Associations Between Physical Activity and Fruit and Vegetable consumption in Female Adolescents in New Zealand

Maria Lauren Wright

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Abstract

Background: Inadequate physical activity and low fruit and vegetable consumption are arguably the greatest modifiable risk factors for cardiometabolic diseases in adolescents. Physical activity (PA) and fruit and vegetable consumption have been reported previously in this age group, however the associations between these two health behaviours together has not been heavily researched. Understanding the relationship between these two crucial risk factors is likely to support the development of future public health messages.

Objective: The purpose of this study was to investigate and describe the relationship between physical activity and fruit and vegetable consumption among adolescent females of the SuNDiAL project.

Design: Adolescent females aged 15-18 y were recruited from high schools in 8 regions around New Zealand (NZ). Hip-worn Actigraph GT3X+ accelerometers and self-report wear-time diaries were used for seven consecutive days to measure moderate-to-vigorous physical activity (MVPA). Fruit and Vegetable consumption was measured using a dietary habits questionnaire.

Results: Participants performed an average of 43 minutes/day in MVPA, and more than 75% of females failed to meet physical activity guidelines of ≥60 min of MVPA per day. Fruit and vegetable consumption were generally low, with only 27% of females consuming ≥5 serves per day. Physically active females were 4.7 (95%CI: 1.7 to 13.1, p=0.0024) and 2.7 (95%CI: 1.1 to 6.6, p=0.0302) times more likely to meet fruit and total fruit and vegetable intakes respectively, than inactive females.

Conclusion: Physical activity and fruit and vegetable intakes are both insufficient in adolescent females. Girls who were more physically active were also more likely to meet the fruit and vegetable guidelines. It is possible that the facilitators and inhibiting factors associated with meeting both the physical activity and fruit and vegetable guidelines are similar. Further research in this area is clearly needed before targeted public health interventions can be developed or implemented.

Preface

This research was completed as part of the Survey of Nutrition, Dietary Assessment, and Lifestyles (SuNDiAL) project from the Department of Human Nutrition, University of Otago. In 2019, the sample was adolescent females, whereas the 2020 sample were adolescent males. The candidate conducted this thesis under the supervision of Dr Meredith Peddie, as a requirement of the Master of Dietetics (MDiet) programme. Primary investigators of the SuNDiAL project (Dr Meredith Peddie and Dr Jill Haszard, University of Otago) were responsible for study design, obtaining ethical approval, initial recruitment of participating schools and general oversight of the study. Dr Meredith Peddie processed accelerometer and wear-time diary data. The candidate was involved in data collection during 2020 on a sample of adolescent boys, however, disruption to research by COVID-19 means the candidate has instead used the data set from adolescent females collected in 2019, to enable analysis of accelerometer data which was unavailable from the 2020 dataset.

The Candidate, and one other MDiet student worked together to:

- Liaise with school staff, phlebotomists and SuNDiAL coordinators
- Develop a digital presentation for recruitment of participants
- Participant recruitment and verbal and written communication with participants

- Take anthropometric measures and two non-consecutive 24-hour dietary recalls
- Distribute accelerometers and wear-time diaries

Individually, the candidate was responsible for the following:

- Taking 15, initial 24-hour diet recalls, and 10 secondary 24-hour diet recalls from participants at John Paul College
- Taking six initial 24-hour diet recalls, and seven secondary 24-hour diet recalls from participants at Papamoa College
- Entering all data collected from these 24-hour diet recalls into FoodworksX9 (dietary assessment software)
- Completing a literature review on fruit and vegetable intake and physical activity in adolescent females
- Creation of tables and figures, and interpretation of results
- Discussing findings and writing this thesis

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List of Abbreviations

BMI	Body mass index
CI	Confidence Interval
cpm	Counts per minute
CVD	Cardiovascular disease
FFQ	Food frequency questionnaire
h	hours
IPAQ-SF	Physical activity questionnaire, short form
kg	Kilograms
LPA	Light physical activity
MDiet	Master of Dietetics
MOH	Ministry of Health
MVPA	Moderate-to-vigorous intensity physical activity
N/A	Not applicable
n	Number of participants
NCD	Non-communicable disease
NZ	New Zealand
OR	Odds ratio
PA	Physical Activity
SuNDiAL	Survey of Nutrition, Dietary Assessment and Lifestyles
sd	Standard deviation
T2DM	Type 2 Diabetes
WHO	World Health Organisation
y	years

1 Introduction

Inadequate physical activity and low fruit and vegetable consumption are both well-researched risk factors for chronic disease (Bellavia et al,. 2013; Mendoza et al.,2012). During adolescence, being physically active, and having sufficient fruit and vegetable intakes lead to short and long-term health benefits, likely influencing health into adulthood (Kelishadi et al., 2007; Pearson et al., 2009). In particular, adhering to guidelines for moderate-to-vigorous activity (MVPA), is vital during adolescence due to the established health benefits of adequate MVPA on non-communicable diseases including cardiovascular disease (Nocon et al., 2008), obesity and some cancers (Reiner et al., 2013; Warburton et al., 2006).

Despite the known health benefits associated with physical activity, rates are generally low. Currently, an average of only 25% of adolescent females are meeting MVPA activity guidelines worldwide (Guthold et al., 2020; Hallal et al., 2012), with time spent in MVPA varying from 32 (Troiano et al., 2008) to 50 (Sanchez et al., 2007) minutes per day. Poor adherence to guidelines was also evident in existing studies of MVPA in NZ females, where accelerometer (Kek et al., 2019; Maddison et al., 2010) and self-report (Ministry of Health, 2019) measures were used, indicating that ~70% of female adolescents in NZ are failing to meet daily activity targets of >60 minutes/day of MVPA (Ministry of Health, 2019).

Similarly, to MVPA, despite the known health benefits of fruit and vegetable consumption, intakes are often low, particularly in adolescents. The results of the 2008/09 Adult Nutrition Survey indicated that 65% and 61.5% of adolescent females were meeting the fruit and vegetable consumption guidelines, respectively (Ministry of Health, 2011a). The results of a more recent survey may indicate a decrease in consumption in this age group with only 30.4% of adolescent girls reporting consuming ≥5 servings of fruit and vegetables a day (Clark et al.,2013). Establishing current intakes among adolescent females will be crucial for future public health planning as healthful behaviours such as diet and activity tend to cluster together (Mendoza et al., 2012; Tarp et al., 2018). Identifying if these behaviours are related in NZ adolescents will provide insight to then develop targeted messages, with hopes of improving fruit and vegetable consumption and activity levels in female adolescents.

Although previous studies have identified positive associations between physical activity and fruit (Cavadini et al., 2000) and total fruit and vegetable intake in adolescents internationally (Kelishadi et al., 2007; Ottevaere et al., 2011), it is not clear if the same patterns are applicable to NZ adolescents. Consequentially, for the first time, this study aims to describe the relationship between physical activity levels and fruit and vegetable consumption in a convenience sample of NZ female adolescents.

2 Literature Review

This literature review aims to summarise current literature on fruit and vegetable consumption and physical activity (PA) in adolescents and is presented in four main sections:

2.2 explores the physical activity guidelines for adolescents (2.2.1), the health benefits of physical activity (2.2.22.2.3) and the current levels of physical activity carried out by adolescents in NZ (2.2.7)

2.3 summarises the health benefits of fruit and vegetables (2.3.1) current intakes in adolescents (2.3.4)

2.4 analyses the relationship between physical activity and fruit and vegetable consumption.

2.5 summarises the methodological considerations when measuring physical activity levels and fruit and vegetable intakes in the free-living population, specifically NZ adolescent females.

2.1 Search Methods

Literature searches were conducted between September 2019 and May 2020, using several databases; Google Scholar, PubMed, ScienceDirect, Medline (Ovid SP), from 1946 to present. Search terms were based on relevance to the research topic, including adolescent, adolescence, teenager, youth, physical activity, activity level, fruit and vegetable, fruit, vegetable, and dietary habits. Keyword combinations were used to increase accuracy and suitability of search results, including "physical activity" AND "fruit and vegetables" combined with terms; "adolescents" OR "clustered". Only literature in English language has been included, with additional relevant references also obtained from reference lists of the articles and studies used.

2.2 Physical Activity

Physical activity is defined as any movement which engages skeletal muscle and results in energy expenditure (Caspersen et al.,1985). Physical activity may or may not be structured or planned, including movement as part of one's occupation, for leisure, and for transportation.

2.2.1 Guidelines

In the wake of increasing rates of non-communicable diseases (NCDs) and obesity, NZ's Ministry of Health have outlined physical activity as a fundamental contributor to achieving "longer, healthier and more independent lives (Ministry of Health, 2011).

For any 24-hour period, individuals aged 5-17 years are recommended to participate in at least 60 minutes of moderate-to-vigorous intensity physical activity daily (Ministry of Health, 2017; Tremblay et al., 2016).

2.2.2 Physical Activity and Health in Adults

There is a large body of evidence supporting the relationship between physical activity and positive health status. Physical activity is associated with a reduction in the risk of developing NCDs such as hypertension, cardiovascular disease (CVD) (Nocon et al., 2008), diabetes (T2DM), and some cancers (Reiner et al., 2013; Warburton et al.,2010; Warburton et al., 2006). In a meta-analysis of 33 prospective cohort studies (Nocon et al., 2008), with follow-up periods of 4-20 y, being physically active was associated with lower risk of all-cause mortality by 33% (RR 0.67, 95% CI: 0.63 to 0.72) and CVD mortality by 35% (RR 0.65, 95% CI: 0.60 to 0.70) in both males and females when compared to inactive individuals. Similarly, in a systematic review of longitudinal cohort studies by Samitz et al (2011) participants meeting MVPA guidelines (group 1 = 150 min/week; group 2= 300 minutes/week) were compared with those who did not (group = <60 minutes/week) in a dose-response meta-analysis. A 14% (RR of 0.86; 95% CI 0.80 to 0.92), and 26% (RR of 0.74; 95% CI 0.65 to 0.85) risk reduction of all-cause mortality in groups one and two respectively, compared to group three was reported (Samitz et al., 2011).

2.2.3 Physical Activity and Health in Adolescence

Adolescents are defined as individuals aged 10-19 years, with adolescence termed as the life stage between childhood and adulthood. Adolescents may be referred to as youth or teenagers, with terms used interchangeably throughout the literature, however, adolescence is primarily the focus of the "second decade of life" (WHO, 2014).

It has been suggested that adolescence is the most crucial time in life to prevent chronic diseases (Telama et al., 2005). The WHO states that physical activity habits in adolescence are likely to be transferred into adulthood, and that being physically active is vital for short and long-term health benefits such as reducing the risk of several non-communicable diseases, particularly in females (WHO, 2016).

2.2.4 Non-communicable Diseases

Due to the time frame of development, incidence of NCDs in adolescents is rare, and research into associations between physical activity and hard disease endpoints in adolescents is almost non-existent. Instead, most of the research in this age group focuses on the impact of physical activity on established risk factors for NCDs.

2.2.5 Cardiometabolic Disease

Risk factors for cardio-metabolic disease include but are not limited to; elevated blood pressure, elevated total cholesterol, and poor glycaemic control (Chu et al., 1998; Kannel & Wilson, 1995).

In adolescents clustered risk provides the most accurate prediction of risk for an individual (Wilson et al.,1999). In 2012, Mendoza et al., reported the significant association ($p<0.039$) between adherence to MVPA guidelines and a lowered clustered risk score (Mendoza et al., 2012). The relationship of activity and lowered cardiometabolic risk was also evident, where greater physical activity, particularly of increased intensity, provided an improved clustered risk profile in a sample of 29,000 youth (Tarp et al., 2018).

In a 2010 systematic review (Janssen & LeBlanc, 2010), the results of eight experimental trials all indicated that participation in an exercise intervention resulted in significant reductions in systolic blood pressure (Bell et al., 2007; Danforth et al., 1990; Ewart et al.,1998; Hagberg et al., 1984, 1983; Jago et al., 2006; Kahle et al., 1996; Lau et al.,2004). Two of the aerobic intervention-based studies (Bell et al., 2007; Hagberg et al., 1983) reported a significant reduction of 1.39 mmHg (95% CI: -2.53 to -0.24) in systolic blood pressure and a non-significant reduction of 0.39 mmHg (95% CI: -1.72 to 0.93) in diastolic pressure, affirming physical activity reduces risk factors of CVD.

In a study conducted in 2005, physical activity in adolescence was reported as an indicator of physical activity patterns in adulthood, (Hallal et al., 2006; Telama et al., 2005). In females specifically, those who were more active throughout adolescence were 6.1 (95% CI: 1.5 to 24.4) times more likely to be active adults (Telama et al., 2005), potentially providing protective health benefits and likely reducing the risk of disease into adulthood (WHO, 2016). While associations between physical activity and hard clinical endpoints are limited, there is consistent evidence to suggest that individuals who are physically active are more likely to have a better cardio-metabolic health profile, and that participating in physical activity can improve established risk factors for cardio-metabolic disease. Therefore, it seems likely that a true association exists between physical activity and cardio-metabolic health in adolescents.

2.2.6 *Obesity*

Janssen and Leblanc (2010) identified 31 studies which reported relationships between physical activity and obesity development with a median odds ratio of 1.33 when comparing least active adolescents to the most active (Janssen & LeBlanc, 2010). A further four studies (Dencker et al., 2006; Eisenmann et al., 2007; Ness et al., 2007; Stevens et al., 2007), using device-measured activity levels, reported a median odds of 3.79 for the development of obesity when comparing inactive youth to those who met local physical activity guidelines. Overall, evidence from these studies suggest physical activity during adolescence is associated with lower obesity, which may indicate a reduction in non-communicable diseases. However, due to the cross-sectional nature of the studies, our ability to determine causality is limited.

Table 2.1: Daily physical activity time and percentage of adolescent participants meeting physical activity guidelines globally

Author (date)	Study/Participants	Measurement of PA	Results
Sanchez et al (2007) **USA**	Health promotion intervention trial n=878, aged 11-15 y, 2001-2002, analysed in 2006.	Actigraph accelerometer, worn for an average of 8.3 days (96% wore for >5 days)	A total average of 58 min/day spent in MVPA (males = 68 min/day, females = 50 min/day) 45% met PA guidelines, specifically, 33.6% females, 59% males.
Troiano et al (2008) **USA**	NHANES, representative cross-sectional study, 2003-2004 n=6329 adolescents, aged 12-19 y	Actigraph accelerometer, worn during waking hours for 7 consecutive days	16-19 y old's spent an average of 32.7 min/day in MVPA and 7.6% of 16-19 y old's met the PA guidelines. Specifically, males 10%, females 5.4%
Pearson et al (2009) **United Kingdom**	n=176 adolescents aged 12-16 y	Accelerometery, worn all-hours, over 7 consecutive days	22.2% participants met PA guidelines, with males more active than females ($p<0.001$)
Colley et al (2011) **Canada**	Canadian Health Measures survey, 2007-2009 n=1608 children and youth, aged 6-19 y	ActiCal Accelerometer worn during waking hours for 7 consecutive days.	15-19 y old's males spent and average 53 min/day in MVPA, females an average of 39 min/day. 6% of males and only 2% of females (15-19 y) met the PA guidelines >6 days/week.
Ruiz et al (2011) **9 European Countries**	HELENA cross-sectional study 2006-2008 n=2200, (12.5 – 17.49 y)	Actigraph GT1M accelerometer, worn during waking hours, for 7 consecutive days	Males spent 64 min/day in MVPA, while females spent 49 min/day. Overall, 41% met the PA guidelines, specifically 56.7% of males, and 27.5% of females
Australian Bureau of statistics (2012)	Australian Health Survey, 2011-2012 n=32000 adults and children (2-17 y)	Self-reported data where possible. Parents answered for children <15 y.	Males participated in 45 min/day MVPA, while females only 30 min/day. Overall, 7.9% participants met PA guidelines. 7.2% females aged 13-17 y met PA guidelines

Dewar et al (2014) Australia	NEAT girls' group, randomised controlled trial, 12-month follow-up n=357	Actigraph accelerometer, worn during waking hours, over 7 consecutive days	246 females met PA guidelines at baseline and/or 12 months.
Guthold et al (2020)	Cross-sectional survey data from 298 surveys, across 146 countries, 2001-2006 n=1,600,000 school students aged 11-17 y	Validated self-report surveys from WHO, or multi-country surveys	81% of adolescents aged 11-17 y did not meet the PA guidelines. Specifically, females 84.7% (95% CI:83.0 to 88.2)
Hanson et al (2019) South Africa	Longitudinal study called the Birth-to-Twenty Plus Cohort. n=1414 youth, aged 12-17 y	Validated self-report questionnaire. (Organised sport was included as a surrogate for MVPA)	18% of males and 0% of females met PA guidelines. 11% of females did participated in sport, however, did not meet duration guidelines

USA = United States of America, n=number, y=years, MVPA = moderate-to-vigorous activity, PA- physical activity, NHANES = National Health and Nutrition Examination Survey, HELENA= Healthy Lifestyle in Europe by Nutrition in Adolescence, NEAT= The Nutrition and Enjoyable Activity for Teen Girls, WHO= World Health Organisation

Table 2.2: Cross-sectional studies describing levels of physical activity performed by adolescents in NZ

Author (date)	Study/participants	Measurement of PA	Results
Maddison et al (2010)	Representative Survey. Representative sample of n=2503 children and young people, aged 5-24 y.	Validated computerised 24-hour recall questionnaire (MARCA), alongside Actigraph accelerometers, worn for 7 days consecutively.	Average 45.9 min/day MVPA (15-19 y). Males completed 55 min/day compared to 36 min/day for females. Of 15-19 y old's 32.3% met PA guidelines, specifically, 49% Males, 33% Females
Clark et al (2013)	Youth2000 survey series, 2012 survey. n=8497 (54.4% female) aged 12-18 y	Data collected by School-based, Self-administered questionnaire. Measured as physical activity accumulated in a 24-hour period. Classified as physically active if participate in ≥60min PA per day.	Total 9.6% (95% CI:8.7 to 10.5) ages 12-18 y met PA guidelines. Specifically, 6.3% (95% CI: 5.6 to 7.0) of females. Met PA guidelines by age: 10.7% (95% CI: 9.3 to 12.2) aged 15 y 8.3% (95% CI: 6.6. to 9.9) aged 16 y 7.9% (95% CI: 6.4 to 9.5) aged 17 y+
Hinckson et al (2017)	BEANZ study 2013-2014 Cross-sectional n=524 Aged 12-18 y Auckland and wellington high schools (n=8), during 2013-2014 school year.	Actigraph GT3X+ accelerometer, worn for 7 consecutive days	Average accumulated MVPA ~112min/day Females accumulated 16.5% less MVPA than males. Each one-year increase in age corresponded to a 6.1% decrease in MVPA
Ministry of Health (2019) NZ Health Survey	Multi-stage sampling design. Representative sample n=13869 adults and n=4723 parents of children in NZ	Self-reported PA. MVPA for 10-minute bouts. Classified as physically active if participate in >5hr/week MVPA	40.6% of 15-19 y old's classified as physically active. Specifically, 37.3% female, 43.6% male.
Kek et al (2019)	Sub-sample from the BEATS study, 2014-2015. n=314 adolescents aged 12-18 y, sample from Dunedin high school	Actigraph GT3X+ accelerometer, worn for up to 24 hours, for 7 days, alongside a self-report wear-time diary (valid if ≥5 days, ≥10-hour wear-time)	Average of 55.8 (21.1) min/day MVPA. A total of 39.2% of participants met to NZ physical activity guidelines. 45.6% of males, 36% of females.

n=number, y=years, MVPA = moderate-to-vigorous physical activity, PA = physical activity, BEANZ = Built Environment in Adolescent New Zealanders, BEATS = The Built Environment and Active Transport to School

2.2.7 How much activity are adolescents doing?

There is sufficient evidence to support the role of PA in disease prevention (Tarp et al., 2018; Telama et al., 2005; WHO, 2016), however, as seen in **Table** 2.1 and

Table 2.2, many adolescents are still not meeting physical activity guidelines. Globally, up to 81% of adolescents aged 11-17 y are insufficiently active, with 84.7% of females not meeting PA guidelines (Guthold et al., 2020). As summarised in **Table** 2.1, on average, only 1 in 4 adolescents is meeting PA guidelines, with time spent in MVPA varying around the world from 20 to 64 minutes per day. Females are also substantially less active than males and older (14-18 y) adolescents are less active than their younger counterparts (11-14 y) (Pearson et al., 2009).

Table 2.2 summarises five NZ studies, which have measured physical activity in adolescents. Of the two studies that used self-report physical activity data, the Youth'12 Survey shows in 2012, of surveyed adolescents aged 15, 16, and 17 y, only 10.7%, 8.3%, and 7.9% respectively, were sufficiently active. Conversely, in early 2019, the Ministry of Health (MOH) reported that of all adolescents aged 15-19 y, 40.6% were physically active. Disparities arise when comparing these studies as the MOH (2019) defined 'physically active' as completing more than 5 hours per week of activity, while other studies use 7 hours (>60 minutes/day) (Clark, et al., 2013), therefore it is unknown if there is a true difference in PA or if it is a reflection of different cut-offs used.

Three studies used accelerometery, however, comparisons between studies was difficult, with studies ranging from single site (Kek et al., 2019) to representative studies (Ministry of Health, 2019), and another using an extremely wide age range from 5-24 y (Maddison et al., 2010).

In 2010, Maddison et al (2010) reported as few as 33% of females were meeting physical activity guidelines, with an average of 36 min/day MVPA; whereas in 2019, Kek et al (2019) indicated an average of 36% were physically active, and average adolescent activity was 55.5min/day, however the use different accelerometer cut points(Evenson et al., 2008) and the inclusion of males in the average min/day may explain greater levels of physical activity recorded. Hinckson et al (2017) reported that adolescents in their study (both male and female) were accumulating 112 min/day MVPA. However, differences in the cut points used to identify MVPA in this study, compared to the two previously described studies limits further comparisons. Overall, current activity levels in NZ adolescents are low, with fewer than 40% of female adolescents meeting national recommendations of at least 60 minutes MVPA daily, with older females (14 y+) being the least active sub-group of this population.

2.3 Fruit and Vegetable Consumption

2.3.1 Health Benefits of Fruit and Vegetables

Containing a variety of vitamins and minerals, fruit and vegetables provide us with many of the micronutrients to support a healthy, functioning body and lifestyle (Slavin & Lloyd, 2012). Fruit and vegetable consumption is also associated with reduced all-cause mortality and provides protection against NCDs such as hypertension and CVD, colorectal cancer (Bellavia et al., 2013) and diabetes mellitus (Li et al., 2014).

World-wide, the most common recommendation is to consume at least 5 servings per day; 3 from vegetables and 2 from fruit (Bellavia et al., 2013; Kann et al., 2000; Muñoz et al.,1997; Roark & Niederhauser, 2014; Sanchez et al., 2007; Slavin & Lloyd, 2012).

2.3.2 Adults

In adults, Gaziano et al (1995) found that those in the highest quartile for fruit and vegetable consumption had a 46% lower risk (95%CI: 14% to 66%) of death from CVD related causes than adults in the lowest quartile of consumption (Gaziano et al., 1995). After 13-years of follow up on Swedish males and females, Bellavia et al (2013) reported a 53% greater mortality rate (HR: 1.53; 95% CI: 1.19 to 1.99) in those who never consumed fruit and vegetables compared to those who ate at least 5 servings per day. Bellavia et al (2013) also reported a 3-year (36 month) reduction in life length in those who never consumed vegetables (95% CI: -58 to -16 months) and 19-month shorter life when comparing no fruit intake to at least 1 serving per day (95% CI: −29 to −10 months).

Slattery et al (1998) reported that adults who followed a "prudent" dietary pattern, which was high in fruits, vegetables, nuts, wholegrains, legumes and fish, had a decreased risk of developing colorectal cancer (men: OR = 0.63, 95% Cl: 0.43 to 0.92; women: OR = 0.58; 95% Cl: 0.38 to 0.87) compared to the individuals who consumed a diet lower in these food groups, and higher in fast foods, saturated fats and processed and refined grains (Slattery et al., 1998).

The results of another study by Hung et al (2004), which involved participants from both the Nurse's health study and the Health professional's follow up study, indicated that for every one serving increase or green leafy vegetables, there was 5% decrease in risk of major chronic disease (95% CI: 8 to 1%). Overall, the body of research available positively links health outcomes of adults with sufficient fruit and vegetable intakes.

2.3.3 Adolescents

Similarly, to physical activity, for reasons such as the limited evidence of outcomes in adolescents, there is a paucity of data investigating the effects of fruit and vegetable intakes on non-communicable disease incidence in adolescents. However, available evidence, tracking from adolescence to adulthood suggests that those who consume health promoting diets, are able to reduce their risk of these lifestyle diseases (Bellavia et al., 2013; Ness et al., 2005; Slattery et al., 1998).

Limited evidence of rates of NCDs in adolescents compared to adults are likely due to the length of follow up required for adolescent studies and the smaller volume of research that has been conducted regarding youth dietary intakes. A cross-sectional study by McNaughton et al (2008) found an inverse association between diastolic blood pressure and adolescents who consumed a diet high in fruit and vegetables compared to those with diets high in fat and sugar ($p=0.0025$).

Dietary behaviours including consumption of at least five servings of fruits and vegetables daily are a strategy for long-term prevention of disease (Dauchet et al.,2006; Ness et al., 2005; Song et al.,2005). Multiple studies have reported that diets lowering stress and inflammation may reduce oxidative stress and inflammations, crucial in the prevention of atherosclerosis (Chisolm & Steinberg, 2000; Hansson, 2005; Holt et al., 2009)

Table 2.3: Fruit and Vegetable consumption by adolescents per day globally

Author (date)	Study/Participants	Data collection method	Fruit (≥2 serves/day)	Vegetables (≥3 serves/day)	Fruit and Vegetable (≥5 serves/day)
Krebs-Smith et al., 1996	USDA's CSFII n = 3148 Aged 2-18 y	24-hour dietary recall, 2 days self-report diet records	N/A	N/A	20.4% overall consumed 5 servings total (17.9% females 12-18 y) 7.2% overall consumed 2 serves fruit AND 3 serves vegetables (7.2% females 12-18 y)
Munoz et al. (1997)	USDA's: CSFII n=3307 Aged 2-19 y	24-hour recall, 2 days weighed food records (recorded by an adult if <12 y)	22% males and 23% females consumed ≥2 servings/day	55% males, 38% females consumed ≥3 servings/day	N/A
Kann et al. (1999)	3-stage cluster sample design n=15,349, Aged 14-18 y	Self-administered questionnaires (food frequency)	N/A	N/A	23.9% of 14-18 y consumed ≥5 servings/day
Grunbaum et al. (2004)	3-stage cluster sample design, representative sample n=15,240 Aged 14-18 y	Self-administered questionnaires	N/A	N/A	22% overall, 23.6% male, 20.3% female 14-15 y female 21.2% vs 17-18 y female 18.3%
Sanchez et al. (2007)	Cross-sectional n=878 Aged 11-15 y	Three 24-hour food recall interviews	N/A	N/A	11.9% met recommendations (Male 12.3% vs Female 11.5%) On average, Females 2.9 serves/day, Males 3.2 serves/day

USDA= United States Department of Agriculture, CFII= Continuing Survey of Food Intakes by Individuals, n=number, y= years, N/A= Not Applicable.

Table 2.4: Daily fruit and vegetable consumption of NZ adolescents

Author (date)	Study/Participants	Data collection Method	Fruit (≥2 serves/day)	Vegetables (≥3 serves/day)	Fruit and Vegetable (≥5 serves/day)
Clark et al (2013)	Youth2012 Survey Series n=8500 Aged 12-18 y	Self-administered questionnaire (FFQ)	51.9% (95% CI: 49.8 to 54.1) 12-18 y. specifically, 54.8% (95% CI: 52.2 to 57.4) females, 48.5% (95% CI: 46.0 to 51.0) males	37% (95% CI: 35.0 to 39.0) 12-18 y. specifically, 37.1% (95% CI: 35.0 to 39.2) females, 36.9% (95% CI: 34.6 to 39.2) males	30% (95% CI: 28.4 to 31.6) 12-18 y. specifically, 30.4% (28.6 to 32.3) females, 29.5% (95% CI: 27.5 to 31.4) males
Ministry of Health (2011)	Adult Nutrition Survey (ANS) 2008-09 n=4721 aged ≥15 y	Dietary Habits questionnaire	65% (95% CI: 59.3 to 70.7) females 15-18 y, 61.2% (95% CI: 54.0 to 68.4) males 15-18 y	61.5% (95% CI: 55.6 to 67.4) females 15-18 y, 50.9% (95% CI: 43.8 to 57.9) males 15-18 y,	N/A

NZ= New Zealand, n=number, y= years, FFQ= Food Frequency Questionnaire

2.3.4 Current intakes of Fruit and Vegetables in Adolescents

Globally, less than 25% of adolescents are consuming the daily recommended levels of fruit and vegetables (≥5 serves/day), as summarised in **Table** 2.3. Only one study (Muñoz et al., 1997), assessed intakes of fruit and vegetables individually and reported less than one quarter of females (23%) aged 2-19 y were consuming ≥2 serves of fruit daily, and less than half (38%) of females were consuming ≥3 serves/day of vegetables . Two studies (Krebs-Smith et al.,1997; Muñoz et al., 1997) included data from a wide age range, including children (2-19 y), therefore it is harder to make comparisons with studies that have only included adolescents or have much tighter age ranges.

Four studies (Grunbaum et al., 2004; Kann et al., 2000; Krebs-Smith et al., 1997; Sanchez et al., 2007), all reported combined fruit and vegetable intakes (≥ 5 serves/day), with Krebs-Smith et al (1997), Grunbaum et al (2004) and Sanchez et al (2007) all reporting that females had the lowest intakes across all ages. Although males are indicated as consuming more fruit and vegetables, it is unlikely males are meeting the guidelines as a result of being more health conscious than females, rather they are likely eating more overall. Two studies from Table 2.3 assessed fruit and vegetable intake via self-administered questionnaires, which resulted in higher reported consumption compared to the studies that used 24-hour recalls

In NZ, available data of fruit and vegetable consumption in adolescents is limited and outdated. As summarised in

Author (date)	Study/Participants	Data collection Method	Fruit (≥2 serves/day)	Vegetables (≥3 serves/day)	Fruit and Vegetable (≥5 serves/day)
Clark et al (2013)	Youth2012 Survey Series n=8500 Aged 12-18 y	Self-administered questionnaire (FFQ)	51.9% (95% CI: 49.8 to 54.1) 12-18 y. specifically, 54.8% (95% CI: 52.2 to 57.4) females, 48.5% (95% CI: 46.0 to 51.0) males	37% (95% CI: 35.0 to 39.0) 12-18 y. specifically, 37.1% (95% CI: 35.0 to 39.2) females, 36.9% (95% CI: 34.6 to 39.2) males	30% (95% CI: 28.4 to 31.6) 12-18 y. specifically, 30.4% (28.6 to 32.3) females, 29.5% (95% CI: 27.5 to 31.4) males
Ministry of Health (2011)	Adult Nutrition Survey (ANS) 2008-09 n=4721 aged ≥15 y	Dietary Habits questionnaire	65% (95% CI: 59.3 to 70.7) females 15-18 y, 61.2% (95% CI: 54.0 to 68.4) males 15-18 y	61.5% (95% CI: 55.6 to 67.4) females 15-18 y, 50.9% (95% CI: 43.8 to 57.9) males 15-18 y,	N/A

Table 2.4, the Adult Nutrition Survey used a dietary habits questionnaire to identify consumption of fruit and vegetables separately (Ministry of Health, 2011a), while the Youth2012 Survey used a self-administered questionnaire, assessing fruit and vegetable intakes individually, then intakes combined. These studies report an average of 30 to 60% of both males and females, aged 12-18 y were consuming the recommended servings of fruit (≥2 serves per day), and vegetables (≥3 serves/day). In contrast to international data, NZ data indicates a greater proportion of female adolescents are meeting the recommendations.

2.4 Physical Activity and Fruit and Vegetable Consumption

Associations between physical activity and fruit and vegetable consumption are rarely reported. Additionally, the five studies identified in this area (Table 2.5) have methodological differences, limiting the ability to make direct comparisons. One study (Pate et al.,1996), reported adolescents who did not consume fruits were 2.6 times as likely to be inactive and those who did not consume vegetables were 2.03 times as likely to be inactive compared to those who did consume fruits and vegetables.

Pearson et al (2009) measured physical activity using accelerometry and found that less than 50% of females were meeting PA guidelines, while more than 30% of females did not meet activity or fruit and vegetable guidelines. Although Pearson et al (2009) did not comment on the relationship between PA and fruit and vegetable consumption, results show that the most active females, also consumed the most fruit and vegetables daily, with older females more likely to meet fruit recommendations than younger females (Pearson et al., 2009).

Ottevaere et al (2011) found the most active females had the greatest fruit intakes but there was no difference in vegetable consumption across levels of PA. Two other studies (Cavadini et al., 2000; Kelishadi et al., 2007) have also found a positive association between fruit consumption and physical activity. Kelishadi et al (2007) reported that those doing the most physical activity had the highest fruit, vegetable and total fruit and vegetable intakes per week compared to the least active participants.

While comparisons between these cross-sectional studies are difficult, findings are consistent, where those who are more physically active tend to consume more fruit, although the association between activity levels and vegetable consumption is less clear. These conclusions are based on a small number outdated of studies, and therefore, it is possible the data is no longer representative of adolescent behaviour. Also, the relationship between fruits and vegetable intake and physical activity has not been investigated in NZ adolescents, further limiting our ability to make conclusions about the relationship between these two lifestyle factors in our local population.

2.5 Methodological Considerations

2.5.1 Self-report Physical Activity

Self-report methods to measure physical activity are not limited to self-administered techniques and may include interviewer-administered questionnaires or diaries (e.g. I-PAQ-SF (Craig et al., 2003). Self-report methods are cost effective and allow collection of type, duration and location of activity from large study populations (Warren et al., 2010). Little to no equipment is required, with reduces the burden on participants and investigators. Unfortunately, self-report approaches are subject to a level of recall bias, particularly in adolescents (Biddle et al., 2011; Sallis & Saelens, 2000).

Table 2.5: Associations between fruit and vegetable consumption and physical activity among adolescents globally

Author (date)	Study/Participants	Methods	Fruit & Veg	Physical Activity	Relationship found
Pate et al., 1996 **USA**	Cross-sectional n=11,631 Aged: 11-18 y Classified as low active (n=1641) and high active (n=2652)	Self-administered questionnaire incl. PA and dietary behaviours Low active defined as <20 min/day MVPA and <20 min/day LPA	N/A	68.3% 16-18 y low active, specifically 68.3% female	Lower active associated with lower fruit & vegetable consumption Inactive were 2.03 times more likely to not consume vegetables daily (OR: 2.03, 95%CI: 1.73 to 2.37) and 2.64 times more likely not to consumer fruit daily (OR: 2.64, 95%CI: 2.21 to 2.73)
Cavadini et al., 2000 **Switzerland**	Cross sectional Main Study, n=3540 Aged: 9-19 y	Self-administered questionnaire incl. PA and Dietary behaviours Athletic: if participate in sports 'nearly every day' or 'every day' Non-athletic: 'never' or 'almost never' participate in sports	Eat fruit daily: Females = 50% Eat vegetables daily: Females = 20%	N/A	Greater consumption fruit in athletic vs. non-athletic (69% compared to 37% had 1+ serve/day) No difference in vegetable consumption
Kelishadi et al., 2007 **Iran**	Cross-sectional (2003/04) =n=21,111 Aged: 6-18 y	Self-administered questionnaire FFQ	Fruit: 1st = 9 serves/week 2nd = 8 serves/week 3rd = 9.5 serves/week Vegetable: 1st = 7.8 serves/week 2nd = 7.5 serves/week 3rd = 8.3 serves/week Fruit & Vegetable: 1st = 16.9 serves/week 2nd = 15.2 serves/week 3rd = 17.8 serves/week	N/A	Highest activity group had the highest intakes of fruit, vegetables, and combined serves fruits and vegetables

Pearson et al., 2009	Cross-sectional n=176 Aged: 12-16 y, mean 14.4 y	Self-administered dietary questionnaire (FFQ) Actigraph Accelerometer worn during waking hrs, 7 consecutive days Categorised into three percentiles (25th, 50th, 75th)	Older (>14.4 y) ate more F&V than younger (<14.4 y) adolescents ($p < 0.001$) Younger group: 25th: 2.5 serves/day 50th: 3.8 serves/day 75th: 6.1 serves/day Older group: 25th: 3.8 serves/day 50th: 5.4 serves/day 75th: 7.8 serves/day Females ≥5 serves/day = 16.8%	27.6% males met guidelines vs 16.8% females. By tertile females: 25th: 25.5 min/day MVPA 50th: 40.5 min/day MVPA 75th: 53.1 min/day MVPA Females ≥60 min/day MVPA = 40.4%	33% did not meet either PA or fruit & vegetable guidelines, specifically 34.8% females, 31% males. Most active females (53.1 minutes MVPA) also consumed most fruit and vegetable serves/day (6.9)
Ottevaere et al., 2011 Europe	HELENA study (2006/07) Cross-sectional n=2176 mean age: 14.7 y	Two self-administered 24-hour diet recalls Self-administered PA questionnaire Categorised as 1st (least active), 2nd, 3rd (most active) tertiles	FRUIT: 1st: 111g/day 2nd: 127.8g/day 3rd: 126.1g/day VEGETABLE: 1st: 122g/d 2nd: 124g/d 3rd: 123g/d	Youngest females (14.4 y) most active, 1248 min/week MVPA Least active females (15.1 y), 159min/week MVPA	Higher consumption fruit in most active (126.1g/day) vs least active (111g/day) Positive association between fruit consumption and level of PA No association between vegetable consumption and PA

USA= United States of America, n= number, y= years, PA = Physical Activity, N/A= Not Applicable, FFQ= Food Frequency Questionnaire, MVPA = Moderate-to-Vigorous Physical Activity, HELENA = Healthy Lifestyle in Europe by Nutrition in Adolescence

Janssen and Leblanc (2010) reported that PA intensity is likely over-estimated when relying on participant memory. Whether self or interviewer-administered, questionnaires require the participant to be literate and numerate to answer questions accurately, therefore may not be appropriate for all populations (Biddle et al., 2011; Janssen & LeBlanc, 2010; Sallis & Saelens, 2000).

2.5.2 Accelerometry

Accelerometers are the most commonly used method of measuring physical activity, providing information on duration and intensity of activity performed (Freedson & Miller, 2000). Accelerometers are small devices worn either on the hip, thigh or wrist, which measure the intensity of body movement as a magnitude of acceleration on one to three different axes. Acceleration is then translated into activity counts per minute and cut points are applied to the counts per minute data to determine the intensity of activity (Ridgers & Fairclough, 2011). Accelerometry is preferred ahead of questionnaires or other devices such as pedometers as they measure activity in all three planes of movement. Accelerometery provides a profile of habitual physical activity , recording the short bouts of moderate-to-vigorous activity, common in adolescents, and often underreported when using self-report measures alone (Rowlands & Eston, 2007).

Accelerometry however, does have limitations, where accelerometers may inaccurately record movement of the upper body and underestimate the intensity of resistance training (Dewar et al., 2014; Warren et al., 2010). Participant burden is present with accelerometry through reliance on participants wearing the device correctly and needing to accurately record activity during times of removal, where poor compliance may lead to under-representation of activity levels (Dewar et al., 2014).

Raw accelerometer data is collected objectively, however, the application of proprietary algorithms and cut points, while aiding in the understanding and interpretation of this data, do introduce an element of subjectivity (Troiano, 2005). The existence of multiple different cut-points often limits the comparability of data between studies. Trost et al (2005) and Ward et al (2005) have both recommended that data be collected consecutively for four to nine days, to allow for weekend variation, and data to be saved in the shortest epoch capture (15 seconds) to record all activity (Trost et al., 2005; Ward et al., 2005).

2.5.3 Fruit and Vegetable consumption

Accurately measuring fruit and vegetable intakes of group of adolescents is difficult due to the high within person variability of young people (Roark & Niederhauser, 2014). Diet records are usually considered the gold standard for measuring dietary intakes, particularly for individual nutrients, although they are rarely used to assess fruit and vegetable intake, and burdensome to both the participant and the research team (Gibson, 2005; Roark & Niederhauser, 2014). Dietary habits and food frequency questionnaires are the most commonly used method of assessing fruit and vegetable consumption (Tables 2.3-2.5). Depending on the design of the questionnaire they can provide information on quantity as well as frequency of consumption, and tend to be quick and easy to administer(Roark & Niederhauser, 2014). However they do have some limitations. They rely on participant memory, and participants must be both literate and numerate to complete them accurately (Gibson, 2005). Twenty-four hour recalls are used occasionally, but they are more burdensome than questionnaires (although less so than diet records), and require repeated recalls to be performed to account for day-to-day variation (Roark & Niederhauser, 2014). However, they are less reliant on memory, numeracy and literacy than questionnaires – particularly when they are administered by a researcher (Gibson, 2005; Roark & Niederhauser, 2014).

2.6 Conclusions and Summary

Fruit and vegetable consumption and physical activity both play a vital role in the prevention and reduction in morbidity and mortality Despite the known importance of these factors, current literature has highlighted how low fruit and vegetable intakes and levels of PA are in adolescents both locally and globally, particularly in females (Guthold et al., 2020). Many recent studies have looked at fruit and vegetable consumption, or physical activity, individually, however few have looked at the association between these two lifestyle behaviours. No research has been conducted in NZ females describing the relationship between fruit and vegetable consumption and physical activity.

3 Objective Statement

The aim of this study is to investigate the association between physical activity and fruit and vegetable consumption of a sample of NZ adolescent females.

The objectives of this study are:

- To measure the average amount of time spent in moderate-to-vigorous physical activity per day
- To measure the average consumption of fruits, vegetables, and fruit and vegetables per day.
- To compare moderate-to-vigorous physical activity levels and fruit and vegetable consumption with existing recommendations within NZ
- To investigate the association between physical activity and fruit and vegetable consumption in this sample of adolescent females

4 Methods

4.1 Overall study design

Data reported in this thesis was collected as part of the larger, nationwide SuNDiAL project. The study was a cross-sectional survey of female adolescents (aged 15-18 years) within NZ. Data was collected from participants in two time points: February-April and July-September 2019. The main aim of this study was to compare the dietary intakes and habits, nutritional and health status, attitudes, motivations and lifestyles of vegetarian and non-vegetarian female adolescents in NZ. A sample size of 300 female adolescents enrolled from 14 high schools was targeted as it provided 80% power to the α=0.05 to detect a 0.5 standard deviation difference (moderate difference) in any continuous outcome variables between vegetarians and non-vegetarians, assuming a 20% prevalence of vegetarianism and a design effect (for school clusters) of 1.5. This thesis investigates the relationship between physical activity and fruit and vegetable consumption, in a subsample of participants from the SuNDiAL projected who consented to wear accelerometers.

4.2 Participants

4.2.1 Recruitment of schools

Adolescent females from eight NZ regions (Whangarei, Tauranga, New Plymouth, Wellington, Nelson, Christchurch, Wanaka and Dunedin) were targeted using school-based recruitment. Schools were first recruited via a contact list, established for each data collection area. Initially, schools which had a considerable female roll (>200) and were lower decile (a measure of the socio-economic status of the school) were prioritized, to attempt to produce a more representative sample of female adolescents.

Each school was contacted via email, then followed up via phone call or email two weeks later to confirm their interest in participating. When schools identified as interested, suitability of dates and time for data collectors (MDiet students) to enter the school were discussed. During these conversations, facilities and spaces available for data collection were also organised. When failure to secure a school in the target area occurred, word of mouth was used to recruit a school in that location.

Data collectors carried out presentations to female students aged 15-18 years at participating schools using a digital presentation and a recruitment video. Printed information sheets were also distributed. Girls who were interested in participating, provided their email address either directly to the data collectors or enrolled online via the study website. All girls who enrolled were then sent an email containing a link to the online REDCap (production server version 9.3.3) questionnaire allowing them to provide informed consent. Parents of girls who were under 16 years were also emailed to provide informed parental consent. Participants completed the questionnaires regarding demographics and health, as well as questions addressing attitudes, motivations and beliefs about food choices.

4.2.2 Eligibility criteria

Inclusion criteria for the SuNDiAL study were persons aged 15-18 years, self-identified as female, and attended a participating NZ secondary school. Participants were only eligible if they were able to understand and speak English. Participants were not eligible if they knew they were pregnant.

4.2.3 Ethics

The SuNDiAL study was approved by the University of Otago Human Ethics Committee (Health): H19/004 (***Appendix A***: SuNDiAL Protocol 2019). Online informed consent was obtained from all participants and from parents/legal guardians of those under 16 years of age. The study is registered with the Australian New Zealand clinical trials registry: ACTRN1269000290190.

4.3 Measurement Procedures

4.3.1 Participant Demographics

To determine their NZ Deprivation Index 2018 decile (Atkinson, Salmond, & Crampton, 2019), participants submitted their home address, which was then categorised based on decile: Low deprivation (deciles 1 to 3); medium deprivation (deciles 4 to 7); and high deprivation (deciles 8 to 10). Ethnicity was assigned in a prioritised manner, collapsed into four categories: NZ European & others; Maori; Pacifica; Asian.

4.3.2 24-hour dietary intake recall

Dietary recall data for each participant was collected by two non-consecutive twenty-four-hour diet recalls, performed using a multi-pass method. The first recall with data collectors was performed during school hours, and the second by video or phone call on the following weekend to ensure dietary intake variation was accounted for. Participants were questioned about intake from midnight to midnight of the previous day, with the assistance of food models, food photographs and household measures to prompt participants for quantities and brands of foods, as well as cooking methods. Data from each recall was entered into the Foodworks9 (Xyris Software Australia Party Ltd) by data collectors to provide calculations of energy, macronutrients and micronutrients. The Multiple Source Method (MSM) (Harttig et al., 2011) was used to adjust dietary intake estimated for 'usual intake'. Although collected, 24-hour recall data was not reported in this thesis.

4.3.3 Dietary Habits Questionnaire

Participants answered a 73-question dietary habits questionnaire, adapted from the questionnaire used in the NZ Adult Nutrition Survey 2008/2009 (Ministry of Health, 2011a), which was cognitively tested by a specialist group (University of Otago & Ministry of Health, 2011). Participants were asked to identify, over the previous 4 weeks: "On average how many servings of fruit - fresh, frozen, canned or stewed - do you eat per day or per week? Do not include fruit juice or dried fruit" and "On average how many servings of vegetables - fresh, frozen or canned - do you eat per day or per week? Do not include vegetable juices". For responses to both the fruit and vegetable questions, participants were able to select a serving size from seven responses, ranging from "never" to "≥3 serves/day. Each participant was asked to complete each section of the questionnaire, with an answer required for each question. There were no timeframes or limitations on completion, and participants were able to go back and change previously answered questions, however, once submitted, it was no longer accessible to change.

A unique code was provided for incomplete questionnaires, allowing participants to return at any point. Reminders were also sent to encourage completion. Incomplete questionnaires were included on a case-by-case basis, depending on the outcome of interest. In this thesis, the focus on fruit and vegetable consumption of adolescent females means that only responses pertaining to fruit and vegetable dietary habits were included.

4.3.4 Anthropometry

Bodyweight was measured with participants wearing light clothing and no footwear using bodyweight scales (one of Medisana PS420; Salter 9037 BK3R; Seca Alpha 770; or Soehnle Style Sense Comfort 400) and recorded to the nearest 0.1kg. Height was measured to the nearest millimetre using a stadiometer (Seca 213 or Wedderburn). All measurements were taken in duplicate, with a third measurement taken if any duplicates were more than 0.5 units apart.

Data collectors were trained to measure anthropometry using published protocols (Ministry of Health, 2008; National Institute for Health Research, 2019) and study protocols (***Appendix A***: SuNDiAL Protocol 2019). Prior to data collection, an inter-rate reliability study was carried out to verify consistency between data collectors, using a sample of 12 females aged 15-18 years who had consented to having anthropometric measurements taken. Each girl was measured twice by data collectors and inter-rate reliability was assessed using mixed effects intra-class correlation co-efficient (ICC). ICC for weight was 1.00, and height was 0.92. These results indicated a high level of consistency between data collectors. Body mass index (BMI) was calculated by weight (kg) divided by height (m) squared, BMI z-scores were calculated for age and sex using the WHO child growth standards (De Onis et al., 2007), providing a reference for 5-19-year old's.

4.3.5 Accelerometry and wear-time diaries

Actigraph GT3X+ accelerometers and self-report wear-time diaries were used to measure MVPA. Accelerometers were distributed on a first-in first-serve basis, therefore due to the limited number available, in some areas, not all females who consented to this portion of the study were given a device. Accelerometers were worn continuously on the right hip for 24 h a day, for seven consecutive days. Instructions for accelerometer use and wear-time diary entries were given to the participants verbally (***Appendix A***: SuNDiAL Protocol 2019). Participants were instructed to remove the accelerometer while showering, bathing, swimming and during contact sports such as rugby or wrestling.

Sleep and wear-time diaries (***Appendix B***: Sleep and Wear-time Diary) were provided to encourage compliance. The seven-day diary included a daily sleep log, instructing the participants to record sleep patterns, noting the time they went to bed, time they believe they went to sleep and the time it took to fall asleep (minutes), as well as the time they woke up and time they got out of bed. Whenever the accelerometer needed to be removed, the participant was asked to record removal time, reason for removal and a description of any activities, which would not be recorded by the accelerometer, including duration and intensity of activity.

4.4 Data processing and analysis

4.4.1 Wear-time

Wear-time was been defined as the time when the participant reported wearing the accelerometer in the wear-time diary. Days were only considered valid if wear time during waking hours totalled 10 hours or more, and total wear time or wear-time plus imputed physical activity totalled 20 hours or more. Valid days also included at least 2 hours of sleep. Data from participant's could only be included in the analysis if there were at least three days of valid data available.

4.4.2 Data processing

Accelerometers and corresponding wear-time diaries were returned to the research team at the University of Otago, where data was downloaded using Actilife software (Actigraph, Pensacola, Florida, Version 6). Accelerometer data was saved in 15-second epochs to capture short bouts of physical activity, then converted to a csv file and assessed using Stata (Stata Statistical Software: Release 16. College station, Texas: StataCorp).

Moderate-to-vigorous physical activity was identified as at least 1952 cpm, using the y-axis (Freedson & Miller, 2000). Any physical activity recorded in the wear time diary while the participant was not wearing the accelerometer was identified as 'non-wear time physical activity' and was added to the amounts of wear time MVPA according to the self-reported intensity of activity.

4.5 Statistical Analysis

4.5.1 Statistical methods

Participant demographic characteristics, anthropometric data and all analyses were carried out via the use of excel software (version 16.30 Microsoft Corporation, Santa Rosa California). Participant demographics mean time spent in MVPA across age categories, and frequency of fruit and vegetable consumption were derived and tabulated. Participants were defined as meeting the physical activity guidelines if their mean MVPA met or exceeded 60 min/day.

Participants were defined as meeting the fruit or vegetable consumption guidelines if they reported consuming ≥2 servings of fruit or ≥3 servings of vegetables, respectively per day. To be defined as meeting the fruit and vegetable guideline of ≥5 servings a day, participants must have separately met both the fruit and vegetables guidelines. The association between physical activity and fruit and vegetable consumption was assessed by calculating the odds of meeting the fruit and vegetable guidelines in those meeting the activity guidelines, compared to those who were not (Stata Statistical Software: Release 16. College station, Texas: StataCorp).

5 Results

Of the 137 participants who wore and returned accelerometers, 16 individuals were not eligible for analysis due to invalid accelerometer data, no BMI status and withdrawal of data from the study. A further five participants also did not have data for fruit and vegetable consumption data so were excluded from analysis. Leaving a total 114 participants included in the analysis presented here.

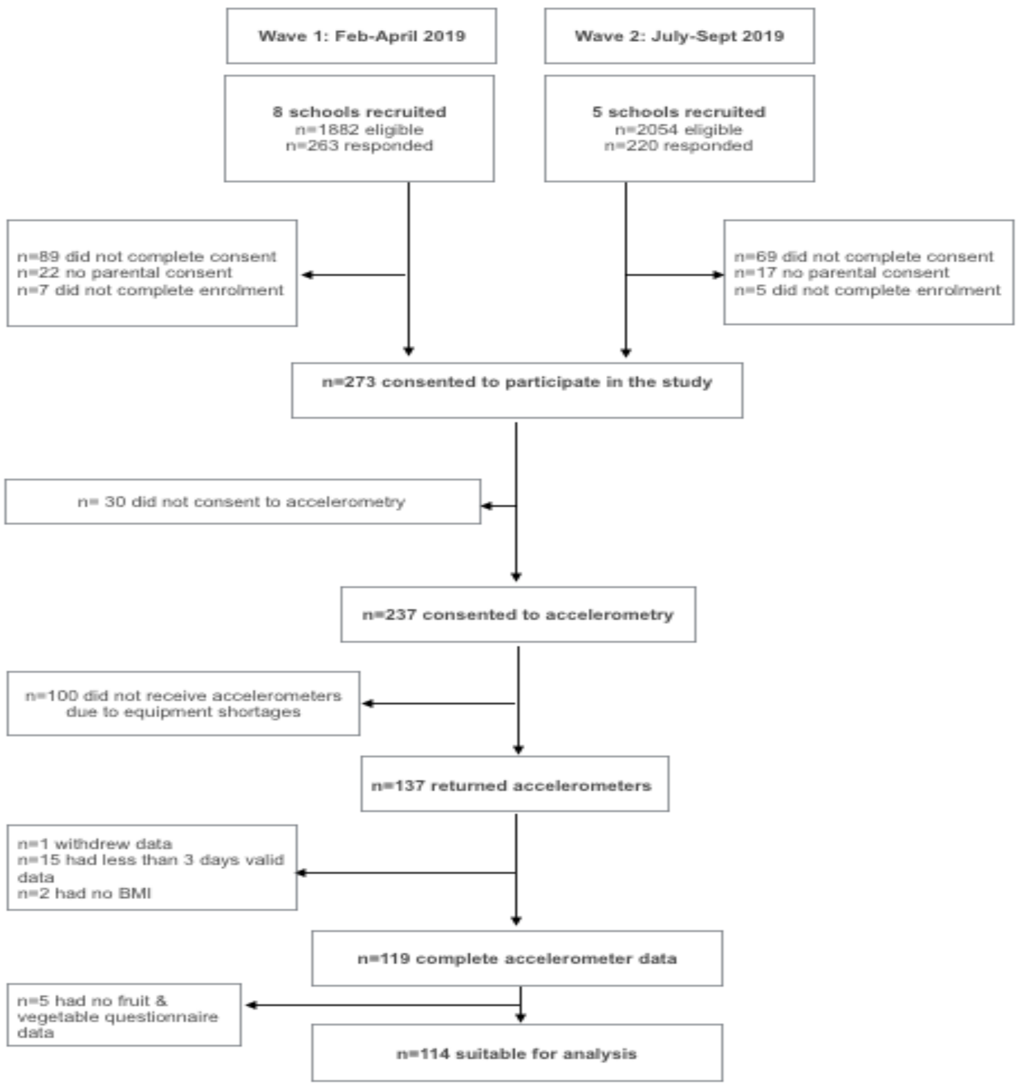

Figure 5.1: Flow of participants through the study, determining numbers for analysis

5.1 Demographics

Participants age ranged from 15-18 years, with the majority of the sample falling into the healthy weight category and identified as 'NZ European and Other' ethnicity. More than two thirds of the sample were reported as being from areas of low to moderate deprivation.

Table 5.1: Demographic characteristics of participants with valid accelerometer and dietary habits data (n = 114)

Characteristic	n=114
Age, y, mean (sd)	17 (0.94)
Weight, kg, mean (sd)	65 (11.14)
Height, cm, mean (sd)	165 (6.6)
Weight status, n (%)[1]	
Healthy	75 (65.8)
Overweight	31 (27.2)
Obese	8 (7.0)
Ethnicity, n (%)	
NZ European and Others[2]	96 (84.2)
Maori	11 (9.7)
Pacifica[3]	3 92.6)
Asian[4]	4 (3.5)
NZ Deprivation Index, n (%)[5]	
Low	41 (36)
Medium	50 (43.9)
High	23 (20.2)

n= number of participants, kg/m^2 = kilograms per meter squared sd= standard deviation
[1]*Categories based on BMI for age and sex z scores (<1 = healthy, >1 = overweight, >2 = obese)* (De Onis et al., 2007)
[2]*New Zealand European, Ethiopian, Somali, Italian, American, Nicaraguan, Irish, Afrikaans, Dutch, German, South African, Middle Eastern, Russian, Zimbabwean*
[3]*Tokelau, Fijian, Cook Island, Samoan*
[4] *Filipino, Indonesian, Indian Japanese, Korean, Malay*
[5]*Derived from NZ Index of Deprivation* (Atkinson et al., 2019)

5.2 Moderate to Vigorous Physical Activity in females

Total average minutes spent in MVPA per day and MVPA by age are presented in **Table** 5.2. The most active age groups were 18 and 16 y olds, participating in 12 and 9 minutes (respectively) more MVPA than 17 y olds. Less than one quarter of all participants met the recommendations of ≥60 minutes MVPA per day (**Figure** 5.2).

Table 5.2: Average min/day of MVPA by age

Age, y (n)	Minutes spent in MVPA/day (mean ± sd)
15 (n= 24)	40 (22)
16 (n= 40)	48 (22)
17 (n= 50)	39 (22)
18 (n= 5)	51 (34)
Total (15-18)	43 (24)

y= years, n= number, MVPA= moderate-to-vigorous physical activity, sd= standard deviation

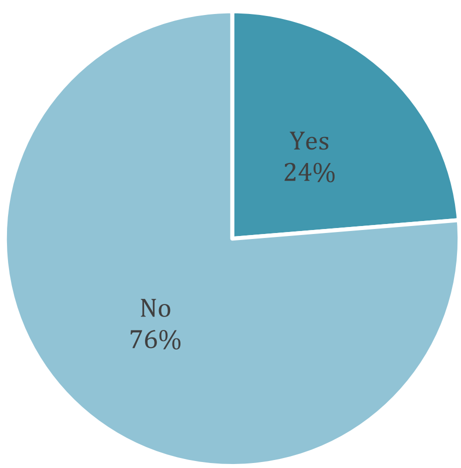

Figure 5.2: Total percentage of females meeting NZ physical activity guidelines of ≥60 minutes MVPA/day

5.3 Fruit and vegetable consumption

The frequency of consumption of fruit and vegetables among adolescent females, and the prevalence of females meeting the MOH guidelines are presented in **Table** 5.3 and

Table 5.4 respectively. Across all ages, fruit consumption was greater than vegetable consumption, however, the number of participants consuming adequate fruit and vegetable intakes is less than one third.

Table 5.3: Distribution of Fruit and Vegetable consumption among females, aged 15-18 y in NZ

Frequency, n (%)	**Fruit, n=114**	**Vegetables, n=113**
Never/don't eat fruit	2 (2)	0
<1 serving/week	4 (3.5)	2 (2)
1 serving/week	4 (3.5)	2 (2)
2-4 serving/week	19 (17)	12 (11)
5-6 serving/week	7 (6)	9 (8)
1 serves/day	14 (12)	13 (12)
2 serves/day	38 (33)	34 (30)
3 serves/day	14 (12)	19 (17)
>3 serves/day	12 (11)	22 (19)

NZ= New Zealand; n= number

Table 5.4: Proportion of adolescent females who met Ministry of Health fruit and vegetable guidelines

	Meeting guidelines, n, (%)
Fruit (≥2 serves/day)	64 (56)
Vegetables (≥3 serves/day)	41 (36)
F&V (≥5 serves/day)	31 (27)

n=number of participants; F&V: fruits and vegetables

5.4 Relationship Between PA and Fruit and Vegetable Consumption

Comparisons between fruit and vegetable consumption and MVPA, and the percentage of participants meeting the recommended guidelines are presented in **Table** 5.5. There are notable differences in being physically active and the prevalence of those meeting fruit consumption guidelines. Being physically active did not increase the statistical likelihood of the participants meeting the vegetable consumption guidelines (OR: 1.9; 95% CI 0.8 to 4.4; p=0.1633). Adolescent girls were however, 4.7 times more likely to meet the fruit recommendations if they were meeting the physical activity guidelines (OR: 4.7; 95% CI 1.7 to 13.1; p=0.0024) as well as 2.7 times more likely to meet both the fruit and vegetable recommendations if they were meeting the physical activity guidelines (OR: 2.7; 95% CI 1.1 to 6.6; p=0.0302).

Table 5.5: Relationship between PA and F&V consumption and the proportion of females meeting guidelines.

	Met Fruit, n=64	Met Veg, n=72	Met F&V, n=32
Met PA n, (%)	22 (34%)	13 (31%)	12 (37.5%)

Didn't meet PAG	42 (66%)	29 (69%)	20 (62.5%)

n=number of participants; PAG: physical activity guidelines; F&V: Fruit and Vegetables

6 Discussion and Conclusion

This study is, to the best of our knowledge, the first to investigate the relationship between fruit and vegetable intakes and physical activity in a sample of female adolescents in NZ. Results show only 24% of participants are currently meeting the physical activity guidelines, and 27% are eating ≥5 serves/day of fruit and vegetables. Interestingly, those who are physically active were 2.7 times more likely to meet the fruit and vegetable consumption guidelines than their inactive counterparts.

6.1 Moderate to Vigorous Physical Activity and Adherence to guidelines

Participants in the current study accumulated an average of 43 min of MVPA per day; which is below the daily recommended level of ≥60 minutes (Ministry of Health, 2017) Previous research on physical activity levels in NZ adolescents also concluded females are insufficiently active, with time spent in MVPA varying from 36 min/day (Maddison et al., 2010), to 55.8 min/day (Kek et al., 2019) with 33% and 36% of females meeting MVPA targets respectively. It is possible that the higher MVPA observed in the Kek et al (2019) study was due to differences in methodology. Specifically, accelerometers were only worn during waking hours, and daily reminders to wear the device may have prompted participants to increase their activity levels during data collection. The fact that the mean amount of MVPA was higher, but the proportion of participants meeting the guidelines was lower in the current study, compared to that of Maddison et al (2010) indicates possible differences in the distribution of MVPA levels between the two study populations. Additional differences in the studies such as ethnicity, location (single-site vs representative) and deprivation further limit the ability to draw definitive conclusions.

Guthold et al (2020) reported that in a sample of 1.6 million adolescents worldwide, 84.7% of females are not meeting their country's activity guidelines. Additionally, data collected by Sanchez et al (2007), Troiano et al (2008), Ruiz et al (2011) and Hanson et al (2019), highlighted that 33%, 5%, 27%, and 0% of females in their study populations were sufficiently active. Overall, the proportion of female adolescents adhering to the guidelines in the current study (24%) is greater than females in the USA (5%) (Troiano et al., 2008), Australia (7%) (Australian Bureau of Statistics, 2013) and South Africa (0%) (Hanson et al., 2019). Therefore, overall, the low levels of MVPA in female adolescents is problematic in NZ and globally, potentially increasing the risk of illness and disease.

6.2 Fruit and Vegetable Consumption

Nearly three quarters (73%) of the participants in the current study are not consuming ≥5 serves/day of fruit and vegetables, which may contribute to poorer health outcomes. When fruit and vegetable consumption were examined individually it appears that the low overall fruit and vegetable consumption is driven more by a lower vegetable consumption rather than poor fruit intakes (only 36% of the sample report eating ≥2 servings of vegetables per day, compared to 56% of the sample that report eating ≥3 servings of fruit per day).

The proportion of participants meeting the guidelines in the current study are similar to that reported in the Youth '12 survey (30% met fruit and vegetables; 37% met the vegetable guidelines and 55% met the fruit guideline (Clark et al., 2013).

However, the intakes reported in the current study are much lower than those reported in the nationally representative adult nutrition survey in 2008/09 (62% met vegetable guidelines; 65% met fruit guidelines). Given that the current study did not use a representative sample it is difficult to determine if the results of the current study represent a true decrease in fruit and vegetable consumption over the last 10 years or is simply due to the different demographic make-up of the study population. What is clear, however is that the fruit and vegetable intake of adolescent girls in NZ is low and is unlikely to have increased over the last 10 years.

Worldwide, as low as 7% (Krebs-Smith et al., 1997) of adolescent females are consuming adequate fruit and vegetables. Similar to NZ females, the low consumption of fruit and vegetables internationally appears to be driven by a lower consumption of vegetables where only 23% report eating ≥3 serves/day vegetables, compared to 38% of females report eating ≥2 serves/day of fruit (Muñoz et al., 1997).

In the overall context, the current study suggests more adolescent females in NZ are consuming adequate fruit and vegetables compared to their international counterparts, however, it is unclear if this is a direct result of more frequent fruit and vegetable consumption or if it due to methodological differences, particularly the age of participants included internationally (2-18 y). Overall, fruit and vegetable consumption among female adolescents in NZ and internationally is ambiguous but is likely low and as a result is possibly negatively impacting their health, either now or into adulthood.

6.3 Relationship between MVPA and Fruit and Vegetable Consumption

The results of the present study indicate that being physically active is associated with an increased likelihood of meeting the fruit and vegetable consumption guidelines. Physically active female adolescents were 2.7 times more likely to meet the overall fruit and vegetable intake target of ≥5 serves/day than their inactive counterparts (OR: 2.7; 95% CI 1.1 to 6.6). However, this association appears to be driven by the relationship between activity and fruit consumption (OR: 4.7; 95% CI: 1.7 to 13.1), rather than activity and vegetable intakes (OR:1.9; 95% CI: 0.8 to 4.4).

Despite the different ways in which data has been presented across different studies, t he relationship between total fruit and vegetable consumption and activity level is consistent (Cavadini et al., 2000; Pate et al., 1996). Physically active adolescents are more likely to consume the recommended amounts of fruit and vegetables compared to their inactive counterparts (Kelishadi et al., 2007). The higher fruit and vegetable consumption by physically active adolescents may be a reflection of the individuals desire to support their activity with a healthier diet among other lifestyle factors. Subjectively, fruit is often promoted as being a suitable and affordable pre-training fuel source, which may contribute to the stronger association between fruit intakes and activity levels.

Results of the present study highlight that physical activity and fruit and vegetable consumption, two separate healthy lifestyle behaviours, tend to cluster together. Although healthful dietary behaviours do not always translate to increased levels of activity, time and time again, being physically active has been associated with adequate consumption of fruit and vegetable consumption (Pate et al., 1996; Pearson et al., 2009). This relationship has implications for future health promotion messages, as it may suggest targeting these behaviours together could result in improved outcomes for both, overall having a positive impact on health and reducing non-communicable disease risk in this population (Nocon et al., 2008; Reiner et al., 2013).

6.4 Strengths and Limitations

The study had a number of limitations. Firstly, a shortage of accelerometers limited the number of participants activity data was collected from. When given their accelerometer, regardless of advice to maintain their usual daily activities, participants may have been more inclined to alter their activity whilst wearing the device. In addition, it is also inevitable in some cases, that wear-time diaries were not filled out correctly and MVPA during non-wear time was inaccurately recorded.

The present study used both activity and fruit and vegetable consumption as categorical variables; defined as meeting the guidelines, or not. However, it is possible that a more continuous relationship exists between fruit and vegetable consumption and activity that was not investigated in the current study.

We chose, for convenience, to apply the children's physical activity guidelines to the whole study population, despite there being five 18-year old's in the sample. Four of these 18 y old's participated in more than 30 minutes of MVPA, and therefore would have been classified as active if using the adult guidelines, increasing the total percentage of participants meeting daily activity recommendations from 24% to 27%.

Social desirability may impact results, as a fear of judgement by others can encourage participants to report their fruit and vegetable intakes as higher than they actually are. Dietary responses are also limited by recall bias and dependence on an individual's mental arithmetic to report accurate fruit and vegetable intakes. Although our ability to get an indication of true intake is limited, other studies are also affected by these factors.

The present study had several strengths. The sample, from eight different regions around NZ provided a more heterogeneous sample than single-site studies. The accelerometers used (Actigraph GT3X) are one of the most commonly used in research for physical activity assessment, allowing comparisons to existing and future research. Non-wear time MVPA was accounted for with wear-time diaries, allowing analysed more accurate representation of true MVPA.

6.5 Recommendations for future research

Both past research and the present study have highlighted that fruit and vegetable consumption and MVPA participation are associated, Therefore, future research should consider investigating which behaviour comes first as public health messages can then be developed to target this aspect, potentially providing benefits to both factors.

***<u>Recommendation:</u>* an intervention study should be conducted that will identify whether diet influences activity or if activity level influences fruit and vegetable consumption**.

Results from this study clearly indicate that females are participating in low levels of MVPA, which suggests, current public health interventions are not effective in promoting activity in this population. For these messages to be effective, there needs to be an understanding of motivations and beliefs around physical activity in adolescent females.

***<u>Recommendation:</u>* Investigate motivations and behaviours regarding the participation of adolescent females in MVPA**.

Female adolescents have been identified as having very low intakes of vegetables, possibly increasing their risk of nutritional inadequacy and future development of illness or chronic disease. As with activity, it is clear there is little correlation between public health messages and actual intakes. Understanding facilitators and inhibitors of adequate fruit and vegetable consumption important for improving the health of this population.

***<u>Recommendation:</u>* Future researchers should identify facilitators and inhibitors to fruit and vegetable consumption in female adolescents.**

6.6 Conclusion

To our knowledge, this is the first study to investigate the relationship between fruit and vegetable consumption and MVPA in NZ adolescent females. The present study highlights that females aged 15 -18 y, are insufficiently active, with more than 70% of females not meeting daily MVPA guidelines. Additionally, more than 60% of females were not meeting daily fruit and vegetable targets. On average, participants spent 43 min/day in MVPA, and only 27% of participants consumed at least 5 serves of fruits and vegetables daily.

Participants who were physically active were more than twice as likely (OR: 2.7, 95% CI: 1.1 to 6.6) to consume fruit and vegetables, yet only 10% of participants were found to meet both the MVPA and fruit and vegetable guidelines daily. A continuation of these insufficient levels of activity and poor dietary behaviours may have potentially harmful effects on this population. Therefore, as these behaviours appear to be clustered, public health interventions may need to target these behaviours together rather than focusing solely on fruit and vegetable consumption or physical activity.

7 Application of Research to Dietetic Practice

7.1 Relevance of Research to Dietetic Practice

Dietitians are not limited to just nutrition-based practice. Many factors, beyond what an individual consumes makes up a healthy lifestyle. Physical activity and dietary behaviours are commonly the basis of public health messages, particularly to adolescents. In order to provide effective interventions, practitioners must be aware of the current trends within the population.

The current study summarises the relationship between sufficient physical activity and subsequent fruit and vegetable intakes. Findings show that female adolescents in NZ are participating in low levels of activity, averaging only 43 min/day of MVPA, and are generally, poor consumers of fruits and vegetables, more so vegetables. Three quarters were not meeting physical activity (>60 min/day) or total fruit and vegetable (>5 serves/day) guidelines, whereas, those who were active, were 4.7 times more likely to consume recommended fruit and 2.7 times more likely to consume recommended total fruit and vegetables.

Conclusions from the current study are applicable to dietetic practice as they highlight the need for understanding the motivations behind these behaviours. Firstly, understanding if one behaviour influences the other can provide information around which behaviour needs targeting first for the other to follow or if they are independent, how as a profession, we can support positive change in these females.

These findings have made me aware of understanding barriers that may be inhibiting an individual from being physically active, or consuming sufficient intakes of fruits and vegetables, therefore, using a multifactorial approach will allow me to provide patient-centred support and advice, whether it be my own recommendations or by using an inter-professional approach, such as referring to green prescription.

7.2 What this research experience has meant to me

Personally, the most relevant attainment from this research project was effective communication, not only with my research partner and supervisor but also the participants. Previously, I have struggled to communicate my ideas clearly and concisely, however I feel over this research period, I have developed this skill considerably. Throughout data collection, in our research pair, if one of us needed support, the other was always there, a direct result of communicating our strengths and weaknesses at the beginning. With participants, I learnt that being relaxed encouraged them to enjoy the experience rather than feeling as though it was a harsh interview.

This experience has highlighted the importance of communication skills, regardless of the size of the team you are working in or who you are working with. As these skills are applicable to many situations, whether it be with patients or a team of other health care professionals, I intend to continue developing my communication skills and gather feedback where possible from those around me, improving my competency as a practicing dietitian in the future.

8 References

Atkinson, J., Salmond, C., & Crampton, P. (2019). *NZDep2018 Index of Deprivation, Interim Research Report, December 2019*. Wellington, New Zealand.

Australian Bureau of Statistics. (2013). Australian (National) Health Survey: First Results, 2011-2012. Retrieved from https://www.abs.gov.au/statistics/health/health-conditions-and-risks/australian-health-survey-physical-activity/2011-12

Bell, L. M., Watts, K., Siafarikas, A., Thompson, A., Ratnam, N., Bulsara, M., … Davis, E. A. (2007). Exercise alone reduces insulin resistance in obese children independently of changes in body composition. *Journal of Clinical Endocrinology and Metabolism*. https://doi.org/10.1210/jc.2007-0779

Bellavia, A., Larsson, S. C., Bottai, M., Wolk, A., & Orsini, N. (2013). Fruit and vegetable consumption and all-cause mortality: A doseresponse analysis. *American Journal of Clinical Nutrition*. https://doi.org/10.3945/ajcn.112.056119

Biddle, S. J. H., Gorely, T., Pearson, N., & Bull, F. C. (2011). An assessment of self-reported physical activity instruments in young people for population surveillance: Project ALPHA. *International Journal of Behavioral Nutrition and Physical Activity*. https://doi.org/10.1186/1479-5868-8-1

Caspersen, C. J., Powell, K. E., & Christenson, G. M. (1985). Physical Activity, Exercise and Physical Fitness Definitions for Health-Related Research. *Public Health Reports*.

Cavadini, C., Decarli, B., Grin, J., Narring, F., & Michaud, P. A. (2000). Food habits and sport activity during adolescence: Differences between athletic and non-athletic teenagers in Switzerland. *European Journal of Clinical Nutrition*. https://doi.org/10.1038/sj.ejcn.1600979

Chisolm, G. M., & Steinberg, D. (2000). The oxidative modification hypothesis of atherogenesis: An overview. *Free Radical Biology and Medicine*. https://doi.org/10.1016/S0891-5849(00)00344-0

Chu, N. F., Rimm, E. B., Wang, D. J., Liou, H. S., & Shieh, S. M. (1998). Clustering of cardiovascular disease risk factors among obese schoolchildren: The Taipei children heart study. *American Journal of Clinical Nutrition*. https://doi.org/10.1093/ajcn/67.6.1141

Clark, T. C., Fleming, T., Bullen, P., Denny, S., Crengle, S., Dyson, B., Fortune, S., Lucassen, M., Peiris-John, R., Robinson, E., R., & F., Sheridan, J., Teevale, T., Utter, J. (2013). *Youth'12 Overview: The health and wellbeing of New Zealand secondary school students in 2012*. Auckland, New Zealand: The University of Auckland.

Craig, C. L., Marshall, A. L., Sjöström, M., Bauman, A. E., Booth, M. L., Ainsworth, B. E., … Oja, P. (2003). International physical activity questionnaire: 12-Country reliability and validity. *Medicine and Science in Sports and Exercise*. https://doi.org/10.1249/01.MSS.0000078924.61453.FB

Danforth, J. S., Allen, K. D., Fitterling, J. M., Danforth, J. A., Farrar, D., Brown, M., & Drabman, R. S. (1990). Exercise as a Treatment for Hypertension in Low-Socioeconomic-Status Black Children. *Journal of Consulting and Clinical Psychology*. https://doi.org/10.1037/0022-006X.58.2.237

Dauchet, L., Amouyel, P., Hercberg, S., & Dallongeville, J. (2006). Fruit and vegetable consumption and risk of coronary heart disease: A meta-analysis of cohort studies. *Journal of Nutrition*. https://doi.org/10.1093/jn/136.10.2588

De Onis, M., Onyango, A. W., Borghi, E., Siyam, A., Nishida, C., & Siekmann, J. (2007). Development of a WHO growth reference for school-aged children and adolescents. *Bulletin of the World Health Organization*. https://doi.org/10.2471/BLT.07.043497

Dencker, M., Thorsson, O., Karlsson, M. K., Lindén, C., Eiberg, S., Wollmer, P., & Andersen, L. B. (2006). Daily physical activity related to body fat in children aged 8-11 years. *Journal of Pediatrics*. https://doi.org/10.1016/j.jpeds.2006.02.002

Dewar, D. L., Morgan, P. J., Plotnikoff, R. C., Okely, A. D., Batterham, M., & Lubans, D. R. (2014). Exploring changes in physical activity, sedentary behaviors and hypothesized mediators in the NEAT girls group randomized controlled trial. *Journal of Science and Medicine in Sport*. https://doi.org/10.1016/j.jsams.2013.02.003

Eisenmann, J. C., Laurson, K. R., Wickel, E. E., Gentile, D., & Walsh, D. (2007). Utility of pedometer step recommendations for predicting overweight in children. *International Journal of Obesity*. https://doi.org/10.1038/sj.ijo.0803553

Evenson, K. R., Catellier, D. J., Gill, K., Ondrak, K. S., & McMurray, R. G. (2008). Calibration of two objective measures of physical activity for children. *Journal of Sports Sciences*. https://doi.org/10.1080/02640410802334196

Ewart, C. K., Young, D. R., & Hagberg, J. M. (1998). Effects of school-based aerobic exercise on blood pressure in adolescent girls at risk for hypertension. *American Journal of Public Health*. https://doi.org/10.2105/AJPH.88.6.949

Freedson, P. S., & Miller, K. (2000). Objective monitoring of physical activity using motion sensors and heart rate. *Research Quarterly for Exercise and Sport*. https://doi.org/10.1080/02701367.2000.11082782

Gaziano, J. M., Manson, J. E., Branch, L. G., Colditz, G. A., Willett, W. C., & Buring, J. E. (1995). A prospective study of consumption of carotenoids in fruits and vegetables and decreased cardiovascular mortality in the elderly. *Annals of Epidemiology*. https://doi.org/10.1016/1047-2797(94)00090-G

Gibson, R. S. (2005). Principles of Nutritional Assessment - Rosalind S. Gibson - Google Books.

Grunbaum, J. A., Kann, L., Kinchen, S., Ross, J., Hawkins, J., Lowry, R., … Collins, J. (2004). Youth risk behavior surveillance - United States, 2003 (Abridged). *Journal of School Health*. https://doi.org/10.1111/j.1746-1561.2004.tb06620.x

Guthold, R., Stevens, G. A., Riley, L. M., & Bull, F. C. (2020). Global trends in insufficient physical activity among adolescents: a pooled analysis of 298 population-based surveys with 1·6 million participants. *The Lancet Child and Adolescent Health*. https://doi.org/10.1016/S2352-4642(19)30323-2

Hagberg, J. M., Ehsani, A. A., Goldring, D., Hernandez, A., Sinacore, D. R., & Holloszy, J. O. (1984). Effect of weight training on blood pressure and hemodynamics in hypertensive adolescents. *The Journal of Pediatrics*. https://doi.org/10.1016/S0022-3476(84)80615-0

Hagberg, J. M., Goldring, D., Ehsani, A. A., Heath, G. W., Hernandez, A., Schechtman, K., & Holloszy, J. O. (1983). Effect of exercise training on the blood pressure and hemodynamic features of hypertensive adolescents. *The American Journal of Cardiology*. https://doi.org/10.1016/0002-9149(83)90412-5

Hallal, P. C., Andersen, L. B., Bull, F. C., Guthold, R., Haskell, W., Ekelund, U., … Wells, J. C. (2012). Global physical activity levels: Surveillance progress, pitfalls, and prospects. *The Lancet*. https://doi.org/10.1016/S0140-6736(12)60646-1

Hallal, P. C., Victora, C. G., Azevedo, M. R., & Wells, J. C. K. (2006). Adolescent physical activity and health: A systematic review. *Sports Medicine*. https://doi.org/10.2165/00007256-200636120-00003

Hanson, S. K., Munthali, R. J., Micklesfield, L. K., Lobelo, F., Cunningham, S. A., Hartman, T. J., … Stein, A. D. (2019). Longitudinal patterns of physical activity, sedentary behavior and sleep in urban South African adolescents, Birth-To-Twenty Plus cohort. *BMC Pediatrics*. https://doi.org/10.1186/s12887-019-1619-z

Hansson, G. K. (2005). Mechanisms of disease: Inflammation, atherosclerosis, and coronary artery disease. *New England Journal of Medicine*. https://doi.org/10.1056/NEJMra043430

Harttig, U., Haubrock, J., Knüppel, S., & Boeing, H. (2011). The MSM program: Web-based statistics package for estimating usual dietary intake using the multiple source method. *European Journal of Clinical Nutrition*. https://doi.org/10.1038/ejcn.2011.92

Hinckson, E., Cerin, E., Mavoa, S., Smith, M., Badland, H., Stewart, T., … Schofield, G. (2017). Associations of the perceived and objective neighborhood environment with physical activity and sedentary time in New Zealand adolescents. *International Journal of Behavioral Nutrition and Physical Activity*. https://doi.org/10.1186/s12966-017-0597-5

Holt, E. M., Steffen, L. M., Moran, A., Basu, S., Steinberger, J., Ross, J. A., … Sinaiko, A. R. (2009). Fruit and Vegetable Consumption and Its Relation to Markers of Inflammation and Oxidative Stress in Adolescents. *Journal of the American Dietetic Association*. https://doi.org/10.1016/j.jada.2008.11.036

Hung, H. C., Joshipura, K. J., Jiang, R., Hu, F. B., Hunter, D., Smith-Warner, S. A., … Willett, W. C. (2004). Fruit and vegetable intake and risk of major chronic disease. *Journal of the National Cancer Institute*. https://doi.org/10.1093/jnci/djh296

Jago, R., Jonker, M. L., Missaghian, M., & Baranowski, T. (2006). Effect of 4 weeks of Pilates on the body composition of young girls. *Preventive Medicine*. https://doi.org/10.1016/j.ypmed.2005.11.010

Janssen, I., & LeBlanc, A. G. (2010). Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *International Journal of Behavioral Nutrition and Physical Activity*. https://doi.org/10.1186/1479-5868-7-40

Kahle, E. B., Zipf, W. B., Lamb, D. R., Horswill, C. A., & Ward, K. M. (1996). Association between Mild, Routine Exercise and Improved Insulin Dynamics and Glucose Control in Obese Adolescents. *International Journal of Sports Medicine*. https://doi.org/10.1055/s-2007-972799

Kann, L., Kinchen, S. A., Williams, B. I., Ross, J. G., Lowry, R., Grunbaum, J. A., & Kolbe, L. J. (2000). Youth risk behavior surveillance--United States, 1999. *MMWR. CDC Surveillance Summaries : Morbidity and Mortality Weekly Report. CDC Surveillance Summaries / Centers for Disease Control*.

Kannel, W. B., & Wilson, P. W. F. (1995). An update on coronary risk factors. *Medical Clinics of North America*. https://doi.org/10.1016/S0025-7125(16)30016-5

Kek, C. C., García Bengoechea, E., Spence, J. C., & Mandic, S. (2019). The relationship between transport-to-school habits and physical activity in a sample of New Zealand adolescents. *Journal of Sport and Health Science*. https://doi.org/10.1016/j.jshs.2019.02.006

Kelishadi, R., Ardalan, G., Gheiratmand, R., Gouya, M. M., Razaghi, E. M., Delavari, A., … Riazi, M. M. (2007). Association of physical activity and dietary behaviours in relation to the body mass index in a national sample of Iranian children and adolescents: CASPIAN Study. *Bulletin of the World Health Organization*. https://doi.org/10.2471/BLT.06.030783

Krebs-Smith, S. M., Cleveland, L. E., Ballard-Barbash, R., Cook, D. A., & Kahle, L. L. (1997). Characterizing food intake patterns of American adults. In *American Journal of Clinical Nutrition*. https://doi.org/10.1093/ajcn/65.4.1264S

Lau, P., Yu, C., Lee, A., & Sung, R. (2004). The physiological and psychological effects of resistance training on Chinese obese adolescents. *Journal of Exercise Science & Fitness*.

Li, M., Fan, Y., Zhang, X., Hou, W., & Tang, Z. (2014). Fruit and vegetable intake and risk of type 2 diabetes mellitus: Meta-analysis of prospective cohort studies. *BMJ Open*. https://doi.org/10.1136/bmjopen-2014

Maddison, R., Turley, M., Legge, N., & Mitchelhill, G. (2010). *A National Survey of Children and Young People's Physical Activity and Dietary Behaviours in New Zealand: 2008/09. Auckland: Clinical Trials Research Unit, The University of Auckland.* Retrieved from https://www.health.govt.nz/system/files/documents/publications/cyp-physical-activity-dietary-behaviours-08-09-keyfindgs.pdf

McNaughton, S. A., Ball, K., Mishra, G. D., & Crawford, D. A. (2008). Dietary Patterns of Adolescents and Risk of Obesity and Hypertension. *The Journal of Nutrition*. https://doi.org/10.1093/jn/138.2.364

Mendoza, J. A., Nicklas, T. A., Liu, Y., Stuff, J., & Baranowski, T. (2012). General versus central adiposity and relationship to pediatric metabolic risk. *Metabolic Syndrome and Related Disorders*. https://doi.org/10.1089/met.2011.0064

Ministry of Health. (2008). Protocol for Collecting Height, Weight and Waist Measurements in New Zealand Health Monitor (NZHM) Surveys. Retrieved from https://www.moh.govt.nz/notebook/nbbooks.nsf/0/e846bf606184f2cdcc257487007eb4e8/$FILE/protocols-for-collecting-height-weight-waist-measurements.pdf

Ministry of Health. (2011a). *A Focus on Nutrition: Key findings of the 2008/09 New Zealand Adult Nutrition Survey*. Wellington, New Zealand.

University of Otago and Ministry of Health. (2011). Methodology Report for the 2008/09 New Zealand Adult Nutrition Survey.

Ministry of Health. (2011b). *Statement of Intent 2011–2014*. Wellington, New Zealand. Retrieved from https://www.health.govt.nz/system/files/documents/publications/a-focus-on-nutrition-v2.pdf

Ministry of Health. (2017). Children and young people (5-17 years). "Sit less, move more, sleep well." Retrieved September 20, 2010, from https://www.health.govt.nz/our-work/preventative-health-wellness/physical-activity#kids

Ministry of Health. (2019). Annual Data Explorer 2017/18: New Zealand Health Survey. Retrieved September 20, 2010, from https://www.health.govt.nz/publication/annual-update-key-results-2017-18-new-zealand-health-survey

Muñoz, K. A., Krebs-Smith, S. M., Ballard-Barbash, R., & Cleveland, L. E. (1997). Food intakes of US children and adolescents compared with recommendations. *Pediatrics*. https://doi.org/10.1542/peds.100.3.323

National Institute for Health Research. (2019). Procedure for measuring adult ulna length. *NIHR Southampton Biomedical Research Centre*. Retrieved from https://www.uhs.nhs.uk/Media/Southampton-Clinical-Research/Procedures/BRCProcedures/Procedure-for-adult-ulna-length.pdf

Ness, A. R., Leary, S. D., Mattocks, C., Blair, S. N., Reilly, J. J., Wells, J., … Riddoch, C. (2007). Objectively measured physical activity and fat mass in a large cohort of children. *PLoS Medicine*. https://doi.org/10.1371/journal.pmed.0040097

Ness, A. R., Maynard, M., Frankel, S., Smith, G. D., Frobisher, C., Leary, S. D., … Gunnell, D. (2005). Diet in childhood and adult cardiovascular and all cause mortality: The Boyd Orr cohort. *Heart*. https://doi.org/10.1136/hrt.2004.043489

Nocon, M., Hiemann, T., Müller-Riemenschneider, F., Thalau, F., Roll, S., & Willich, S. N. (2008). Association of physical activity with all-cause and cardiovascular mortality: A systematic review and meta-analysis. *European Journal of Preventive Cardiology*. https://doi.org/10.1097/HJR.0b013e3282f55e09

Ottevaere, C., Huybrechts, I., Béghin, L., Cuenca-Garcia, M., De Bourdeaudhuij, I., Gottrand, F., … De Henauw, S. (2011). Relationship between self-reported dietary intake and physical activity levels among adolescents: The HELENA study. *International Journal of Behavioral Nutrition and Physical Activity*. https://doi.org/10.1186/1479-5868-8-8

Pate, R. R., Heath, G. W., Dowda, M., & Trost, S. G. (1996). Associations between physical activity and other health behaviors in a representative sample of US adolescents. *American Journal of Public Health*. https://doi.org/10.2105/AJPH.86.11.1577

Pearson, N., Atkin, A. J., Biddle, S. J. H., Gorely, T., & Edwardson, C. (2009). Patterns of adolescent physical activity and dietary behaviours. *International Journal of Behavioral Nutrition and Physical Activity*. https://doi.org/10.1186/1479-5868-6-45

Reiner, M., Niermann, C., Jekauc, D., & Woll, A. (2013). Long-term health benefits of physical activity - A systematic review of longitudinal studies. *BMC Public Health*. https://doi.org/10.1186/1471-2458-13-813

Ridgers, N. D., & Fairclough, S. (2011). Assessing free-living physical activity using accelerometry: Practical issues for researchers and practitioners. *European Journal of Sport Science*. https://doi.org/10.1080/17461391.2010.501116

Roark, R. A., & Niederhauser, V. P. (2014). Fruit and vegetable intake: Issues with definition and measurement. *Public Health Nutrition*. https://doi.org/10.1017/S1368980012000985

Rowlands, A. V., & Eston, R. G. (2007). The measurement and interpretation of children’s physical activity. *Journal of Sports Science and Medicine*.

Ruiz, J. R., Ortega, F. B., Martínez-Gómez, D., Labayen, I., Moreno, L. A., De Bourdeaudhuij, I., … Sjöström, M. (2011). Objectively measured physical activity and sedentary time in european adolescents. *American Journal of Epidemiology*. https://doi.org/10.1093/aje/kwr068

Sallis, J. F., & Saelens, B. E. (2000). Assessment of physical activity by self-report: Status, limitations, and future directions. *Research Quarterly for Exercise and Sport*. https://doi.org/10.1080/02701367.2000.11082780

Samitz, G., Egger, M., & Zwahlen, M. (2011). Domains of physical activity and all-cause mortality: Systematic review and dose-response meta-analysis of cohort studies. *International Journal of Epidemiology*. https://doi.org/10.1093/ije/dyr112

Sanchez, A., Norman, G. J., Sallis, J. F., Calfas, K. J., Cella, J., & Patrick, K. (2007). Patterns and Correlates of Physical Activity and Nutrition Behaviors in Adolescents. *American Journal of Preventive Medicine*. https://doi.org/10.1016/j.amepre.2006.10.012

Slattery, M. L., Boucher, K. M., Caan, B. J., Potter, J. D., & Ma, K. N. (1998). Eating patterns and risk of colon cancer. *American Journal of Epidemiology*. https://doi.org/10.1093/aje/148.1.4-a

Slavin, J. L., & Lloyd, B. (2012). Health Benefits of Fruits and Vegetables. *Advances in Nutrition*. https://doi.org/10.3945/an.112.002154

Song, Y., Manson, J. A. E., Buring, J. E., Sesso, H. D., & Liu, S. (2005). Associations of Dietary Flavonoids with Risk of Type 2 Diabetes, and Markers of Insulin Resistance and Systemic Inflammation in Women: A Prospective Study and Cross-Sectional Analysis. *Journal of the American College of Nutrition*. https://doi.org/10.1080/07315724.2005.10719488

Stevens, J., Murray, D. M., Baggett, C. D., Elder, J. P., Lohman, T. G., Lytle, L. A., … Young, D. R. (2007). Objectively assessed associations between physical activity and body composition in middle-school girls. *American Journal of Epidemiology*. https://doi.org/10.1093/aje/kwm202

Tarp, J., Bugge, A., Andersen, L. B., Sardinha, L. B., Ekelund, U., Brage, S., & Møller, N. C. (2018). Does adiposity mediate the relationship between physical activity and biological risk factors in youth?: A cross-sectional study from the International Children's Accelerometry Database (ICAD). *International Journal of Obesity*. https://doi.org/10.1038/ijo.2017.241

Telama, R., Yang, X., Viikari, J., Välimäki, I., Wanne, O., & Raitakari, O. (2005). Physical activity from childhood to adulthood: A 21-year tracking study. *American Journal of Preventive Medicine*. https://doi.org/10.1016/j.amepre.2004.12.003

Tremblay, M. S., Carson, V., Chaput, J. P., Connor Gorber, S., Dinh, T., Duggan, M., … Zehr, L. (2016). Canadian 24-hour movement guidelines for children and youth: An integration of physical activity, sedentary behaviour, and sleep. *Applied Physiology, Nutrition and Metabolism*. https://doi.org/10.1139/apnm-2016-0151

Troiano, R. P. (2005). A timely meeting: Objective measurement of physical activity. In *Medicine and Science in Sports and Exercise*. https://doi.org/10.1249/01.mss.0000185473.32846.c3

Troiano, R. P., Berrigan, D., Dodd, K. W., Mâsse, L. C., Tilert, T., & Mcdowell, M. (2008). Physical activity in the United States measured by accelerometer. *Medicine and Science in Sports and Exercise*. https://doi.org/10.1249/mss.0b013e31815a51b3

Trost, S. G., Mciver, K. L., & Pate, R. R. (2005). Conducting accelerometer-based activity assessments in field-based research. In *Medicine and Science in Sports and Exercise*. https://doi.org/10.1249/01.mss.0000185657.86065.98

Warburton, D. E. R., Charlesworth, S., Ivey, A., Nettlefold, L., & Bredin, S. S. D. (2010). A systematic review of the evidence for Canada's Physical Activity Guidelines for Adults. *International Journal of Behavioral Nutrition and Physical Activity*. https://doi.org/10.1186/1479-5868-7-39

Warburton, D. E. R., Nicol, C. W., & Bredin, S. S. D. (2006). Health benefits of physical activity: The evidence. *CMAJ*. https://doi.org/10.1503/cmaj.051351

Ward, D. S., Evenson, K. R., Vaughn, A., Rodgers, A. B., & Troiano, R. P. (2005). Accelerometer use in physical activity: Best practices and research recommendations. In *Medicine and Science in Sports and Exercise*. https://doi.org/10.1249/01.mss.0000185292.71933.91

Warren, J. M., Ekelund, U., Besson, H., Mezzani, A., Geladas, N., & Vanhees, L. (2010). Assessment of physical activity - A review of methodologies with reference to epidemiological research: A report of the exercise physiology section of the European Association of Cardiovascular Prevention and Rehabilitation. *European Journal of Cardiovascular Prevention and Rehabilitation*. https://doi.org/10.1097/HJR.0b013e32832ed875

WHO, W. H. O. (2014). Recognizing Adolescence. Retrieved from https://apps.who.int/adolescent/second-decade/section2/page1/recognizing-adolescence.html

WHO, W. H. O. (2016). Physical Activity in Adolescence. Retrieved from https://www.euro.who.int/__data/assets/pdf_file/0018/303480/HBSC-No.7_factsheet_Physical.pdf

Wilson, P. W. F., Kannel, W. B., Silbershatz, H., & D'Agostino, R. B. (1999). Clustering of metabolic factors and coronary heart disease. *Archives of Internal Medicine*. https://doi.org/10.1001/archinte.159.10.1104

9 Appendices

Appendix A: SuNDiAL Protocol 2019

Protocol

Dietary Intake Nutritional Status and Lifestyle of Adolescent Vegetarian and Nonvegetarian Girls in New Zealand (The SuNDiAL Project): Protocol for a Clustered, Cross-Sectional Survey

Meredith Peddie, PhD; Chaya Ranasinghe, MSc; Tessa Scott, BSc; Anne-Louise Heath, PhD; Caroline Horwath, PhD; Rosalind Gibson, PhD; Rachel Brown, PhD; Lisa Houghton, PhD; Jillian Haszard, PhD

Department of Human Nutrition, University of Otago, Dunedin, New Zealand

Corresponding Author:
Meredith Peddie, PhD
Department of Human Nutrition
University of Otago
PO Box 56
Dunedin, 9054
New Zealand
Phone: 64 4798157
Fax: 64 4797985
Email: meredith.peddie@otago.ac.nz

Abstract

Background: Anecdotally, vegetarian eating patterns seem to be increasing in parallel with growing concerns about environmental sustainability. While this pattern of eating is widely believed to be associated with benefits for the planet and individual health, it may increase the risk of inadequate intakes and nutrient deficiency if not planned carefully. Adolescent girls may be particularly at risk, as they have increased requirements for nutrients such as iron, zinc, calcium, and vitamin B12 during growth and development.

Objective: The objective of the SuNDiAL Project (Survey of Nutrition, Dietary Assessment, and Lifestyles) is to compare the dietary intakes and habits, nutrition status, motivations, attitudes, and physical activity of a sample of vegetarian and nonvegetarian adolescent girls in New Zealand.

Methods: A clustered, cross-sectional, nationwide study of adolescents aged 15-18 years was conducted. Secondary schools were recruited throughout New Zealand, and pupils (n=290) were invited to participate in data collection in either the first (February to April) or third (August to October) school term of 2019 (New Zealand schools operate on a 4-term year). Sociodemographic and health information; vegetarian status; dietary habits; and attitudes, motivations, and beliefs regarding food choices were assessed via an online self-administered questionnaire. Dietary intakes were collected via two 24-hour diet recalls on nonconsecutive days and will be adjusted for within-person variation using the Multiple Source Method, to represent usual intakes. Nutrient adequacy will be assessed by the estimated average requirement cut-point method or probability approach as appropriate. Height and weight were measured, and blood and urine samples collected for micronutrient status assessment. Participants wore an accelerometer for 7 days to assess 24-hour activity patterns (time spent asleep, sedentary, or engagement in light-intensity or moderate-to-vigorous intensity physical activity).

Results: Recruitment and data collection were conducted in 2019. Data are currently being cleaned and analyzed, with publication of the main results anticipated at the end of 2020.

Conclusions: The SuNDiAL Project will provide a meaningful and timely description of diet, nutrition status, and motivational factors associated with vegetarianism and identify any risks this pattern of eating may pose for female adolescents. The results of this study will support the development of targeted recommendations and interventions aimed at enhancing the health, growth, and development of adolescent girls.

Trial Registration: Australian New Zealand Clinical Trials Registry ACTRN12619000290190; https://tinyurl.com/yaumh278

International Registered Report Identifier (IRRID): DERR1-10.2196/17310

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KEYWORDS

vegetarianism; teenagers; women; iron; zinc; calcium; B12; physical activity; attitudes motivations, beliefs

Introduction

Background

Few, if any, robust estimates of the prevalence of vegetarianism in populations exist, although plant-based and vegetarian diets (defined as not consuming any red meat, poultry, or seafood for the purposes of this article) appear to be growing in popularity. Increasing concern regarding the importance of environmental sustainability may explain this apparent rise; however, health is reported as a significant motivator for many vegetarians [1]. Indeed, vegetarians tend to have a body mass index that is 1-2 kg/m^2 lower than their otherwise comparable nonvegetarian peers and exhibit less weight gain during adulthood [2]. Vegetarians also have a slightly lower risk of some cancers [2] and as much as a 24% lower risk of ischemic heart disease [2], presumably because they tend to have lower total and low-density lipoprotein cholesterol concentrations [2]. However, much of the data that underpin our understanding of how vegetarianism may affect disease incidence was collected from adult populations prior to the 1990s [3,4] or in the early 2000s [5]. Much less is understood about the foods and nutrient intake of vegetarian adolescents. Recent advances in food technology, food fortification, and the widespread availability of products designed to be plant-based substitutes for meat and milk imply that vegetarians can now choose from many commercially produced food products [6]. However, consistent with older research, more recent studies indicate that vegetarian or vegan eating patterns score higher on the healthy eating index due to a lower sodium and saturated fat intake and higher intakes of fruits and vegetables [7].

A well-planned vegetarian diet containing vegetables, fruits, whole grains, legumes, nuts, and seeds can provide adequate nutrition for most members of the population [8]. In general, vegetarian diets provide large amounts of phytate, dietary fiber, folate, vitamins C and E, and magnesium, but without planning, they may have low protein, vitamins D and B12, iron, zinc, and calcium (particularly among vegans who do not consume animal products of any kind) [8,9]. Additionally, while the iron and zinc content of a vegetarian diet may be similar to that of a nonvegetarian diet, the high phytate content, absence of heme iron from cellular animal sources, and lower animal protein intake reduces the bioavailability of iron and zinc, significantly increasing the risk of deficiency [10]. The risk of vitamin B12, calcium, iron, and zinc deficiency may be greater in certain sex and life-stage groups such as young female adults [10-12]. The pubertal growth spurt, sexual maturation, and the onset of menarche increase requirements for vitamin B12, calcium, iron, and zinc in adolescent girls [12]. Increased autonomy over food intake and reductions in energy intake due to a desire to lose weight or achieve a certain body type may further contribute to the risk of nutrient deficiencies in this age group that could be exacerbated in vegetarians without careful food choice. Indeed, the latest representative data collected in New Zealand over a decade ago indicates that 88% of female adolescents have inadequate intakes of calcium, and 34% have inadequate intakes of iron, with 11% being identified as having iron deficiency and a further 5% as having anemia [13], despite the estimation that less than 9% of this age group was likely to be vegetarian at the time of data collection [14].

Reasons for following a vegetarian diet include health [1], ethical and environmental concerns [1,15,16], animal welfare [1,15,16], and religious beliefs [16]. However, adolescent girls in New Zealand, who are already at risk of low calcium intakes and iron status, may be further increasing that risk if they do not follow a carefully planned vegetarian diet. It is crucially important to develop guidelines that mitigate the risk and maximize potential benefits, such as reducing saturated fat and increasing fiber intakes. Understanding the motivations, attitudes, and beliefs that underpin food choices is important to inform the development of appropriate and effective guidelines, in particular, to understand why some people choose to be vegetarian and others do not. Other lifestyle behaviors, such as physical activity, that may go hand-in-hand with food choices, should also be examined in relation to health risks and benefits of a vegetarian diet. This knowledge can then be used to appropriately and effectively communicate lifestyle recommendations for those following a vegetarian diet.

Objectives

Anecdotally, vegetarianism appears to be increasing in popularity. While this increase in popularity may confer some health benefits to the population, adolescent girls in New Zealand are already at an increased risk of inadequate intakes of iron and calcium, which would clearly be exaggerated if animal products were avoided. A poorly planned vegetarian diet can increase the risk of some nutrient deficiencies that may be exacerbated in female adolescents. Therefore, it is critical that the nutrient intake and status of vegetarian adolescent girls are assessed. Furthermore, assessing motivations, attitudes, and beliefs will further our understanding of dietary choices and inform the development of health promotion materials and programs targeted to this age group.

The aim of the SuNDiAL Project (Survey of Nutrition, Dietary Assessment and Lifestyles) is to compare the dietary intakes and habits, nutrition status, motivations, attitudes, and physical activity of a sample of vegetarian and nonvegetarian adolescent girls in New Zealand. The objectives of this study are to describe and compare the following between vegetarians and nonvegetarians:

- Dietary intakes of macronutrients, free and added sugars, phytate, fiber, and key micronutrients (iron, zinc, vitamin B12, folate, iodine, and calcium)
- Biochemical status of key micronutrients (iron, zinc, vitamin B12, and folate)
- Attitudes toward and motivations for food choice (eg, the environment, animal welfare, health)

- Twenty-four–hour activity patterns (sleep, sedentary behavior, and physical activity)
- Dietary habits
- Weight loss intentions

Methods

Study Design

The SuNDiAL project is a nationwide cross-sectional survey of female adolescents aged 15-18 years. Nationwide data collection was achieved by utilization of a cohort of postgraduate research students. At the University of Otago, second-year Master of Dietetics students are required to undertake a 6-month research project in addition to 6 months of clinical placement. These student researchers are trained in dietary assessment and clinical skills, making them ideal data collectors for this study. In groups of 2-4 students, they collected data in locations convenient to their clinical placement or home city in New Zealand. In total, data were collected in 8 locations throughout New Zealand. The goal was to recruit at least one secondary school in each of Dunedin, Christchurch, Wanaka, Nelson, Wellington, Tauranga, Whangarei, and New Plymouth. These locations cover a range of cities from small (Wanaka) to large (Christchurch), from the south (Dunedin) to the north (Whangarei) of New Zealand. Data were collected in the first (February to April) or third (August to October) term of school in 2019 (New Zealand secondary schools operate on a 4-term year). The underlying ethnic makeup of the female population aged 15-18 years living in these areas is 70% New Zealand European, 17% Māori, 8% Pacific, and 15% Asian. Socioeconomic status information for this age group is not readily available in New Zealand. However, because we used a convenience sample, the final study population may differ from the overall population. This study has been approved by the University of Otago Human Ethics Committee (Health) (H19/004) and is registered with the Australian New Zealand Clinical Trials Registry (registration number: ACTRN12619000290190). Informed consent was obtained electronically from all participants via an online questionnaire [Research Electronic Data Capture (REDCap), production server version 9.3.3]. In addition, parental consent was obtained via email for participants who were under 16 years of age.

Selection of Schools

Initially, secondary schools in the predetermined locations were selected to be invited to participate. Initial selection was made by selecting 2-5 schools per location, with a female roll number of at least 200. Lower decile schools (a measure of the socioeconomic status of the school) were preferentially selected for this round of invitation to ensure representation (Figure 1). The selected schools received emails and follow-up phone calls inviting them to participate. If the required number of schools was not reached through this method, other schools in the area were contacted and invited to participate. Schools that were interested provided written consent to participate (signed by an appropriate representative from the school).

Recruitment of Participants

A brief information session (10-15 min) was delivered by the Master of Dietetics students to eligible pupils at each consenting school. At the session, pupils were given detailed information about the study and the required commitment. An expression of interest form was distributed for individuals to indicate their interest in participating by providing their email address. Individuals were also able to indicate interest on the study website [17]. Electronic and print information about the study was distributed at the school for anyone who required further information about the study. Individuals who provided their email address were sent a link to an online questionnaire (hosted on REDCap), on which they completed consent forms and answered a series of sociodemographic and general health questions. Participants who were under 16 years of age were asked to provide a parent’s email address and did not receive the link to the online questionnaire until a parent or guardian had consented to their participation.

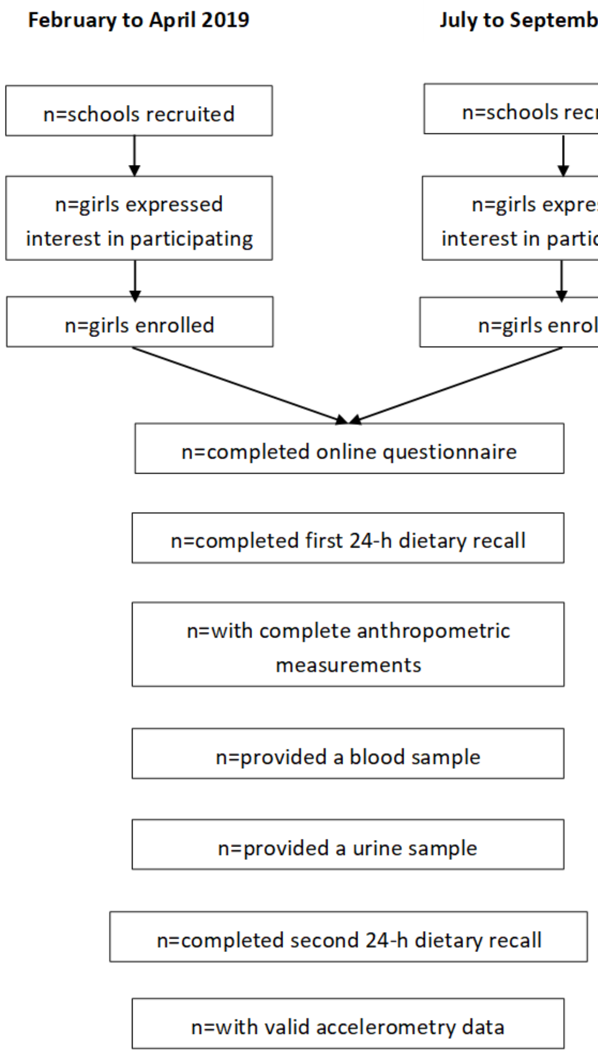
Inclusion Criteria

Adolescents who identify as female, are aged between 15 and 18 years, are enrolled in one of the selected secondary schools, can speak and understand English, and are not pregnant were eligible to participate.

Sample Size

A sample size of 300 adolescent girls from 13 secondary schools will have 80% power to the P=.05 level to detect a 0.5 standard deviation difference (a “moderate” difference) in continuous outcome variables between vegetarians and nonvegetarians, assuming a prevalence of vegetarianism of 20% and a design effect (for school clusters) of 1.5. If the prevalence of vegetarianism is much less than 20%, then purposeful sampling of vegetarians was planned in the second half of the recruitment year.

Figure 1. Study Design.



Outcome Measures

Online Questionnaire

Once participants completed enrollment, they were asked to complete an online questionnaire that follows from the enrolment questions on REDCap. This questionnaire is divided into three sections. The health and demographics section consists of 29 questions about sociodemographic characteristics and health status including current menstrual status, and food allergies or intolerances. It also asks participants if they identify as vegetarian. Initially, this was done by simply asking them, "Are you a vegetarian or vegan?" If they answered in the affirmative, they were asked to identify which of the following foods they eat: *Eggs, Milk, Fish or seafood, Chicken or poultry, Meat/red meat occasionally,* or *None of the above*. If they selected *None of the above*, they were asked if they identify as vegan. Participants were asked how long they have been following this way of eating, to which they could select options ranging from *less than a month* to *my whole life*. Adaptive questioning is used in this section so that, for example, if a participant answered "no" to "Are you a vegetarian?" they then moved on to the next question and did not see the questions pertaining to identifying as vegan or how long they have been following that eating pattern. The attitudes and motivations section includes 4 previously validated questionnaires [18-21] (Table 1) that, combined, consist of a total of 81 questions. In this section, questions that ask about similar concepts have been randomly distributed within each of the 4 questionnaires. Responses will be scored according to the published instructions [18-21]. The Dietary Habits section consists of 73 questions from the Dietary Habits Questionnaire that was used in the New Zealand Adult Nutrition Survey 2008/2009, which includes questions about weight loss intentions [22]. Each participant completed the questions from all sections in the same order, and an answer was required for each question. There was no timeframe limitation on completion. Participants were able to go back to previously answered questions and change their answers but there was no review step, and once the questionnaire was completed, they could not access it again. However, participants could leave the questionnaire at any point without completing it. A code was provided to participants so they could log back in and complete the questionnaire later, and reminders were sent to encourage them to do this. Incomplete questionnaires will be included in analysis on a case-by-case basis, depending on the outcome of interest.

Table 1. Summary of outcome measures to be collected in the SuNDiAL Project.

Outcome	Assessment Method
Online Questionnaire	
Demographics and health status	Self-report
Vegetarian/vegan status	Self-report
Dietary Habits	Dietary Habits Questionnaire
Attitudes and motivations towards food choice	Rationalizing meat consumption: The 4Ns Questionnaire [19]
	The Food Choice Questionnaire [21]
	Ethical Food Choice Motives [18]
	Dietarian Identity Questionnaire [20]
School visit	
Estimated usual dietary intake	Two 24-hour recalls, with adjustment of usual intake using MSM[a]
Height	Stadiometer
Weight	Body weight scales
Ulna Length	Steel measuring tape
Blood sample	
Hemoglobin	Cyanide-free photometry
Plasma ferritin	Immunoassay
Soluble transferrin receptor	Immunoassay
C-reactive protein	Immunoassay
Alpha-glycoprotein	Immunoassay
Zinc	ICP-MS[b]
Selenium	ICP-MS
Vitamin B12	Electrochemiluminescence immunoassay
Folate	Microbiological Assay
Urine Sample	
Iodine	ICP-MS
Accelerometry	
Average daily 24 h Activity	ActiGraph GT3x+, and accompanying wear time and sleep diary.
Average daily sleep	
Average daily sedentary time	
Average daily light intensity activity	
Average daily moderate to vigorous intensity physical activity	

[a]MSM: Multiple source method

[b]ICP-MS: Inductively couple plasma mass spectrometry

Usual Dietary Intake

Dietary intake was assessed using two 24-hour diet recalls. The first recall was completed face-to-face by a Master of Dietetics student during the in-school data collection visit. The recall was performed using a multiple-pass technique. In the first pass, a “quick list” of all foods and beverages consumed during the previous day (midnight to midnight) is obtained. In the second pass, a detailed description is added to each food and beverage, including cooking methods, recipe information (where appropriate), and brand and product information. In the third pass, the amounts of each food and beverage consumed are obtained. Participants were asked to estimate the amount consumed for each food and beverage using standard household measures (cups, tablespoons, etc), food photographs, shape dimensions, food portion assessment aids (dried beans), and information from packaging. Finally, the full food list was reviewed and any additions or changes were recorded. Upon completion of the recall, participants were asked if salt was added to any of the food consumed, and if so, whether it was iodized. A second recall was completed over video call on a nonconsecutive day, with preference given, where possible, to performing the second recall on a weekend day. All 24-hour diet recalls were entered into FoodWorks dietary analysis software (version 9, Xyris Software) using the New Zealand Food Composition Database, FOODfiles (2016; The New Zealand Institute for Plant and Food Research Limited and the Ministry of Health) and nutrient data for commonly consumed recipes collated in the 2008/09 New Zealand Adult Nutrition Survey [22]. Dietary intake estimated for each nutrient of interest will be adjusted to represent usual intakes based on the estimated within-person variance of vegetarians and nonvegetarians using the Multiple Source Method [23]. Individual daily intakes from supplements will then be calculated and added to the usual intakes. The median (IQR) (for data that are not normally distributed) or mean (SD) (for data that are normally distributed) of daily intakes of energy and key macro- and micro-nutrients, and the main food sources of these nutrients will then be calculated. Molar ratios of phytate:zinc will be calculated to provide estimates of absorbable zinc. The estimated average requirement (EAR) cut-point method will be applied to the usual intake distribution to assess the prevalence of inadequate intakes with the exception of iron, for which the full probability approach will be used because of the skewed iron requirements as a result of menstruation in this population. [24].

Anthropometric Assessments

Body weight was measured to the nearest 0.1 kg using calibrated body weight scales. Standing height was measured to the nearest 0.1 cm using a calibrated stadiometer and standardized protocols. Both these measurements were taken with participants wearing light clothing and no footwear. Ulna length was measured on the nondominant arm between the point of the elbow and the midpoint of the prominent bone of the wrist, using a nonexpandable steel measuring tape, with the arm positioned across the torso with the hand resting on the front of the opposite shoulder. Wrist watches and jewelry were removed for this measurement. All anthropometric measurements were performed in duplicate, with a third measurement performed if the difference between the initial two measurements was ≥0.5 units, and the mean of the two closest measurements used as the "true" value. BMI was calculated by weight (in kg) divided by height (in m) squared. BMI z-scores for age and sex will be calculated using the World Health Organization child growth standards [25].

Biochemical Assessment

Participants were able to opt-out of providing the blood and urine samples while still participating in the other components. A nonfasting venous blood sample was collected by a trained phlebotomist, using trace element free equipment. A spot urine sample was also collected. Time of collection and time of the last meal were recorded, and all blood and urine samples were transferred in a cooler to an accredited testing laboratory where hemoglobin and vitamin B12 concentrations were analyzed within 8 hours of collection. The remaining blood sample was centrifuged and the serum aliquoted and frozen at –80°C. Frozen serum and urine samples were transferred on ice to the Department of Human Nutrition at the University of Otago where they are stored for later analysis (outlined in Table 1).

Twenty-four–hour Activity

Average daily 24-hour activity (sleep, sedentary time, light activity, moderate-to-vigorous physical activity) was measured via a triaxial GT3x+ accelerometer (ActiGraph) among those who consented to accelerometry. Participants were asked to wear the accelerometer continuously for 7 days (except for water-based activities or during full contact sports) on an elasticated belt around their waist, so that the accelerometer was situated over their right hip. The raw accelerometer data were collected at 30 Hz. A daily wear time diary was used to record bedtime, sleep, and wake times and any times when the device was removed. If the device was removed for the purpose of engaging in water-based physical activity or full contact sports, then participants were asked to record the duration and intensity of this activity. Customized Stata (Release 16; StataCorp) code will be used for both accelerometer and log data, to differentiate nonwear and wear time. Time spent asleep will be identified using the Sadeh algorithm [26], and time spent in sedentary behavior and in light intensity and moderate-to-vigorous intensity physical activity will be identified using Freedson cut points [27].

Statistical Analysis

Statistical analyses will be carried out using Stata (StataCorp). School clusters will be accounted for in all analyses using appropriate methodology (for example, with a sandwich estimator or as a random effect). Estimates of prevalence and means will be reported with 95% confidence intervals. A binary variable for vegetarianism will be created, and comparisons between vegetarians and nonvegetarians will be carried out using regression models: linear regression for continuous outcomes and logistic regression for binary outcomes.

Results

Recruitment and data collection were conducted and completed with 290 participants in 2019. Data are currently being cleaned and analyzed, with publication of the main results anticipated at the end of 2020.

Discussion

Anecdotal reports suggest that the popularity of plant-based and vegetarian eating patterns may be rising in parallel with growing concerns about environmental sustainability. This pattern of eating is associated with some positive health outcomes [2,3,9]. Nonetheless, without careful planning, a vegetarian diet can increase the risk of inadequate intakes of bioavailable iron, zinc, calcium, and B vitamins [9,28]. The pubertal growth spurt combined with sexual maturation [12] increases the requirements for these nutrients, and therefore, we propose that female adolescents adopting a vegetarian diet may be at particular risk of nutrient inadequacy and deficiency.

The SuNDiAL project will provide a well-timed investigation into the dietary intakes, micronutrient status, physical activity, motivations, and beliefs of New Zealand adolescent girls. This project will also assess whether the current vegetarian diet consumed by adolescent girls in New Zealand offers substantial benefits or risks over a nonvegetarian eating pattern. The collection of biochemical data, dietary intakes, and 24-hour activity patterns will provide additional important details on benefits associated with vegetarianism, and the identification of individuals "at risk." The results of this study will support the development of targeted interventions and recommendations aimed at enhancing the health, growth, and development of adolescent girls.

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Conflicts of Interest

None declared.

References

1. Fox N, Ward KJ. You are what you eat? Vegetarianism, health and identity. Social Science & Medicine 2008 Jun;66(12):2585-2595. [doi: 10.1016/j.socscimed.2008.02.011]
2. Appleby PN, Key TJ. The long-term health of vegetarians and vegans. Proc. Nutr. Soc 2015 Dec 28;75(3):287-293. [doi: 10.1017/s0029665115004334]
3. Beeson WL, Mills PK, Phillips RL, Andress M, Fraser GE. Chronic disease among seventh-day adventists, a low-risk group. Rationale, methodology, and description of the population. Cancer 1989 Aug 01;64(3):570-581. [doi: 10.1002/1097-0142(19890801)64:3<570::aid-cncr2820640303>3.0.co;2-4]
4. Cade J, Burley V, Greenwood D. The UK Women's Cohort Study: comparison of vegetarians, fish-eaters and meat-eaters. Public Health Nutr 2007 Jan 02;7(7):871-878. [doi: 10.1079/phn2004620]
5. Orlich MJ, Singh PN, Sabaté J, Jaceldo-Siegl K, Fan J, Knutsen S, et al. Vegetarian Dietary Patterns and Mortality in Adventist Health Study 2. JAMA Intern Med 2013 Jul 08;173(13):1230. [doi: 10.1001/jamainternmed.2013.6473]
6. Melina V, Craig W, Levin S. Position of the Academy of Nutrition and Dietetics: Vegetarian Diets. Journal of the Academy of Nutrition and Dietetics 2016 Dec;116(12):1970-1980. [doi: 10.1016/j.jand.2016.09.025]
7. Clarys P, Deliens T, Huybrechts I, Deriemaeker P, Vanaelst B, De Keyzer W, et al. Comparison of Nutritional Quality of the Vegan, Vegetarian, Semi-Vegetarian, Pesco-Vegetarian and Omnivorous Diet. Nutrients 2014 Mar 24;6(3):1318-1332. [doi: 10.3390/nu6031318]
8. Craig W, Mangels A, American Dietetic Association. Position of the American Dietetic Association: Vegetarian Diets. Journal of the American Dietetic Association 2009 Jul;109(7):1266-1282. [doi: 10.1016/j.jada.2009.05.027]
9. Key TJ, Appleby PN, Rosell MS. Health effects of vegetarian and vegan diets. Proc. Nutr. Soc 2007 Mar 07;65(1):35-41. [doi: 10.1079/pns2005481]
10. Craig W. J., Health effects of vegan diets. Am J Clin Nutr 2009;89(5):1627. [doi: 10.3945/ajcn.2009.26736n]
11. Gibson R, Heath AL. Population groups at risk of zinc deficiency in Australia and New Zealand. Nutrition & Dietetics 2011;68(2):97-108. [doi: 10.1111/j.1747-0080.2011.01516.x]
12. Gibson RS, Heath AM, Ferguson EL. Risk of suboptimal iron and zinc nutriture among adolescent girls in Australia and New Zealand: causes, consequences, and solutions. Asia Pac J Clin Nutr 2002 Dec;11(s3):S543-S552. [doi: 10.1046/j.1440-6047.11.supp3.10.x]
13. University of Otago, Ministry of Health. A Focus on Nutrition - Key Findings of the 2008/09 New Zealand Adult Nutrition Survey. In: A Focus on Nutrition - Key Findings of the 2008/09 New Zealand Adult Nutrition Survey. Wellington, New Zealand: Ministry of Health; 2011.
14. Roy Morgan. 2016. Vegetarianism on the rise in New Zealand URL: http://www.roymorgan.com/findings/6663-vegetarians-on-the-rise-in-new-zealand-june-2015-201602080028 [accessed 2020-08-24]
15. Fox N, Ward K. Health, ethics and environment: A qualitative study of vegetarian motivations. Appetite 2008 Mar;50(2-3):422-429. [doi: 10.1016/j.appet.2007.09.007]
16. Hoffman SR, Stallings SF, Bessinger RC, Brooks GT. Differences between health and ethical vegetarians. Strength of conviction, nutrition knowledge, dietary restriction, and duration of adherence. Appetite 2013 Jun;65:139-144. [doi: 10.1016/j.appet.2013.02.009]
17. University of Otago. SuNDiAL Survey of Nutrition, Dietary Assessment and Lifestyles. 2019. URL: https://www.otago.ac.nz/sundial/index.html
18. Lindeman M, Väänänen M. Measurement of ethical food choice motives. Appetite 2000 Feb;34(1):55-59. [doi: 10.1006/appe.1999.0293]
19. Piazza J, Ruby MB, Loughnan S, Luong M, Kulik J, Watkins HM, et al. Rationalizing meat consumption. The 4Ns. Appetite 2015 Aug;91:114-128. [doi: 10.1016/j.appet.2015.04.011]

20. Rosenfeld DL, Burrow AL. Development and validation of the Dietarian Identity Questionnaire: Assessing self-perceptions of animal-product consumption. Appetite 2018 Aug;127:182-194. [doi: 10.1016/j.appet.2018.05.003]
21. Steptoe A, Pollard TM, Wardle J. Development of a Measure of the Motives Underlying the Selection of Food: the Food Choice Questionnaire. Appetite 1995 Dec;25(3):267-284. [doi: 10.1006/appe.1995.0061]
22. University of Otago, Ministry of Health. Methodology report for the 2008/09 New Zealand Adult Nutrition Survey. In: Methodology report for the 2008/09 New Zealand Adult Nutrition Survey. Wellington, New Zealand: Ministry of Health; 2011.
23. Harttig U, Haubrock J, Knüppel S, Boeing H. The MSM program: web-based statistics package for estimating usual dietary intake using the Multiple Source Method. Eur J Clin Nutr 2011 Jul 6;65(S1):S87-S91. [doi: 10.1038/ejcn.2011.92]
24. Institutes of Medicine. Dietary Reference Intakes: Applications in Dietary Assessment. Washington, DC: National Academy Press; 2000.
25. de Onis M. Development of a WHO growth reference for school-aged children and adolescents. Bull World Health Organ 2007 Sep 01;85(09):660-667. [doi: 10.2471/blt.07.043497]
26. Sadeh A. The role and validity of actigraphy in sleep medicine: An update. Sleep Medicine Reviews 2011 Aug;15(4):259-267. [doi: 10.1016/j.smrv.2010.10.001]
27. Freedson PS, Melanson E, Sirarad J. Calibration of the Computer Science and Applications, Inc. accelerometer. Medicine & Science in Sports & Exercise 1998;30(5):777-781. [doi: 10.1097/00005768-199805000-00021]
28. Schüpbach R, Wegmüller R, Berguerand C, Bui M, Herter-Aeberli I. Micronutrient status and intake in omnivores, vegetarians and vegans in Switzerland. Eur J Nutr 2015 Oct 26;56(1):283-293. [doi: 10.1007/s00394-015-1079-7]

Abbreviations

REDCap: Research electronic data capture

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Appendix B: Sleep and Wear-time Diary

PARTICIPANT ID: ____________________

sundial PROJECT

Accelerometer Sleep and Wear Time Diary

Accelerometer fitted: Day________________ Date_____________ Time:__________

Accelerometer removed: Day________________ Date_____________ Time:__________

Day One

Date ____________________ Day of the Week ____________________ Participant ID: ____________

During the day I removed the accelerometer *(please complete using the 24 h clock eg. 1 pm = 13:00):*

Removal time __________ back on: ____________ Reason ____________________

Removal time __________ back on: ____________ Reason ____________________

Removal time __________ back on: ____________ Reason ____________________

Removal time __________ back on: ____________ Reason ____________________

Removal time __________ back on: ____________ Reason ____________________

Removal time __________ back on: ____________ Reason ____________________

During the day I did the following activity that might not have been recorded e.g swimming, biking or resistance activities (weights) *(please complete using the 24 h clock eg. 1 pm = 13:00)*:

Description of Activity _______________ Time began: ________________ Time ended: ________

Intensity of activity: Light* ☐ Moderate** ☐ Vigorous*** ☐

Description of Activity _______________ Time began: ________________ Time ended: ________

Intensity of activity: Light ☐ Moderate ☐ Vigorous ☐

Description of Activity _______________ Time began: ________________ Time ended: ________

Intensity of activity: Light ☐ Moderate ☐ Vigorous ☐

*Activities which do not markedly increase heart rate of breathing rate

** Activities that elevate heart rate and breathing, but during which you can hold a conversation

***Activities that involve considerable exertion, and during which you are breathing so hard you can talk

Sleep Log

Complete the morning of Day 2

Question	Answer	Instruction
What time did you lie down in bed last night (*end of day one*):		Record time (use 24 h clock)
What time did you try to go to sleep? (turned off light/put down phone)		Record time (use 24 h clock)
About how long do you think it took you to fall asleep?		Record minutes
What time did you wake up this morning? (*beginning of day two*)		Record time (use 24 h clock)
What time did you get out of bed this morning?		Record time (use 24 h clock)

Day Two

Date ____________________ Day of the Week ___________________ Participant ID: ____________

During the day I removed the accelerometer *(please complete using the 24 h clock eg. 1 pm = 13:00):*

Removal time __________ back on: ____________ Reason ____________________

Removal time __________ back on: ____________ Reason ____________________

Removal time __________ back on: ____________ Reason ____________________

Removal time __________ back on: ____________ Reason ____________________

Removal time __________ back on: ____________ Reason ____________________

Removal time __________ back on: ____________ Reason ____________________

During the day I did the following activity that might not have been recorded e.g swimming, biking or resistance activities (weights) *(please complete using the 24 h clock eg. 1 pm = 13:00)*:

Description of Activity _______________ Time began: ________________ Time ended: ________

Intensity of activity: Light* ☐ Moderate** ☐ Vigorous*** ☐

Description of Activity _______________ Time began: ________________ Time ended: ________

Intensity of activity: Light ☐ Moderate ☐ Vigorous ☐

Description of Activity _______________ Time began: ________________ Time ended: ________

Intensity of activity: Light ☐ Moderate ☐ Vigorous ☐

*Activities which do not markedly increase heart rate of breathing rate

** Activities that elevate heart rate and breathing, but during which you can hold a conversation

***Activities that involve considerable exertion, and during which you are breathing so hard you can talk

Sleep Log

Complete the morning of Day 3

What time did you lie down in bed last night (*end of day one*):		Record time (use 24 h clock)
What time did you try to go to sleep? (turned off light/put down phone)		Record time (use 24 h clock)
About how long do you think it took you to fall asleep?		Record minutes
What time did you wake up this morning? (*beginning of day two*)		Record time (use 24 h clock)
What time did you get out of bed this morning?		Record time (use 24 h clock)

Day Three

Date ____________________ Day of the Week ____________________ Participant ID: ____________

During the day I removed the accelerometer *(please complete using the 24 h clock eg. 1 pm = 13:00):*

Removal time __________ back on: ____________ Reason ____________________

Removal time __________ back on: ____________ Reason ____________________

Removal time __________ back on: ____________ Reason ____________________

Removal time __________ back on: ____________ Reason ____________________

Removal time __________ back on: ____________ Reason ____________________

Removal time __________ back on: ____________ Reason ____________________

During the day I did the following activity that might not have been recorded e.g swimming, biking or resistance activities (weights) *(please complete using the 24 h clock eg. 1 pm = 13:00)*:

Description of Activity _______________ Time began: ________________ Time ended: ________

Intensity of activity: Light* ☐ Moderate** ☐ Vigorous*** ☐

Description of Activity _______________ Time began: ________________ Time ended: ________

Intensity of activity: Light ☐ Moderate ☐ Vigorous ☐

Description of Activity _______________ Time began: ________________ Time ended: ________

Intensity of activity: Light ☐ Moderate ☐ Vigorous ☐

*Activities which do not markedly increase heart rate of breathing rate

** Activities that elevate heart rate and breathing, but during which you can hold a conversation

***Activities that involve considerable exertion, and during which you are breathing so hard you can talk

Sleep Log

Complete the morning of Day 4

What time did you lie down in bed last night (*end of day one*):		Record time (use 24 h clock)
What time did you try to go to sleep? (turned off light/put down phone)		Record time (use 24 h clock)
About how long do you think it took you to fall asleep?		Record minutes
What time did you wake up this morning? (*beginning of day two*)		Record time (use 24 h clock)
What time did you get out of bed this morning?		Record time (use 24 h clock)

Day Four

Date ______________ Day of the Week ______________ Participant ID: __________

During the day I removed the accelerometer *(please complete using the 24 h clock eg. 1 pm = 13:00):*

Removal time ________ back on: __________ Reason ______________

Removal time ________ back on: __________ Reason ______________

Removal time ________ back on: __________ Reason ______________

Removal time ________ back on: __________ Reason ______________

Removal time ________ back on: __________ Reason ______________

Removal time ________ back on: __________ Reason ______________

During the day I did the following activity that might not have been recorded e.g swimming, biking or resistance activities (weights) *(please complete using the 24 h clock eg. 1 pm = 13:00)*:

Description of Activity ____________ Time began: ____________ Time ended: ______

Intensity of activity: Light* ☐ Moderate** ☐ Vigorous*** ☐

Description of Activity ____________ Time began: ____________ Time ended: ______

Intensity of activity: Light ☐ Moderate ☐ Vigorous ☐

Description of Activity ____________ Time began: ____________ Time ended: ______

Intensity of activity: Light ☐ Moderate ☐ Vigorous ☐

*Activities which do not markedly increase heart rate of breathing rate

** Activities that elevate heart rate and breathing, but during which you can hold a conversation

***Activities that involve considerable exertion, and during which you are breathing so hard you can talk

Sleep Log

Complete the morning of Day 5

What time did you lie down in bed last night (*end of day one*):		Record time (use 24 h clock)
What time did you try to go to sleep? (turned off light/put down phone)		Record time (use 24 h clock)
About how long do you think it took you to fall asleep?		Record minutes
What time did you wake up this morning? (*beginning of day two*)		Record time (use 24 h clock)
What time did you get out of bed this morning?		Record time (use 24 h clock)

Day Five

Date ____________________ Day of the Week ___________________ Participant ID: ____________

During the day I removed the accelerometer *(please complete using the 24 h clock eg. 1 pm = 13:00):*

Removal time __________ back on: ____________ Reason ____________________

Removal time __________ back on: ____________ Reason ____________________

Removal time __________ back on: ____________ Reason ____________________

Removal time __________ back on: ____________ Reason ____________________

Removal time __________ back on: ____________ Reason ____________________

Removal time __________ back on: ____________ Reason ____________________

During the day I did the following activity that might not have been recorded e.g swimming, biking or resistance activities (weights) *(please complete using the 24 h clock eg. 1 pm = 13:00)*:

Description of Activity _______________ Time began: ________________ Time ended: ________

Intensity of activity: Light* ☐ Moderate** ☐ Vigorous*** ☐

Description of Activity _______________ Time began: ________________ Time ended: ________

Intensity of activity: Light ☐ Moderate ☐ Vigorous ☐

Description of Activity _______________ Time began: ________________ Time ended: ________

Intensity of activity: Light ☐ Moderate ☐ Vigorous ☐

*Activities which do not markedly increase heart rate of breathing rate

** Activities that elevate heart rate and breathing, but during which you can hold a conversation

***Activities that involve considerable exertion, and during which you are breathing so hard you can talk

Sleep Log		
Complete the morning of Day 6		
What time did you lie down in bed last night (*end of day one*):		Record time (use 24 h clock)
What time did you try to go to sleep? (turned off light/put down phone)		Record time (use 24 h clock)
About how long do you think it took you to fall asleep?		Record minutes
What time did you wake up this morning? (*beginning of day two*)		Record time (use 24 h clock)
What time did you get out of bed this morning?		Record time (use 24 h clock)

Day Six

Date ____________________ Day of the Week ____________________ Participant ID: ____________

During the day I removed the accelerometer *(please complete using the 24 h clock eg. 1 pm = 13:00):*

Removal time __________ back on: ____________ Reason ____________________

Removal time __________ back on: ____________ Reason ____________________

Removal time __________ back on: ____________ Reason ____________________

Removal time __________ back on: ____________ Reason ____________________

Removal time __________ back on: ____________ Reason ____________________

Removal time __________ back on: ____________ Reason ____________________

During the day I did the following activity that might not have been recorded e.g swimming, biking or resistance activities (weights) *(please complete using the 24 h clock eg. 1 pm = 13:00)*:

Description of Activity _______________ Time began: ________________ Time ended: ________

Intensity of activity: Light* ☐ Moderate** ☐ Vigorous*** ☐

Description of Activity _______________ Time began: ________________ Time ended: ________

Intensity of activity: Light ☐ Moderate ☐ Vigorous ☐

Description of Activity _______________ Time began: ________________ Time ended: ________

Intensity of activity: Light ☐ Moderate ☐ Vigorous ☐

*Activities which do not markedly increase heart rate of breathing rate

** Activities that elevate heart rate and breathing, but during which you can hold a conversation

***Activities that involve considerable exertion, and during which you are breathing so hard you can talk

Sleep Log

Complete the morning of Day 7

What time did you lie down in bed last night (*end of day one*):		Record time (use 24 h clock)
What time did you try to go to sleep? (turned off light/put down phone)		Record time (use 24 h clock)
About how long do you think it took you to fall asleep?		Record minutes
What time did you wake up this morning? (*beginning of day two*)		Record time (use 24 h clock)
What time did you get out of bed this morning?		Record time (use 24 h clock)

Day Seven

Date ____________________ Day of the Week ____________________ Participant ID: ____________

During the day I removed the accelerometer *(please complete using the 24 h clock eg. 1 pm = 13:00):*

Removal time __________ back on: ____________ Reason ____________________

Removal time __________ back on: ____________ Reason ____________________

Removal time __________ back on: ____________ Reason ____________________

Removal time __________ back on: ____________ Reason ____________________

Removal time __________ back on: ____________ Reason ____________________

Removal time __________ back on: ____________ Reason ____________________

During the day I did the following activity that might not have been recorded e.g swimming, biking or resistance activities (weights) *(please complete using the 24 h clock eg. 1 pm = 13:00)*:

Description of Activity _______________ Time began: ________________ Time ended: ________

Intensity of activity: Light* ☐ Moderate** ☐ Vigorous*** ☐

Description of Activity _______________ Time began: ________________ Time ended: ________

Intensity of activity: Light ☐ Moderate ☐ Vigorous ☐

Description of Activity _______________ Time began: ________________ Time ended: ________

Intensity of activity: Light ☐ Moderate ☐ Vigorous ☐

*Activities which do not markedly increase heart rate of breathing rate

** Activities that elevate heart rate and breathing, but during which you can hold a conversation

***Activities that involve considerable exertion, and during which you are breathing so hard you can talk

Sleep Log

Complete the morning of Day 8

What time did you lie down in bed last night (*end of day one*):		Record time (use 24 h clock)
What time did you try to go to sleep? (turned off light/put down phone)		Record time (use 24 h clock)
About how long do you think it took you to fall asleep?		Record minutes
What time did you wake up this morning? (*beginning of day two*)		Record time (use 24 h clock)
What time did you get out of bed this morning?		Record time (use 24 h clock)