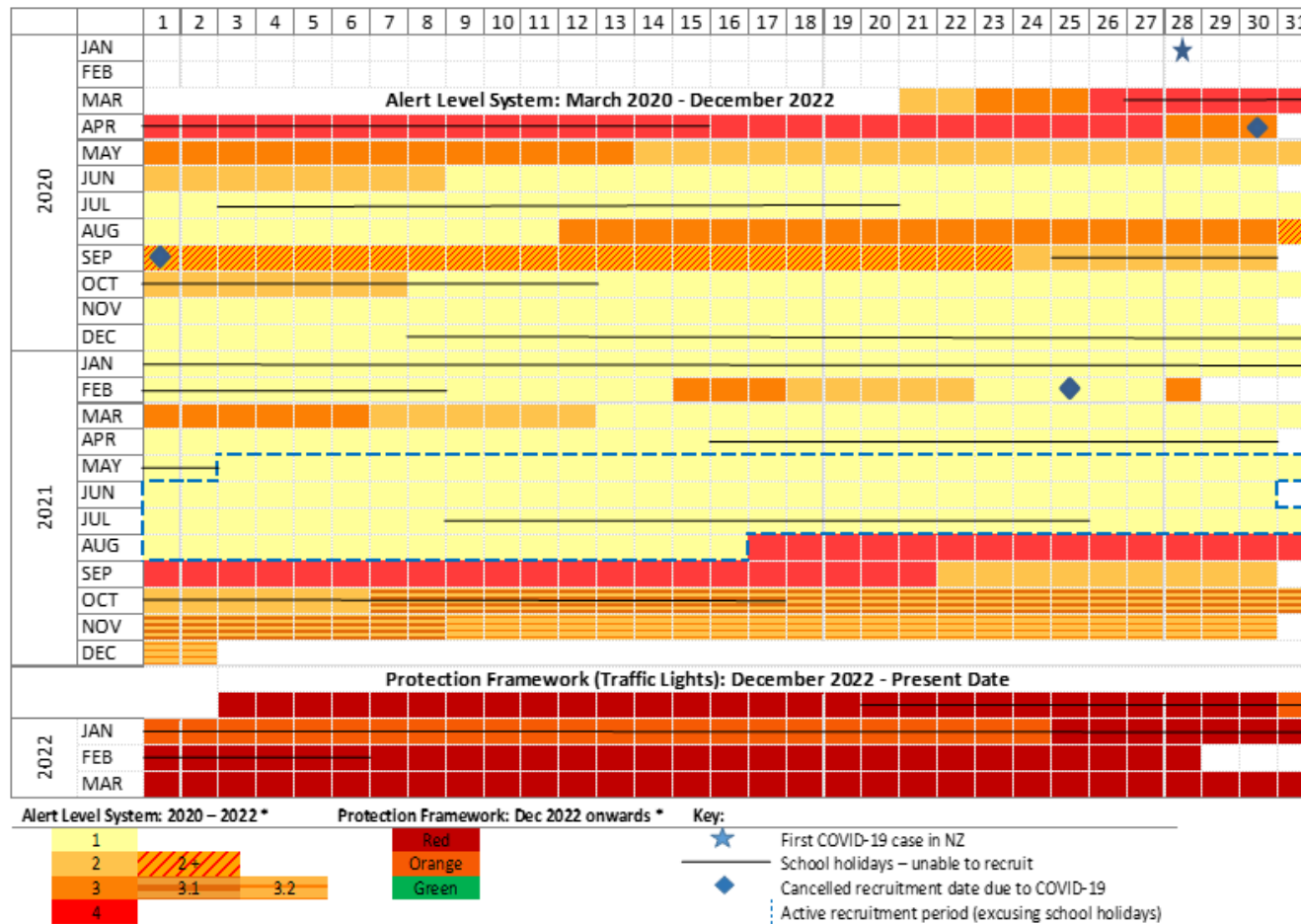
Appendix H: Minimisation and Protection Strategy for New Zealand: Protection Framework (Traffic Light System)

	Measures applied locally or nationally
Green	
COVID-19 across New Zealand, including sporadic imported cases Limited community transmission COVID-19 hospitalisations are at a manageable level Health system ready to respond	Face mask on flights and workers at large gatherings All education, public facilities and businesses open with no restrictions No gathering limits *Some restriction variations for non-vaccinated individuals – limited to gatherings of 100
Orange	
Community transmission with pressure on health system Health system ready to respond Increasing risk to at-risk populations	Record keeping / QR code scanning required Face mask in some public spaces if 12 years + Education opens with public health measures in place Public facilities, events and business open with capacity limits based on 1m distancing No gathering limits *Some restriction variations for non-vaccinated individuals – limited to gatherings of 50 and restricted venue access
Red	
Action needed to protect health system – facing unsustainable numbers of hospitalisations Action needed to protect at-risk populations	Record keeping / QR code scanning required Face mask when out in public if 12 years + Education opens with public health measures in place Encouraged to work from home if practical Public facilities, events and business open with capacity limits based on 1m distancing, and seated for food and drink services Gatherings limited to 100 people *Some restriction variations for non-vaccinated individuals – limited to gatherings of 25 and restricted venue access

Note. Mandatory record keeping / QR code scanning was stopped March 2022; Last updated 27th October 2021.

Reference: <https://covid19.govt.nz/assets/COVID-19-Protection-Framework/COVID-19-Protection-Framework-traffic-lights-summary-table.pdf>

Appendix I: Gantt chart of COVID-19's Alert Levels System in Auckland and its impact on study recruitment



Note. Refer to Alert Level System (Appendix G) and Protection Framework Appendix H) for definitions.

Appendix J: Global Initiative for Asthma (GINA) assessment of asthma symptom control in children 5 – 11 years

A. Asthma symptom control				Level of asthma symptom control		
In the past 4 weeks, has the patient had:						
• Daytime asthma symptoms more than twice/week?	Yes ☐	No ☐	}	Well controlled	Partly controlled	Uncontrolled
• Any night waking due to asthma?	Yes ☐	No ☐		None of these	1-2 of these	3-4 of these
• Reliever needed for symptoms* more than twice/week?	Yes ☐	No ☐				
• Any activity limitation due to asthma?	Yes ☐	No ☐				

Note. Table sourced from McNamara, D., Asher, I., Davies, C., Demetriou, T., Fleming, T., Harwood, M., Hetaraka, L., Ingham, T., Kristiansen, J., Reid, J., Rickard, D., Ryan, D., & Turner, J. (2020). New Zealand child asthma guidelines: A quick reference guide. Asthma + Respiratory Foundation NZ.

Appendix K: Health and Disability Ethics Committee - Approval letter



Health and Disability Ethics Committees

Ministry of Health
133 Molesworth Street
PO Box 5013
Wellington
6011

0800 4 ETHICS
hdec@health.govt.nz

14 May 2020

Mrs Laura Rensford
Paediatric Physiotherapy Department
Acute Allied Health Office
Middlemore Hospital
Private Bag 93311
Otahuhu, Auckland 1640

Dear Mrs Rensford,

Re: Ethics ref:	20/CEN/88
Study title:	Physical activity levels in children with bronchiectasis living in Counties Manukau, New Zealand.

I am pleased to advise that this application has been approved by the Central Health and Disability Ethics Committee. This decision was made through the HDEC-Full Review pathway.

Summary of Study

1. The aim of this study is to investigate how physically active children with bronchiectasis are compared to healthy matched controls. Ninety children (30 bronchiectasis/60 controls) aged 7 to 12 years will be recruited from Kidz First and Starship hospitals. Their legal guardian will be given an information pack to take home, and rung after a week to discuss further, and if they are interested an appointment is to provide more information.
2. Those children will be matched with healthy controls, who will be recruited from two or three local schools in the Counties Region. Control children are told about the study in class, and interested kids take an information pack home to read with their parents and bring back signed assent/consent forms. There is an opportunity to attend a prearranged meeting to discuss the study further.

Summary of resolved ethical issues

The main ethical issues considered by the Committee and addressed by the Researcher are as follows.

3. The Committee queried how those with bronchiectasis would be screened for. The Researcher explained that they would first be identified from the clinical records. A research nurse would introduce the study to potential participants, and if they are interested, the nurse would present them with an information pack to take home and read before consenting. An information evening will also be available for those who want to hear more about the study.
4. The Committee queried how schools will be approached. The Researcher explained that they will approach schools where they know that there are pockets of bronchiectasis children. The original contacts would be with the CENCO (?) teachers, through which they will be able to contact the principal and the board of trustees for approval. The Committee asked to see an information sheet for the principal and/or board of trustees.
5. Application question p.3.2.2.1 indicated that assent was not being sought from the children. The Researcher confirmed that assent would be sought.
6. The Committee noted that application question p.4.3 indicated that Māori consultation was not required, however the Researcher confirmed that consultation had been sought.

The Committee requested the following changes to the Participant Information Sheet and Consent Form:

7. Please make sure that all points in the consent form are previously mentioned in the PIS.
8. The Committee asked for clarification if the PIS was for all children involved in the study, or for a specific age group. The Researcher confirmed that the PIS is intended of all children aged 7-12 years old.
9. PIS for parents: 'Healthy' group may be stigmatising for those children with bronchiectasis. Please use "children with"/"without bronchiectasis" instead.
10. Please add to the PIS that participants have the right to request correction of their personal information.

Conditions of HDEC approval

HDEC approval for this study is subject to the following conditions being met prior to the commencement of the study in New Zealand. It is your responsibility, and that of the study's sponsor, to ensure that these conditions are met. No further review by the Central Health and Disability Ethics Committee is required.

Standard conditions:

1. Before the study commences at *any* locality in New Zealand, all relevant regulatory approvals must be obtained.
2. Before the study commences at *each given* locality in New Zealand, it must be authorised by that locality in Online Forms. Locality authorisation confirms that the locality is suitable for the safe and effective conduct of the study, and that local research governance issues have been addressed.

After HDEC review

Please refer to the *Standard Operating Procedures for Health and Disability Ethics Committees* (available on www.ethics.health.govt.nz) for HDEC requirements relating to amendments and other post-approval processes.

Your next progress report is due by 14 May 2021.

Decision

- Please amend the information sheet and consent forms, taking into account the suggestions made by the committee.

Note to the researcher: to clarify a confusion at the meeting, it is confirmed that nonstandard conditions *do not* need to be uploaded to the Online Forms portal, but it is helpful to include them along with any minor (non-substantial) amendments in the annual progress report. The CI and Sponsor are responsible for ensuring that nonstandard conditions are met before the study commences.

Participant access to ACC

The Central Health and Disability Ethics Committee is satisfied that your study is not a clinical trial that is to be conducted principally for the benefit of the manufacturer or distributor of the medicine or item being trialled. Participants injured as a result of treatment received as part of your study may therefore be eligible for publicly-funded compensation through the Accident Compensation Corporation (ACC).

Please don't hesitate to contact the HDEC secretariat for further information. We wish you all the best for your study.

Yours sincerely,

A handwritten signature in black ink, appearing to read 'Helen Walker', written in a cursive style.

Mrs Helen Walker
Chairperson
Central Health and Disability Ethics Committee

Appendix L: Counties Manukau Health Research Committee - Approval letter



Research & Evaluation Office
 Level 1, Ko Awatea, Middlemore Hospital
 100 Hospital Road, Otahuhu; Private Bag 93311, Auckland – 1640
cmdhb.org.nz – koawatea.co.nz

20 May 2020

For the attention of: Laura Rensford

Thank you for the information you have supplied to the CM Health Research & Evaluation Office regarding the following research proposal:

CM Health Research Registration Number: 1213

Ethics Approval Reference Number: HDEC: 20/CEN/88

Research Project Title: Physical activity levels in children with bronchiectasis living in the Counties Manukau region compared to healthy matched controls

I am pleased to inform you that the CM Health Research Office has received all the required service lead approvals and the Chief Medical Officer's final sign-off for the above research project, which has you named as the Principal Investigator.

This CM Health locality approval is valid until 31 March 2022, which is the Final Reporting Date specified on your registration information.

All external reporting requirements must be adhered to. Please note that failure to notify us of amendments, and/or submit copies of annual Progress Reports and annual Ethics renewal letters may result in the withdrawal of ethical and CM Health organisational approval.

FINAL REPORT: It is a requirement of the CM Health Research Policy that all research and audit projects conducted within CM Health should complete the CM Health Final Report template and submit no later than 3 months following completion of the study. This report is to be uploaded to your study file on the Registry and is viewable by CM Health staff. Contact us for the report template or download it from the Registry.

Yours sincerely

Angela Bennett
 Research Coordinator
 Counties Manukau Health

Under delegated authority from CM Health Research Committee and the Chief Medical Officer

Appendix M: Health and Disability Ethics Committee - Approved extension



Health and Disability Ethics Committees
Ministry of Health
133 Molesworth Street
PO Box 5013
Wellington
6011
hdec@health.govt.nz

Ethics reference: 2022 PR 9374

11 April 2022

Tēnā koe

APPROVAL OF PROGRESS REPORT

Study title: Physical activity study in Bronchiectasis

I am pleased to advise that this annual progress report has been **approved** following review by the Chair of the Central Health and Disability Ethics Committee on 8 April 2022. Existing approval remains valid.

Your next progress report is due by **14 May 2023**.

Further information and assistance

Please contact the HDECs Secretariat at hdec@health.govt.nz or visit our website at www.ethics.health.govt.nz for more information, as well as our [General FAQ](#) and [Ethics RM manual](#).

Nāku noa, nā

A handwritten signature in black ink, appearing to read "Helen Walker".

Mrs Helen Walker
Chair
Central Health and Disability Ethics Committee

Appendix N: Counties Manukau Health Research Committee - Approved extension



Level 1, Ko Awatea, Middlemore Hospital Research & Evaluation Office

100 Hospital Road, Otahuhu; Private Bag 93311, Auckland – 1640

cmdhb.org.nz – koawatea.co.nz

29 June 2022

For the attention of: Laura Rensford

Thank you for the information you have supplied to the CM Health Research Office regarding an extension of the timeline of this research project:

CM Health Research Registration Number: 1213

Ethics Reference Number: HDEC: 20/CEN/88

Research Project Title: "Physical activity levels in children with bronchiectasis living in the Counties Manukau region compared to healthy matched controls"
--

I am pleased to inform you that the CM Health Research Office has received all the required service lead approvals for the requested extension, which has you named as the Principal Investigator.

This CM Health locality approval will remain valid until the date specified on the most recent HDEC ethics approval letter on your study file. Please keep these letters and your annual Progress Reports up to date.

All external reporting requirements must be adhered to. Please note that failure to notify us of any further amendments, and/or submit copies of annual Progress Reports and annual Ethics renewal letters may result in the withdrawal of ethical and CM Health organisational approval.

FINAL REPORT: It is a requirement of the CM Health Research Policy that all research and audit projects conducted within CM Health should complete a Final Report within three months following completion of the study. The Final Report questionnaire can be found in your study file in the online Registry, under the Documents tab. This report will be viewable by all staff with access to the CM Health network. **Please Note** that having an overdue Final Report will impact your application for locality approval of any new studies.

Yours sincerely

Angela Bennett

Locality Coordinator

Counties Manukau Health

Under delegated authority from CM Health Research Committee and the Chief Medical Officer

Appendix O: Study pack information sheets for participants



If you're interested please ask your friendly
bronchiectasis team for further information.

Or you can contact the lead researcher directly.
Laura – Lead researcher
Phone: 021546238
Email: Laura.Rensford@middlemore.co.nz

The Physical Activity Study in Bronchiectasis



WHAT IS THE PHYSICAL ACTIVITY STUDY IN BRONCHIECTASIS?

The study aims to find out how physically active children with bronchiectasis are compared to children without bronchiectasis.

- How much do they move?
- How fast do they move?
- How long do they move for?
- Types of activity/exercise they participate in

WHO ARE WE LOOKING FOR?

We need 90 children to participate in the study

- 30 children with bronchiectasis
- 60 children without bronchiectasis

All children must:

- Live in the Counties Manukau region
- Be aged 7 – 12 years old
- Meet the study criteria

WHAT WOULD MY CHILD NEED TO DO?

If your child joins the study they will need to:

1. Attend one appointment for baseline measuring
2. Wear a special watch for 7 days and 6 nights to record their physical activity
3. Answer 10 physical activity questions
4. Receive a thank you gift for participating



WHY IS THIS STUDY IMPORTANT

Participating in this study will help us find ways to better care for children with bronchiectasis so they can live happier and healthier lives.

Participant Information Sheet for

Bronchiectasis Group / Non-Bronchiectasis Group

Study title: Physical activity levels in children with bronchiectasis living in Counties Manukau, New Zealand.

Locality: Counties Manukau, Auckland

Ethics committee ref.: 20/CEN/88

Lead investigator: Laura Rensford

Contact phone number: 021546238

Your child has been invited to take part in a study that measures physical activity levels in children living in Counties Manukau. Whether or not your child takes part in the study is your choice. If you don't want your child to take part, you don't have to give a reason, and it won't affect their future health care. If you do want your child to take part now, but change your mind later, you can leave the study at any time.

This Participant Information Sheet will help you decide if you'd like your child to take part. It sets out why we are doing the study, what the study involves, what the benefits and risks might be, and what would happen after the study ends. We will go through this information with you and your child and answer any questions you may have.

You do not have to decide today whether or not your child will participate in this study. Before you decide you may want to talk about the study with other people, such as family/whānau, friends, or healthcare providers. Feel free to do this.

If you agree for your child to take part in this study, you will be asked to sign a consent form on your child's behalf (see page 6). You will be given a copy of these signed forms.

This form is 7 pages long, including the Consent Form. Please make sure you have read and understood all the pages.

What is the purpose of the study?

In Counties Manukau we have a very high rate of children with bronchiectasis (scarred lungs). We are looking for ways to keep these children as healthy as possible. One option might be physical activity. Physical activity includes any movement your body does such as exercise, chores at home or playing outside. Physical activity has many health benefits such as strong bones and muscles, healthy hearts and lungs and improved mental health.

At present, we don't know if children with bronchiectasis do enough physical activity each day.

To find out we need two groups of children. Children with bronchiectasis and children without bronchiectasis. It's important we measure both of these groups so we can see how physically active children are in Counties Manukau, and if having bronchiectasis changes this.

What will my participation in the study involve?

Why has my child been chosen to participate?

Your child has been chosen to participate in this study because they live in the Counties Manukau region and have either attended a bronchiectasis clinic OR are enrolled in a school participating in the study. We are expecting 90 children and their families to be involved in this study.

What would my child need to do?

Each child will need to complete 2 appointments, 8 days apart. The appointments will be slightly differently depending on which group your child is participating in. Your child's group is written at the top of this information sheet in **red**. Please read the appropriate section below.

Children with bronchiectasis will be in the 'Bronchiectasis Group':

Seven days after receiving this information sheet in clinic you will be contacted via phone to ask if your child would like to participate in the study. You can say yes or no, both answers are ok. If you say yes, an appointment will be organised. The appointment will be at the physiotherapy gym at Kidz First or Manukau SuperClinic. You can choose the location that best suits your family/whānau. The appointment will take approximately 30-45 minutes. You will have the opportunity to ask the researcher any questions you may have about the study before signing consent forms. We will then ask you and your child questions about their bronchiectasis, measure their height, and weight and fit them with the activity monitor on their non-dominant (non-writing) wrist. Your child needs to wear the activity monitor for 7 days and 6 nights in a row, only taking it off for a bath or swimming. On the 8th day, the researcher will go to your child's school to take off the activity monitor and complete a short questionnaire with them. The questionnaire will be made up of 10 physical activity questions. Parents/caregivers do not need to attend this appointment but are welcome to come if they would like. Once the activity monitor is removed the study is finished.

Children without bronchiectasis will be in the 'Non-Bronchiectasis Group':

Your child will have brought this information sheet home from school for you to read. If you would like your child to participate in the study, you need to complete the attached consent forms and send them back to your child's school for enrolment. You will see a meeting date is attached to this information sheet. This meeting is an opportunity for you and other parents/caregivers to meet the researcher and ask any questions you may have about the study. You do not have to attend this meeting if you are happy with the information that is written on this sheet. Both of your child's appointments will take place at their school during school hours. Parents/caregivers do not need to attend these appointments but are welcome to come if they would like. At the first appointment, we will measure your child's height and weight and then fit the activity monitor on their non-dominant (non-writing) wrist. Your child needs to wear the activity monitor for 7 days and 6 nights in a row, only taking it off for a bath or swimming. On the 8th day, the researcher will go to your child's school to take off the activity monitor and complete a short questionnaire with them. The questionnaire is made up

of 10 short physical activity questions. Once the activity monitor is removed the study is finished.

Both groups: Bronchiectasis Group and Non-Bronchiectasis Group

The activity monitor used in this study is a special medical device. It looks a similar to a watch or Fitbit and is worn on the wrist with a plastic strap. The activity monitor will record all your child's movements during the 7-day study, so it is really important that your child carries on doing the same types of things that they would normally do. This will give us the most accurate results. Do not encourage them to do activities they wouldn't normally do until after the study is finished.

What are the possible benefits and risks of this study?

What are the benefits of the study?

By taking part in this study your child is helping us learn more about physical activity levels in children with bronchiectasis, in particular those living in Counties Manukau. These results will help physiotherapists give meaningful and achievable treatment to patients and their family/whānau. Improvements in physiotherapy knowledge will help children with bronchiectasis live healthier lives.

What are the risks of the study?

There is minimal risk involved with participating in the study as children will be carrying on with their normal daily activities. In rare cases, the skin around the child's activity monitor may become irritated from the plastic strap. If this occurs the strap can be easily cut off and removed. To reduce the chances of this happening, participants will be provided instructions for safely wearing the activity monitor and a second wrist strap in case it needs to be changed.

Who pays for the study?

Participating in the study is free. Children with bronchiectasis will need to attend one appointment at an agreed upon location. You will need to find your own transport to the appointment, but your parking will be free. All other appointments will occur at your child's school so there will be no cost to you.

It is really important that your child looks after the activity monitor. If the activity monitor breaks you will need to contact the researcher as soon as possible so it can be replaced. You will not have to pay for the activity monitor to be fixed.

At the end of the study, after your child has completed the questionnaire and returned their activity monitor, they will be given a thank you card and \$10 Warehouse voucher as a Koha (thank you) for participating.

What if something goes wrong?

If your child was injured during this study, you would be eligible **to apply** for compensation from ACC for them just as you would be if they were injured in an accident at school or at

home. This does not mean that your claim will automatically be accepted. You will have to lodge a claim with ACC, which may take some time to assess. If your claim is accepted, you will receive funding to assist in your child's recovery.

If you have private health or life insurance, you may wish to check with your insurer that taking part in this study won't affect your cover.

What are my rights?

Your child's participation in this study is voluntary (your choice). Your decision will not affect your child current or future healthcare.

All information in the study will be confidential. This means that only the research team will see your child's study information. To protect your child, their name will be removed from all documents and replaced with a study identification number. No participants' names will appear on any material produced as a result of this research.

You have the right to access any information collected from your child as part of the study. You also have the right to request correction of your child's information if it's incorrect. If you wish to do either of these, please contact the researcher (contact details on page 5). A member of the research team will respond to your request within 14 days to organise a time to go your child's study information with you.

What happens after the study or if I change my mind?

What happens to the information collected in the study?

The data from the activity monitor's will be downloaded and analysed by the researchers. The study information will be kept in a secure place and stored for ten years before being destroyed. Only the study's researchers will have access to the information. The only time your child's information will be reviewed by someone outside the study is if the study is audited by the New Zealand Healthy and Disability Ethics Committee or other regulatory committee. If this occurs the information reviewed is only used to check accuracy of data collection.

At the end of the study, approximately March 2022, you will be sent a summary of the study's results and have an opportunity to attend a community/school-based presentation. The results will also be published and presented at national and international paediatric conferences.

Can I ask for physical activity advice for my child?

Once your child has completed the study, you are welcome to discuss their physical activity needs with your child's usual physiotherapist or school physical education teacher. They won't have access to your child's study results, but they can discuss suitable physical activity options with you and your child.

Can my child leave the study?

Yes, your child can leave the study at any time without giving a reason. This decision will not affect your child's future health care or treatment. If your child leaves the study, you can

choose whether or not the data collected up until the point of stopping the study can be used in analysis.

Who do I contact for more information or if I have concerns?

If you have any questions, concerns, or complaints about the study at any stage, you can contact:

Name: Laura Rensford (lead researcher)

Phone: 021546238

Email: Laura.Rensford@middlemore.co.nz

Name: Sarah Mooney (study supervisor)

Phone: 09 921 0000 ext 6208

Email: sarah.mooney@aut.ac.nz

If you want to talk to someone who isn't involved with the study, you can contact an independent health and disability advocate on:

Phone: 0800 555 050

Fax: 0800 2 SUPPORT (0800 2787 7678)

Email: advocacy@advocacy.org.nz

Website: <https://www.advocacy.org.nz/>

For Māori Health support please contact :

Name: Ulima Tofi

Phone: 021 195 6459

Email: Ulima.Tofi@middlemore.co.nz

You can also contact the health and disability ethics committee (HDEC) that approved this study on:

Phone: 0800 4 ETHICS

Email: hdecs@moh.govt.nz

Physical Activity Study - Consent Form

Please initial to indicate whether you consent to the following

I have read, or have had read to me, and I understand the Participant Information Sheet.

I have been given sufficient time to consider whether or not my child will participate in this study.

I have had the opportunity to use a legal representative, family/whānau support or a friend to help me ask questions and understand the study.

I am satisfied with the answers I have been given regarding the study and I have a copy of this consent form and information sheet.

I understand that my child taking part in this study is voluntary (my choice) and that I may withdraw my child from the study at any time without this affecting their medical care.

I consent to the research staff collecting and processing my child's information, including information about my child's health.

If I decide to withdraw my child from the study, I agree that the information collected about my child up to the point when I withdraw may continue to be processed. Yes ☐ No ☐

I agree to an approved auditor appointed by the New Zealand Health and Disability Ethic Committees, or any relevant regulatory authority or their approved representative reviewing my child's relevant medical records for the sole purpose of checking the accuracy of the information recorded for the study.

I understand that my child's participation in this study is confidential and that no material, which could identify my child personally, will be used in any reports on this study.

I understand the compensation provisions in case of injury during the study.

I know who to contact if I have any questions about the study in general.

I understand mine and my child's responsibilities as a study participant.

I wish to receive a summary of the results from the study. Yes ☐ No ☐

Declaration by participant:

I hereby consent for my child to take part in this study.

Child (participants) name:

Legal guardian's name:

Legal guardians' signature:

Date:

Declaration by member of research team:

I have given a verbal explanation of the research project to the participant and their guardian and have answered their questions about the study.

I believe that the participant and their guardian understand the study and have given informed consent to participate.

Researcher's name:

Signature:

Date:

Physical Activity Study for Children

- We are looking for children living in South Auckland to be part of our physical activity study. We need 90 children - 30 children with bronchiectasis (scarred lungs) and 60 children with non-bronchiectasis lungs.
- Taking part in this study is your choice. It is ok to say yes or no. If you say yes, you can still change your mind at any time and stop.
- This study wants to find out how active you are each day:
 - How much you move
 - How fast you move
 - How long you move for
 - Types of activities/exercise you are doing
- The study will help us find ways to help children with bronchiectasis live healthier lives.
- If you join the study, you will see a researcher two times:
 - Day 1. You will be measured (height, weight) and answer a few health questions. Then a special red watch will be put on your non-writing arm (just like the picture here).
 - Day 8. You will give the watch back to the researcher and answer 10 physical activity questions.
- You will need to wear the watch on your arm for 7 days and 6 nights in a row. It's important that you continue doing the same things (activities) you would normally do each day.
- It's really important that you look after the watch.
 - Don't take it off or pull it apart – this will break it.
 - The watch can go in the shower, but you can't wear it in the bath or swimming.
- The study is really safe but there is a small risk that the watch may rub (irritate) your skin. If this happens tell someone in your family so they can replace the strap for you.
- As a thank you, every child that completes the study will get a thank you card and a \$10 Warehouse voucher.
- Before you decide about being part of the study, it is important you talk to your family first so you can make the decision together. Your family has more information about the study.
- If you have any questions, you can ask the research team anytime, or get someone in your family to call us.
 - Lead Researcher – Laura Rensford
 - Phone – 021546238
 - Email – Laura.Rensford@middlemore.co.nz



Assent Form for Children

I have read, or have had read to me, the Physical Activity Study for Children sheet, and I understand what it is saying.

I have had enough time to think about the study and if I want to join in or not.

I have had enough time to talk to my family/whānau about the study.

I understand that taking part in this study is my choice and I can stop at any time.

I give consent (permission) to the research staff to collect and process my information, and keep it stored safely.

I know I can ask the researchers or my family any questions I might have about it at any time.

I understand my role in the study and what I need to do.

Declaration by participant:

I give my consent (permission) to take part in this study.

Child's name: _____

Signature: _____

Date: _____



Declaration by member of research team:

I have explained the research project to the participant and have answered their questions.

I believe that the participant understands the study and has given their consent (permission) to participate.

Researcher's name: _____

Signature: _____

Date: _____

Appendix P: Additional forms for control participants

Physical Activity Study

Participant Demographic Information Form

Participants Name: _____

Date of birth: _____ Current age: _____

Gender: ☐ Female ☐ Male

Ethnicity: ☐ Asian ☐ Indian ☐ Māori ☐ NZ European ☐ Pasifika ☐ Other

Medical History: _____

Medications: _____

Home address: _____

School: _____

Non-Dominant Hand: ☐ Left ☐ Right

LEAVE BLANK - RESEARCH TEAM TO COMPLETE BLUE BOX

Research ID Number: _____ Study Group: _____

Enrolment Date: _____

Device Number: _____

Weight (kgs): _____ Height (cm): -

Research Invitation to the Physical Activity Study



Your child has brought home this invitation and study pack because they expressed an interest in participating our physical activity study.

We are looking for 60 children aged 7-12 years, living in South Auckland, to be part of our study to find out if children without bronchiectasis are more active then children with bronchiectasis.

See study pack for more information.

You can consent based on the information provided, but if you would like to discuss the study more, or have any additional questions, please come join us for a research meeting/hui on the

_____ (insert date) _____ At: _____ (insert time) _____

At: _____ (insert school and location within school) _____

A small afternoon tea will be provided.

If you have any questions before then, or unable to attend, please feel free to contact the Laura, the lead researcher, on 021546238 or Laura.Rensford@middlemore.co.nz

Appendix Q: Standardised recruitment process

Physical Activity Study - Recruitment Process

- ☐ Screen patient for inclusion / exclusion criteria.

☐ Inclusion Criteria

- ☐ Able to communicate in English
- ☐ Aged 7-12 years at time of recruitment
- ☐ Lives in Counties Manukau District Health Board catchment area
- ☐ Bronchiectasis diagnosis on HRCT
- ☐ Spirometry uploaded online in the last 6 months
- ☐ Clinically stable for a least 30 days before starting the study

A positive bronchiectasis exacerbation includes one major criteria PLUS and two minor criteria, see Appendix C.

Major Criteria

- Significant increase in cough frequency over 72 hours
- Wet cough for 72 hours

Minor Criteria

- Sputum colour ≥ 3 on Bronko Test
- Parent/child perceived breathlessness
- Chest pain
- Crepitations or crackles on auscultation
- Wheeze
- Hypoxia

☐ Exclusion Criteria

- ☐ Physical or cognitive comorbidity that may influence participation
 - I.e., poorly controlled asthma, cerebral palsy, trisomy 21, neuromuscular conditions, cognitive impairment, or acute musculoskeletal injury
- ☐ Approach family/child and introduce study briefly.
- ☐ If interested provide study pack and give more in-depth overview of study including context of envelope and contact details.
 - Inside the study pack there must be
 - Study brochure
 - Caregiver information sheet and consent form (circle correct group)
 - Child information sheet and assent form
- ☐ Inform the potential participant and legal guardian they have 7 days to consider the study. Can offer a shorter period if keen.
- ☐ Gain consent for a research team to call after 7 days (or pre-agreed time) to follow up.
- ☐ Check patient contact details are correct.
 - What is the best method of contact for the research team to contact them?
- ☐ Upload information to recruitment spread sheet and forward to Laura at end of clinic.

Appendix R: School information sheet

Physical Activity Study

School Information Sheet

What is the physical activity study for children?

In Counties Manukau there is a very high rate of children with bronchiectasis (scarred lungs). We are looking for ways to keep these children as healthy as possible. One option might be physical activity. Physical activity has many health benefits and children are recommended to be physically active for 60 minutes every day.

We want to find out how physically active children aged 7 to 12 years with bronchiectasis living in Counties Manukau are compared to children without bronchiectasis.

To do this we need two groups of children – 30 children with bronchiectasis and 60 children without bronchiectasis. It's important we measure both of these groups so we can see how physically active children are in Counties Manukau, and if having bronchiectasis changes this.

Why has our school been approached?

Your school has been approached because there are known cases of children with bronchiectasis in your community. To get the best results it's important that all the children in the study are from similar communities, which is why we are asking your school to participate in our non-bronchiectasis group.

The decision, whether or not to participate in the study, will not affect your students current or future physiotherapy care. Both the school, and students, are free to withdraw from the study at any time without pressure of providing a reason.

What does the study involve?

If your school chooses to be part of the study children aged 7 to 12 years will be provided an information pack to take home and read with their families. If their legal guardian's consent to the study the child will need to return the signed consent forms to school. On an agreed upon time the researcher will come into the school on two separate occasions.

On Day 1, each child will have their height and weight measured and then have an activity monitor fitted on their non-dominant wrist. The activity monitor will then be worn for 7 days and 6 nights in a row, only taking it off for a bath or swimming.

On Day 8, the researcher will return to school, take off the activity monitor, and complete a short questionnaire (10 physical activity questions). Once the activity monitor is removed the study is finished. Each child will receive a thank you card and \$10 Warehouse voucher as a Koha (thank you) for participating.

What does the school need to provide?

All the equipment and resources required for the study will be provided by the research team. There is no cost to the school, but we will need assistance with the following:

- A key contact person within the school to assist with study logistics and student organisation.
- A collection point for children to return consent forms i.e., a box at reception that can be stored safely at the end of the day to maintain privacy.
- A space to hold a parent meeting (after school) for those who wish to ask the lead researcher questions about the study before enrolling their child.
- A quiet space to take baseline measure and fit/remove the activity device on day 1 and day 8.

If we are interested, what do we do next?

We would really like your school to be part of our study. If your school is interested, please contact us so we can meet and discuss the study in more detail.

Name: Laura Rensford (lead researcher)

Phone: 021546238

Email: Laura.Rensford@middlemore.co.nz

We look forward to hearing from you.

Appendix S: Accelerometer handout for participants



◀ If you have any questions please feel free to contact us

Contact Details:

Laura – Lead researcher

Phone: 021546238

Email: Laura.Rensford@middlemore.co.nz

The Physical Activity Study in Bronchiectasis

How to use the activity monitor



WHAT IS THE ACTIVITY MONITOR?

This activity monitor is a small watch (similar to a Fitbit) that records your movement and tell us how physically active you are.

HOW TO PUT ON THE ACTIVITY MONITOR

The researcher will put on the watch for you the first time and show you how this is done. If you need to remove the watch for any reason it's important you put it back as soon as possible.

1. Thread the plastic strap through the watch and pull tight



2. Put the watch on your non-writing wrist.
3. Clip shut the strap. It should be firm but not too tight. Trim off the extra strap with scissors.



At first, the watch may feel slightly awkward, but after a few hours, you will get used to it and hardly notice it. It is **extremely** important for our study that you wear the watch properly so we can get accurate data.

KEY INSTRUCTIONS FOR WEARING THE WATCH

- Please **keep the watch on at all times** for the next 7 days. We need to collect as many hours as we can for our research project.
- The watch is **splash proof and can go in the shower. It can not go under water i.e. bath or swimming pool.** Please take it off for these activities.
- If you need to remove the watch or change the wrist band simply cut the plastic strap. As soon as possible replace the strap and **put the watch back on the same wrist.** There are two replacement straps in your study pack. If you need more straps please call or text the researcher.
- In your study pack there is a study letter and a study card you can show your school, sports coach etc. This letter explains that you are part of a study and that it is really important that you wear the watch at all time.
- Please look after the watch but if it does break, call or text the researcher so we can replace this. You will **not** have to pay for the watch to be fixed or replaced.
- **Do not let anyone else wear it.**

Thanks for participating in the study

Appendix T: Safety protocol for researchers working offsite

Physical Activity Study – Offsite Safety Protocol

This protocol will be utilised when the primary researcher is conducting assessments in a potentially risky location, away from Kidz First hospital, the SuperClinic or a participating school, for example at a participant's home. The researcher will comply with all policies and procedures set out below to ensure her safety in these situations.

Policies

- The researcher will ensure the majority of assessments are completed at Kidz First, Manukau SuperClinic or the participating school.
- On the rare occasion where a participant cannot be seen in one of the dedicated locations, the researcher will arrange an assessment in a location both the researcher and participant feel comfortable in.
- Assessments completed off hospital grounds (i.e., participants home) the researcher will notify her Counties Manukau physiotherapy colleague or supervisor of the participants NHI and the exact time, date, and location of the assessment prior to her departure.
- The researcher will carry her fully charged cell phone on her person at all times.
- The researcher will also be guided by Counties Manukau Community / home-based visiting policy.

Procedures

- Prior to the day of the assessment taking place, the researcher will inform her Counties Manukau physiotherapy colleague or supervisor of the participants NHI and the exact time, date, and location of the assessment. One colleague will indicate that they are available to be contacted on the day of the assessment.
- On the day of and immediately prior to the interview, the researcher will contact the nominated Counties Manukau physiotherapy colleague or supervisor by text message or phone call to indicate that she will be meeting the participant shortly.
- Immediately following the assessment, the researcher will contact the nominated Counties Manukau physiotherapy colleague or supervisor by text message or phone call to indicate that she has exited the assessment.

- If anything happens during the assessment that makes the researcher uncomfortable, she will cease the assessment and leave the environment. She will notify her Counties Manukau physiotherapy colleague or supervisor and her manager, or, if necessary, call emergency services using her cell phone.

Reference: Counties Manukau Health. (2013). Policy: Community / home-based visiting. Counties Manukau District Health Board: Occupational Health and Safety.

Appendix U: Baseline outcome measure form

Participant Demographic Information Form

Research ID Number: _____ Study Group: _____
Enrolment Date: _____
Device Number: _____

Participants Name: _____

Participants NHI (if applicable): _____

School: _____

Home address: _____

Date of birth: _____ Current age: _____

Gender: ☐ Female ☐ MaleEthnicity: ☐ Asian ☐ Indian ☐ Māori ☐ NZ European ☐ Pasifika ☐ Other

Weight (kgs): _____ Height (m): _____

Non-Dominant Hand: ☐ Left ☐ Right

For the Bronchiectasis Group Only:

Date of Bronchiectasis diagnosis: _____

(use date of HRCT which confirms diagnosis)

Number of Lobes Affected on HRCT: _____

Aetiology: ☐ Airway abnormality ☐ Aspiration ☐ Idiopathic ☐ Immune deficiency
☐ Foreign body ☐ PCD ☐ Post infectious ☐ Other

Spirometry: (results must be within the last six months from date of study enrolment)

FVC (L) Z score: _____ FVC (L) % Predicted: _____

FEV1 (L) Z score: _____ FEV1 (L) % Predicted: _____

FEV1 / FVC Ratio Z score: _____ FEV1 / FVC Ratio % Predicted: _____

From date of study enrolment:

Number of Antibiotics in last year: _____

Number of Hospital admissions in last year: _____

Uses Oxygen of VPAP: ☐ Yes ☐ No

If yes, details of use: _____

Appendix V: Standardised initialisation procedure for the accelerometer

Before initialising device:

- Carefully examined for unit cracks, water seal issues, locking ability and general wear and tear. Only accelerometers in excellent condition were used to avoid losing data due to faulty hardware.

Accelerometers were initialised with the following information using the ActiLife software (v6.11.9, ActiGraph, Pensacola, FL, USA):

- Output file name = Accelerometer serial number, research identification number and participant's last name.
- Participant demographics = gender, height, weight, date of birth.
- Accelerometer application details = non-dominant wrist.
- Sample rate = 30Hz.
- Idle sleep mode = enabled battery saving mode.
- LED lights = disabled (stops flashing lights on the accelerometer).

Recording hours:

- Start time = Day One at 0000 hours, the day after participants received the accelerometer.
- End time = Not specified, the accelerometer continued recording until removed by the researcher.

Appendix W: Letters for participants school or coach(s)



To whom it may concern,

_____ is enrolled the Physical Activity Study in Bronchiectasis currently been undertaken at Kidz First, Middlemore hospital (Health and Disability Ethic Committee approved - Ref 20/CEN/88).

The aim of the study is to find out how physically active children aged 7 to 12 years with bronchiectasis living in the Counties Manukau region are compared to healthy matched controls. The study will recruit 90 children (30 with bronchiectasis, 60 without bronchiectasis). Each child will wear an activity monitor (accelerometer) on their non-dominant wrist for 7 days and 6 nights.

It is really important that the child always wears this device, including sports games, so we can accurately capture how physically active they are throughout the day. The device should only be removed for swimming or other water submersion activities; it is splash proof and is ok for hand washing etc. If the device does need to be removed for safety reason or in an emergency simply cut the plastic strap. The child has replacements straps and will require the device to be reapplied as soon as safely able to so. If the device can't be replaced, please return the device to the child so they can put it on again later or contact the lead researcher if needed.

The device is the child's responsibility, and this should not interfere with their usual activities. If the device is broken or damaged there is no liability or cost to the child, school, local body, company, or sporting event they are participating in. Please encourage the child/family to contact the researcher for a replacement device as soon as possible.

If you have any further questions, please feel free to contact the lead researcher

Laura.Rensford@middlmore.co.nz or phone 021546238

Thank you for supporting this child in participating in the Physical Activity Study in Bronchiectasis.

Yours sincerely

A handwritten signature in black ink, appearing to be "Laura Rensford".

Laura Rensford
Lead Researcher
Kidz First, CMDHB

Appendix X: Standardised procedure checklist for study

Physical Activity Study -Study Check List

Research ID Number: _____ Study Group: _____

Enrolment Date: _____

Device Number: _____

Prior to Appointment

- ☐ Check child still meets study criteria
- ☐ Call to confirm appointment
- ☐ Check if the child has been sick in the last 30 days
 - No - continue with appointment
 - Yes - reschedule the appointment in 4-6 weeks

First Appointment

- ☐ Review study protocol with child/family – use information sheets
- ☐ Complete/ sign consent forms
 - ☐ Caregiver consent form
 - ☐ Child assent form
- ☐ Complete participant demographic form
- ☐ Assign research study ID number and device number
- ☐ Activity monitor
 - ☐ Watch insitu / shown how to put on and remove
 - ☐ Go through watch handout – give to patient
 - ☐ Additional straps provided
- ☐ Give explanation letters / cards
- ☐ Discussed plan for retrieving device on day 8
 - ☐ Consent to inform school of study and permission to pick up device
- ☐ Parking card

Immediately Post Appointment

- ☐ Contact school
 - ☐ Inform them of study

- ☐ Permission to pick up device and complete quick questionnaire on day 8
- ☐ Date and location

Second Appointment

- ☐ Before leaving call to confirm appointment with school and if the child is at school
- ☐ Complete PAQ-C questionnaire
- ☐ Collect device
- ☐ Thank you card/gift

Final Tasks

- ☐ Scan and save consent forms into e-file
- ☐ Download device – save file under research ID number and date into e-file
- ☐ Upload data into database 1 and 2 on e-file
 - ☐ Participant demographic data
 - ☐ PAQ-C questionnaire

Appendix Y: Key coding sheet for data spreadsheets

Drop Down Box Setup for Spreadsheet						
Study Group	Gender	Ethnicity	BMI Group	Aetiology	Grouped FEV1 (L) % Predicted	Use of oxygen / VPAP
Bronchiectasis	Female	Asian	≤ 18.4	Airway abnormality	> 80 %	Yes
Control	Male	Indian	18.5 - 24.9	Aspiration	60 - 80 %	No
		Maori	25.0 - 29.9	Idopathic	50 - 60 %	Other
		NZ European	≥ 30	Immune deficiency	< 50 %	
		Pacific		Foreign body		
		Other		Post infectious		
				PCD		
				Other		
Day	Day of Week	Weekday / Weekend	Valid Day (≥ 600 mins)	Achieved 60 Mins MVPA		
1	Monday	WeekDAY	Yes	Yes		
2	Tuesday	WeekEND	No	No		
3	Wednesday					
4	Thursday					
5	Friday					
6	Saturday					
7	Sunday					
Q1: Activities	Q2: PE Class	Q3: Recess	Q4: Lunch	Q5: After School	Q6: Evening	Q7: Weekend
1	1	1	1	1	1	1
2	2	2	2	2	2	2
3	3	3	3	3	3	3
4	4	4	4	4	4	4
5	5	5	5	5	5	5
Q8: Describes best	Q9: Total Score	Q10: Sick	Non-Dominant Hand	Q1 Total Score	Q9: Total Score	Q11: Device removed
1	1	Yes	Left	1	1	Yes
2	2	No	Right	2	2	No
3	3			3	3	
4	4			4	4	
5	5			5	5	
PAQ-C Questionnaire Key Codes						
Question 01	1 = No	2 = 1-2	3 = 3-4	4 = 5-6	5 = 7 or more	
Question 02	1 = I don't do PE	2 = Hardly ever	3 = Sometimes	4 = Quiet often	5 = Always	
Question 03	1 = Sat down	2 = Stood around or walked around	3 = Ran or played a little bit	4 = Ran around and played quite a bit	5 = Ran and played hard most of the time	
Question 04	1 = Sat down	2 = Stood around or walked around	3 = Ran or played a little bit	4 = Ran around and played quite a bit	5 = Ran and played hard most of the time	
Question 05	1 = None	2 = 1 time last week	3 = 2 or 3 times last week	4 = 4 times last week	5 = 5 times last week	
Question 06	1 = None	2 = 1 time last week	3 = 2 or 3 times last week	4 = 4 or 5 times last week	5 = 6 or 7 times last week	
Question 07	1 = None	2 = 1 time	3 = 2-3 times	4 = 4-5 times	5 = 6 or more times	
Question 08	1 = All or most of my free time was spent doing things that involved little physical effort	2 = I sometimes (1-2 times last week) did physical things in my free time	3 = I often (3-4 times last week) did physical things in my free time	4 = I quite often (5-6 times last week) did physical things in my free time	5 = I very often (7 or more times last week) did physical things in my free time	
Question 09	1 = None	2 = Little bit	3 = Medium	4 = Often	5 = Very often	

Appendix Z: Supplementary results table: Associations between MVPA and disease severity markers

Grouped FEV1 % predicted					
	50 - 79 %		> 80 %		P-value
Days	Valid N	Mean (SD)	Valid N	Mean (SD)	
Monday	2	31.6 (28.7)	14	78.2 (33.4)	0.083
Tuesday	3	59.63 (32.3)	14	83.2 (36.2)	0.317
Wednesday	3	73.63 (50.9)	15	80.5 (42.7)	0.807
Thursday	3	59.1 (40.5)	15	93.9 (35.2)	0.145
Friday	3	72.83 (31.3)	15	82 (47.6)	0.757
Saturday	2	56.1 (25.5)	14	60.2 (31.2)	0.863
Sunday	3	50.07 (51.1)	14	70.6 (35.6)	0.409

Number of lobes							
	1-2' (n=3)		3 (n=7)		4-5' (n=6)		P-value
Days	Valid N	Mean (SD)	Valid N	Mean (SD)	Valid N	Mean (SD)	
Monday	5	67.24 (43)	7	80.53 (41.3)	4	64.48 (14.6)	0.745
Tuesday	5	78.82 (31.7)	7	97.34 (40.8)	5	53.56 (14.7)	0.108
Wednesday	5	73.48 (35.9)	7	110.26 (40.5)	6	48.23 (25.1)	0.019
Thursday	5	97.64 (40.7)	7	102.51 (31.9)	6	63.4 (32.7)	0.134
Friday	5	90.18 (26.5)	7	91.91 (60.3)	6	58.95 (31.9)	0.374
Saturday	5	60.4 (22.5)	7	61.04 (29.6)	4	56.45 (44.7)	0.972
Sunday	5	97.6 (34.2)	7	69.63 (31.1)	5	32.76 (20.6)	0.012

Hospital admissions					
	No (N=15)		Yes (n=3)		P-value
Days	N	Mean (SD)	N	Mean (SD)	
Monday	14	75.16 (37.4)	2	52.8 (1.3)	0.426
Tuesday	14	84.16 (36.4)	3	55.03 (24.5)	0.211
Wednesday	15	81.23 (43.4)	3	70.07 (45)	0.691
Thursday	15	91.66 (33.4)	3	70.4 (58.9)	0.384
Friday	15	76.97 (42.4)	3	97.83 (61.7)	0.477
Saturday	14	62.59 (30.9)	2	39.45 (1.9)	0.321
Sunday	14	74.7 (35.9)	3	31.13 (25.2)	0.067