The effect of physical activity and sedentary behaviour on mental health amongst young adults

By

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I am the author of the thesis entitled

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Foreword

The current thesis has been structured according to the guidelines for a conventional thesis, as detailed by Deakin University for a Doctorate of Psychology program. As stipulated by these guidelines, the candidate is encouraged to present publishable work that may be more detailed than that generally presented for publication. The reviewer’s comments can then serve as useful feedback to the candidate. Generally, the conventional thesis is structured such that there is a general introduction, a review of the literature, methods chapter, several results chapters and a general discussion. In light of the intention to submit work for publication, the relevant methods, results and discussion for each intended publication will be described separately for each study of the thesis. The manner in which the work is connected will be described in linking summary sections at the beginning and end of each chapter. The thesis will conclude with a general discussion, which will include a detailed examination regarding the theoretical, methodological and empirical issues and implications relevant to the whole body of work. The thesis author and primary supervisor believe that the following thesis accords with the requirements described by the Deakin guidelines.
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Abstract

Relative to the general population, young adults (18 - 29 years) report higher levels of poor mental health, characterised by psychological distress, anxiety and depressive symptoms. To improve mental health, and reduce the associated burden, a necessary first step is to identify modifiable influences (risk and protective factors). The current thesis investigated the independent and interacting roles of physical activity and sedentary behaviour as influences on common young adult mental health symptoms (indexed by psychological distress, anxiety and depressive symptoms). Following a systematic review, a cross-sectional study and a two-year longitudinal study were completed within large state-representative cohorts (recruited sample N = 2,884).

The studies found that physical activity was associated with reduced mental health symptoms; however, this effect was not maintained after multivariate control for young adult psychosocial characteristics. Further, engagement in long periods of sedentary behaviour (sitting time) was associated with higher psychological distress in the cross-sectional study, but not related in the longitudinal study. A significant contribution of the thesis was the finding of a threshold at which sitting time may be related to mental health.

The current thesis began its journey identifying existing literature findings through the systematic review. A systematic search identified 26 previous studies (16 cross-sectional and 10 longitudinal studies) that had examined the effect of physical activity or sedentary behaviour on common mental health symptoms in young adults. In overview, findings suggested an inverse association between physical activity and mental health. Further, a positive association was found between sedentary behaviour and mental health symptoms. Only three cross-sectional studies and no longitudinal studies had previously examined the effects of both physical activity and sedentary
behaviour on young adult mental health. Methodological problems in the prior studies included their failure to examine representative samples and the inadequate control of relevant correlates in multivariate analyses. The previous research examining the effect of physical activity on mental health mostly used deficient measures of physical activity. The prior research investigating the effect of sedentary behaviour on mental health was limited in extent and utilised proxy measures of sedentary behaviour, such as screen time. The current thesis included cross-sectional and longitudinal studies and a psychometrically sound, internationally utilised measure of physical activity and sedentary behaviour. Through the investigation of cross-sectional and longitudinal data, the effect of both physical activity and sitting time on mental health was investigated, amongst a state representative sample of young adults, using multivariate analyses controlling for important correlates.

The study aims were fourfold. First, to provide prevalence rates of psychological distress, and rates of engagement in physical activity and sedentary behaviour at two time points in early adulthood. Consideration of prevalence rates included analysis of the change in physical activity, sedentary behaviour and psychological distress over a period of two years. Second, the aim was to determine the extent to which physical activity and sedentary behaviour independently predicted young adult psychological distress after controlling for significant correlates. Third, analysis of an interaction effect between physical activity and sedentary behaviour on psychological distress was completed. Finally, these analyses were conducted using both cross-sectional and longitudinal designs to determine the extent to which physical activity and sedentary behaviour were found to be concurrently versus prospectively related with mental health.

The current thesis aims were addressed via analysis of data from Australian young adults, who participated in the International Youth Development Study
The IYDS recruited a cohort of 2884 adolescent students who were sampled in 2002 to be state representative of schools in the state of Victoria, using a two-stage cluster sampling approach. Participants completed an online survey at two time points in young adulthood; 2010 ($M_{age} = 21.2, SD = 1.7$) and 2012 ($M_{age} = 23.2, SD = 1.7$; 56.7% female). The International Physical Activity Questionnaire (Short form) was used to measure physical activity and sedentary behaviour while the Kessler Psychological Distress Scale was used to measure psychological distress. All data were adjusted for clustering of responses associated with the initial school recruitment and weighted to reflect Victorian Census rates of young adults, defined by age and gender.

It was found that most young adults engaged in 150+ minutes of moderate to vigorous physical activity. Over 60% engaged in 2.6 or more hours of sitting time each weekday. Rates of physical activity and sedentary behaviour engagement remained relatively stable across 21 to 23 years of age. Over one in four young adults reported psychological distress severe enough to reflect a high risk of being diagnosed with a mental disorder.

The cross-sectional multivariate analyses indicated that young adults who engaged in 5.6 or more hours of sitting time were significantly more likely to report psychological distress than those who engaged in 2.5 or fewer hours. This association was maintained after controlling for the effect of physical activity and psychosocial correlates. Longitudinally, sedentary sitting time in 2010 had a bivariate association with 2012 psychological distress. However, this did not remain significant in the multivariate analyses. Engagement in moderate to vigorous physical activity sufficiently to meet Australian public health guidelines predicted lower psychological distress in bivariate analyses, but this effect was no longer significant in the multivariate analyses, with similar findings in the cross-sectional
and longitudinal analyses. The cross-sectional interaction analyses suggested no significant interactive effect of physical activity and sedentary behaviour on mental health.

Theoretically, the results indicate that sedentary behaviour is related to young adult mental health while the effect of physical activity may be explained by the associated influences of sedentary behaviour and psychosocial characteristics. Practically, the results suggest that engaging in 5.6 or more hours of weekday sitting may be a threshold at which young adult mental health is affected. Further research is required to elucidate the processes in which the relationship between physical activity and mental health is moderated and mediated by psychosocial correlates. Future research is also required to confirm whether the threshold identified in the present study is also found in other studies that measure sedentary behaviour as total sitting time.

The current research builds beyond prior research in several important ways. First, the current studies utilised psychometrically sound, internationally accepted self-report measures of physical activity and sedentary behaviour, which has been done in only one prior study (Feng, 2014). Second, the analyses of the effects of physical activity and sedentary behaviour on mental health controlled for a wider range of known psychosocial correlates than previous studies and simultaneously included both physical activity and sedentary behaviour. Third, the current study considered both the cross-sectional and longitudinal effects on mental health. Finally, the study comprehensively examined the evidence for interactive effects between sedentary behaviour and physical activity on the mental health of young adults.

The current research has implications for future studies of young adult mental health. The study shows for the first time associations with high sitting time and high rates of young adult mental health symptoms and. The study suggests specifically,
that further studies of the processes that lead from sedentary behaviour to mental health problems in young adults are warranted. The current study raises questions as to whether physical activity has a direct effect on young adult mental health, suggesting instead that its effect may be mediated through associated factors such as sedentary behaviour, unemployment and physical health. The current research may contribute to public health guidelines in demonstrating in a large state representative sample that engaging in more than 5.6 hours of weekday sitting was associated with higher poor young adult mental health symptoms.
Chapter 1: Introduction and Overview

The current thesis investigates the effect of physical activity and sedentary behaviour on young adult mental health. The introductory Chapter that follows will provide a general theoretical and empirical backdrop for the studies included in the thesis. As will be indicated throughout, the current thesis reflects the prevention science model, whereby possible influences on mental health are modelled to inform young adult mental health prevention programs.

As a core component of prevention science, epidemiology is defined as the study of behavioural and/or physical health concerns in human populations, to provide high-quality data to inform prevention intervention policies and practices (Herman, Riley-Tillman, & Reinke, 2012). Based on this platform, prevention science involves several steps, which allows the establishment of a solid knowledge-base. First, a clear definition of the problem is required (Herman et al., 2012). This is achieved in Chapter 2, in which an overview is presented of young adulthood as a developmental period during which many mental health problems arise. This will be set in the context of recent sociocultural changes that young adults have experienced that result in new challenges relative to previous generations for youth in Australia and other nations. Prevalence rates of psychological distress, anxiety and depressive symptoms, and associated psychosocial consequences for young adults are described that indicate a high level of disease burden.

Next, a theoretical framework that informs the understanding of the mental health of young adults is required (Herman et al., 2012). As described in Chapter 3, theoretical and empirical foundations are set for the thesis in the biopsychosocial model and developmental frameworks that seek to establish relevant influences (risk and protective factors) that may explain changes in young adult mental health. As a key tenet of the prevention science framework, contextualism defines that the risk or
protective factors that are investigated are amenable to change (Herman et al., 2012; Mrazek & Haggerty, 1994). As such, the empirical indicators and theoretical mechanisms that have been posited in relationship to the independent and interactive effects of physical activity and sedentary behaviour on mental health will be described in Chapter 4. Chapter 5 will detail a systematic review conducted to determine the independent and interacting relationships between physical activity, sedentary behaviour and young adult mental health. The current thesis will reflect investigations of both the cross-sectional and longitudinal relationships between physical activity, sedentary behaviour and mental health in Chapters 6 and 7, respectively. The use of these designs is described from the quality standards within the prevention science methodological framework and as relevant to the investigation of the risk and protective factors that relate to mental health. Finally, Chapter 8 presents an integrated discussion that evaluates the manner in which existing evidence and that of the contribution of the current thesis, coalesce together. The integration of findings is relevant to prevention science's ultimate aim which is to inform intervention and practices (Herman et al., 2012).

Summary

The current thesis will address the extent to which physical activity and sedentary behaviour have independent and interactive relationships with mental health, amongst contemporary young adults. The existing theoretical and empirical evidence will be detailed in the introductory Chapters 2 to 4, to indicate the rationale for the empirical work that follows. The research program will utilise three designs to address the overarching aim, namely: a systematic review of prior existing literature; a cross-sectional; and longitudinal study. Subsequently, the manner in which existing literature findings can be integrated with the findings detailed in the current thesis studies will be detailed in the final general discussion Chapter. The
final discussion Chapter will describe how the thesis findings may inform the development of promotive and preventive strategies designed to improve mental health amongst young adults.
Chapter 2: Young adulthood and mental health

Young adulthood is a developmental period marked by increasing mental health challenges (Heaven, 1996). This Chapter will detail the developmental period of young adulthood and how it is a period during, which many mental health problems arise. The unique challenges of young adults will be described. In line with prevention science (Herman et al., 2012), a definition of poor mental health and the associated outcomes at the individual and at the societal level, will be provided. Consequently, this Chapter will provide evidence for a high level of disease burden associated with poor mental health amongst young adults.

Young adulthood as a developmental period

Young adulthood occurs approximately between 18 to 29 years of age (Arnett, Žukauskienė, & Sugimura, 2014) and is a distinct developmental period of marked change, involving instability, and uncertainty (Arnett, 2000, 2004). It involves living through several developmental processes that are highly influenced by socio-cultural expectations of normative social behaviour (Schulenberg, Sameroff, & Cicchetti, 2004). Specifically, Schulenberg, Bryant and O'Malley (2004) described six inter-dependent developmental processes; establishing relationships with intimate partner and friends, completing education, starting work, establishing financial independence, citizenship, and defining personal healthy lifestyle choices.

During this period, young adults establish themselves as autonomous beings, through making more independent choices regarding romantic relationships, education, work and lifestyle (Schulenberg, Bryant, et al., 2004). Young adults often establish long-term intimate partnerships during this period, as well as developing long-term close peer relationships (Arnett, 2004). These social changes also involve
separation from the family of origin, for example by moving out of the family home and finding an independent source of income. This process of moving home may allow for the young adult to challenge family of origin beliefs and norms, which in turn may facilitate a greater sense of independence. Further, the process of transitioning from adolescence to young adulthood is said to involve becoming more conscious of one’s role in the community and society as a whole, which reflects the development of self as a citizen (Schulenberg, Bryant, et al., 2004). Moving out of home often coincides with the completion of tertiary education and/ or starting full-time work, which is important in terms of developing financial independence.

**Young adulthood and mental health**

Young adulthood is marked by an increase in mental health problems (Arnett, 2006; Newman et al., 1996; Rickwood, Mazzer, & Telford, 2015). Mental health is defined as the state in which an individual uses psychological skills and abilities to manage daily demands and social requirements in order to realise their potential in the context of relationships, culture and socioeconomic factors (Australian Institute of Health and Welfare, 1999). The most commonly occurring mental health problems for young adults are anxiety and/ or depression that are captured by measures of psychological distress (Aalto-Setälä, Marttunen, Tuulio-Henriksson, Poikolainen, & Lönnqvist, 2001). Attending to the most commonly occurring mental health issues for young adults can inform prevention efforts with the greatest reach potential and thus lead to improvement in mental health. As a result, the current thesis will investigate commonly occurring mental health concerns amongst young adults.

Approximately 20 – 26% of young adults across several countries including Australia, Finland, New Zealand and Cyprus report mental health problems (Aalto-Setälä et al., 2001; Australian Institute of Health and Welfare, 2007; Newman et al., 1996; Sokratous, Merkouris, Middleton, & Karanikola, 2014; Suvisaari et al., 2009),
of which the most commonly occurring are depressive and anxiety disorders or symptoms (Aalto-Setälä et al., 2001; Newman et al., 1996). To illustrate, evidence from Finland indicates that approximately 10.8% and 6.9% of young adults experience a depressive or anxiety disorder in the previous month, respectively (Aalto-Setälä et al., 2001). Depressive disorders are characterised by depressive symptoms including low mood, loss of interest or pleasure in previously enjoyable activities or irritability (American Psychiatric Association, 2013). Young adults without disorders but with high depressive symptoms may also experience problems such as; low concentration, indecisiveness, low self-esteem, pessimism and/or feelings of guilt or worthlessness, sleep disturbance and associated fatigue, and changes in appetite or movement. Anxiety disorders are marked by symptoms of intense and recurring fear or apprehension regarding a particular situation or stimulus (American Psychiatric Association, 2013), ranging from social contexts (i.e., Social Anxiety Disorder), distance from emotionally-salient places or people (i.e., Separation Anxiety Disorder), being in public places (i.e., Agoraphobia), or generalised sense of anxiety related to many aspects of living (i.e., Generalised Anxiety Disorder) (American Psychiatric Association, 2013).

Common mental health problems amongst young adults have been measured utilising standardised diagnostic tools such as the University of Michigan Composite International Diagnostic Interview Short Form (Haarasilta, Marttunen, Kaprio, & Aro, 2004), the Psychiatric Diagnostic Screening Questionnaire (PDSQ; Herring, O’Connor, & Dishman, 2014), and the Composite International Diagnostic Interview (Ströhle et al., 2007). Self-report questionnaires measuring depression have been utilised such as the Center for Epidemiologic Studies-Depression Scale (CES-D; Ball et al., 2009), Beck Depression Inventory (Gerber, Brand, Herrmann, et al., 2014), Depression Scale (Gerber, Brand, Elliot, Holsboer-Trachsler, & Puhse, 2014),
Common self-report measures of anxiety symptoms include the Self-Rating Anxiety Scale (Wu et al., 2015), Social Anxiety Scale (Gordon et al., 2007), and State-Trait Anxiety Inventory (Thome & Espelage, 2004).

Depressive disorders most often onset during late childhood to early adolescence (Hankin & Abela, 2005). However, Newman and colleagues (1996) found that 29.8% and 19.5% of those who met diagnostic criteria for depressive or anxiety disorders, respectively, were new cases, not previously diagnosed by 21 years of age. This suggests that whilst there is a high proportion of children and adolescents with mental health concerns, approximately one in four of young people are at risk of reaching diagnostic criteria by the time they enter young adulthood. Further, prospective evidence suggests that young adulthood onset depression predicts depression later in life (Korten, Comijs, Lamers, & Penninx, 2012).

There is evidence that young adults who meet diagnostic criteria for a common mental health problem, do not seek adequate help to address their concerns (Rickwood et al., 2015). Specifically, of those who met criteria for depressive disorder, eight out of ten (82%) reported no ongoing contact with a mental health service, while seven out of ten (76%) with an anxiety disorder reported no ongoing mental health support (Aalto-Setälä et al., 2001). Young adults cite a lack of trust in the mental health system, and avoidance of stigma as barriers to help-seeking (Ojeda & Bergstresser, 2008). In light of the disease burden associated with the experience of common mental health problems, research is required to identify avenues of prevention and treatment which supports ongoing mental health support.

**Burden of disease associated with common mental health problems**

Depressive and anxiety symptoms are associated with negative outcomes for the individual and society. For the individual, evidence suggests that young adults
who experience one common mental health problem are at significantly higher risk of experiencing another. For example, Aalto-Setala and colleagues (2001) indicated that of 20 - 24-year-old young adults who met the diagnostic criteria for a depressive disorder (Major Depressive Disorder, Dysthymia), 59% also met the criteria for another mental health concern, of which anxiety disorders were most common. Similarly 62% of those who reported anxiety symptoms sufficient to diagnose an anxiety disorder also reported experiencing another mental disorder. The high rate of comorbidity lends itself to research that considers young adults who experience either depressive or anxiety symptoms, simultaneously.

These young adults with elevated mental health symptoms also tend to engage in risky behaviours including substance use such as cigarette use, alcohol abuse (Caldwell et al., 2002) and self-injury (Martin, Swannell, Hazell, Harrison, & Taylor, 2010). Young adults with poor mental health are at an elevated risk to experience physical ill-health (Cvetkovski, Reavley, & Jorm, 2012) such as insulin resistance (a biomarker of diabetes) (Timonen et al., 2006) and obesity (Sánchez-Villegas et al., 2010). Importantly, young adults with mental health problems are more likely to attempt suicide than young adults without mental health problems (Page et al., 2014).

For the society, mental disorders account for 17.6 of total Disability-Adjusted Life Years (DALYs) lost per 1000 people in Australia making them the second leading cause of DALYs lost during young adulthood (Begg, Vos, Barker, Stanley, & Lopez, 2008). This burden is associated with significant treatment and prevention costs exceeding $7 billion dollars spent annually (Australian Institute of Health and Welfare, 2014). In light of the associated consequences, an empirical focus on young adult mental health is warranted.
**Sub-threshold symptoms**

Sub-threshold symptoms have been defined as mental health symptoms that do not meet the diagnostic criteria (Judd, 1995; Lewinsohn, Solomon, Seeley, & Zeiss, 2000; Solomon, Haaga, & Arnow, 2001). Approximately 12.3% of young adults experience sub-clinical threshold anxiety symptoms (Wittchen, Nelson, & Lachner, 1998). Youth who experience sub-threshold depressive symptoms are 2-3 times more likely to experience a Major Depressive Episode (MDE) in adulthood (Pine, Cohen, Cohen, & Brook, 1999). This suggests that the onset of common mental disorders begins through the experience of sub-threshold symptoms.

There has been some debate about the clinical significance of sub-threshold depressive symptoms relative to diagnosable disorders (Judd, Akiskal, & Paulus, 1997), suggesting that clinically diagnosable disorders warrant more empirical focus due to the significant reduction in functioning (American Psychiatric Association, 2013). However, evidence suggests that individuals who experience sub-threshold symptoms are functionally distinct from asymptomatic individuals and functionally similar to those who experience diagnosable disorders. In particular, evidence suggests that the association between depressive symptoms and health outcomes is linear such that as the number of depressive symptoms increase, the poorer the psychological and behavioural functioning (Lewinsohn, Rohde, Seeley, Klein, & Gotlib, 2000). Further, individuals with sub-threshold depressive symptoms reported significantly poorer functioning in social, financial, physical health and work domains compared to non-symptomatic individuals (Judd et al., 1997). Also, youth with sub-threshold depressive symptoms are more likely to attempt suicide than those without sub-threshold symptoms (Judd et al., 1997). This illustrates that even sub-threshold depressive symptoms can impair functioning. In addition, evidence indicates that individuals who experience sub-threshold symptoms and clinically
diagnosable disorders share similar correlates and outcomes (Solomon et al., 2001). The similarities suggest that irrespective of the severity of symptomology, poor mental health symptoms can cause significant consequences for the individual.

In conclusion, the functional impact of poor mental health symptoms is not necessarily determined by the clinical cut-off (Goldney, Fisher, Dal Grande, & Taylor, 2004; Judd & Akiskal, 2000; Lewinsohn, Solomon, et al., 2000). In order to reduce the associated burden and prevent the onset of common mental disorders, it is important that efforts are made to measure the full range of symptomology.

**Psychological distress**

In epidemiologic research, one of the challenges is utilising a measure that can validly and reliably identify common mental health problems and be limited in length, in order to reduce participant burden. One answer to this challenge has been the development of measures of psychological distress, combining indicators of anxiety and depressive symptoms. Theoretical evidence suggests that psychological distress reflects the ‘common factor’ emotional experience, which underpins common mental health problems (Goldberg & Williams, 1988). Several measures have been developed and are utilised to measure psychological distress involving participants from the general population, of which one of the most psychometrically sound is the Kessler-10 (K10; Kessler et al., 2002). Evidence indicates that compared to the rest of the population, young adults experience high rates of psychological distress (Casey, 2013).

Several studies indicate high comorbidity between depression and anxiety disorders, such that those who report being diagnosed with depression, are also diagnosed with an anxiety disorder (Aalto-Setälä et al., 2001; Kessler, Borges, & Walters, 1999; Reavley, Jorm, Cvetkovski, & Mackinnon, 2011; Wittchen, Kessler,
The current thesis will utilise the K10 to measure psychological distress, as it is a widely utilised measure, with excellent psychometric properties for both the general population (Andrews & Slade, 2001; Kessler et al., 2002) and young adults (Abdulghani, AlKanhal, Mahmoud, Ponnamperuma, & Alfaris, 2011; Stallman, 2010). Following a systematic review investigating the psychometric properties of mental health measures for young people aged 12 to 25 years, Kwan and colleagues (2015) concluded that the K10 was a suitable measure for both clinical and non-clinical settings and population groups. Several studies have found that the K10 measure of psychological distress can be used to reliably identify those who have been diagnosed with anxiety or depressive disorders (e.g. Furukawa, Kessler, Slade, & Andrews, 2003). Given it is a measure that was developed by combining items from other anxiety and depressive symptom measures, several studies indicate strong correlations between the K10 and diagnostic assessments of anxiety and depressive disorders (Andrews & Slade, 2001; Sunderland, Slade, Stewart, & Andrews, 2011). In light of these findings, the current thesis will define poor mental health in terms of psychological distress, anxiety and depressive symptoms.

Summary

Young adulthood is a distinct developmental life stage during which mental health problems are prevalent. In this period, choices aimed at developing personal autonomy across contexts, are made. Young adult developmental, autonomy-building life choices including the age of marriage, leaving the family of origin home, completing education and establishing financial independence are occurring later in young adulthood than in previous generations. As such, young adults are a cohort that has experienced distinct sociocultural changes, making them an important population to study in contemporary conditions. Poor mental health, characterised by
high psychological distress, anxiety and/or depressive symptoms, is highly prevalent in this age group, and these symptoms are associated with serious individual and society level consequences. To have the greatest preventive reach, it is vital to assess mental health using a measure that reflects both sub-threshold and also potential clinical level symptoms.
Chapter 3: Predictors of young adult mental health

In order to reduce the burden of disease associated with poor mental health, it is important to determine which factors are related to mental health (Lewinsohn et al., 1994). As the current thesis addresses commonly occurring mental health problems, the current Chapter will present risk and protective factors relevant to psychological distress, sub-threshold and clinical-level anxiety and depressive symptoms. These commonly occurring mental health problems will be referred to in what follows as ‘poor mental health’. In this Chapter, the influence of the prevention science methodology will be detailed. Then, in following sections two theoretical models that underpin the development of poor mental health will be examined. First, the Biopsychosocial model will be used to define the risk and protective factors related to mental health. A brief review of empirical evidence for the role of biological, psychological and social factors in the development of mental health among young adults will be completed. Second, the life course theory (Elder, 1998) will indicate the way in which these risk factors interrelate across specific periods of development and may exist across a trajectory of change to produce their effect on young adult mental health. This information will be used to provide a rationale for the research presented in subsequent Chapters.

Prevention Science

The prevention science research process and how the current thesis is guided by this process will be explained in what follows. Prevention science integrates research in areas that include life course human development, program evaluation and systems research (Toumbourou et al., 2014). Prevention science seeks to identify risk factors (longitudinal predictors of problems) and protective factors (risk modifiers) that are amenable to change, in order to inform prevention interventions to reduce the aetiology of mental disorders (Mrazek & Haggerty, 1994).
The identification of risk and protective factors often begins with the detection of predictors of disease aetiology in cross-sectional research. Next, through longitudinal analyses, the extent to which the predictor is related to prospective mental health is identified. Risk factors are defined as internal (individual) or external (events or context) factors that are associated with increased risk of poor mental health or mental disorders (Shortt & Spence, 2006). Conversely, protective factors are internal or external factors that support positive mental health or reduce the likelihood of common mental disorders (Shortt & Spence, 2006), or modify the effects of risk factors (Toumbourou et al., 2014). Analytically risk and protective factors are determined by using multivariate statistical techniques. If, after multivariate control for other known risk factors, a predictor significantly increases the risk of poor mental health, via its effect on the duration, intensity or onset of symptoms, it is considered a risk factor (Coie et al., 1993). Conversely, if a variable is a significant predictor of reduced risk of poor mental health (Coie et al., 1993) or modifies the effect of risk factors (Toumbourou et al., 2014), it is considered a protective factor. The use of multivariate modelling is vital to the process of identifying risk and protective factors, as it controls or adjusts for the complex multitude of factors that can predict mental health. A predictor that remains a significant prospective predictor of mental health after adjusting for other known risk factors indicates the possibility that the predictor is a risk factor. The identification of risk and protective factors in multivariate research leads to the next step in the prevention science process, the maturation of existing causal theories explaining how the risk factor leads to the outcome.

The knowledge base of risk and protective factors are applied to prevention science interventions. Coupled with an understanding of elements that impact volitional action (e.g., motivation, self-efficacy), interventions are designed to
address change to one or more of identified risk factors. The general premise of this approach is that through the reduction of risk factors and/or increase in protective factors, that the associated risk of poor mental health is decreased. This information is applied to populations within three overarching prevention intervention formats; universal, selective and indicated intervention programs (Gordon, 1983). Universal interventions are applied to reduce risk factors and enhance protective factors in whole populations. Selective interventions, designed to reduce the risk of developing serious mental disorders, are applied to those at risk of mental disorders. Finally, indicated interventions are applied to specific sub-groups, which are showing signs of poor mental health symptoms (Gordon, 1983). By targeting modifiable risk or protective factors with effective prevention programs it is feasible to reduce the aetiology of mental health problems across whole populations (Toumbourou et al., 2014). The designed prevention programs undergo empirical investigations, iterations of which serve to increase the effectiveness of the programs in increasingly ‘real world’ contexts. The final stage of prevention science is knowledge dissemination which involves the establishment of designed intervention programs into large-scale programs, where they may be of most use to the community (Cordova et al., 2014).

**Biopsychosocial Model**

The Biopsychosocial model (Engel, 1980) recognises that young adult mental health is influenced by several interacting biological, psychological and social risk and protective factors (Schotte, Van Den Bossche, De Doncker, Claes, & Cosyns, 2006). Developed to extend the biomedical model of illness, the Biopsychosocial model recognises that health is not purely a reflection of the biological and genetic influences but also social and psychological factors (Engel, 1980). Biological factors include individual level factors including genetic influence on biological functioning,
as well as physiological functioning. Psychological factors include cognition, emotion and behaviour of the young adult. Social factors are reflected in the interpersonal interactions between the young adult and their family, friends, community and society. The model indicates that factors within and between domains interact with one another to produce an influence on health (Engel, 1980).

**The role of biological factors in relation to young adult mental health**

The biological and physiological bases of poor mental health have been widely studied (Cicchetti & Toth, 1998; Schotte et al., 2006). Research indicates that young adults with a history of depressive and anxious behaviours, psychological distress and of parents who experience depression or other mood disorders are at an elevated risk for experiencing depression themselves (Hope & Henderson, 2014; Lewinsohn, Rohde, et al., 2000; Reinherz, Giaconia, Hauf, Wasserman, & Paradis, 2000). It has been suggested that genetic predispositions, inherent in parental psychopathology, are related to biological irregularities in neurological and endocrine functioning evident amongst those with common mental disorders (Shortt & Spence, 2006). Specifically, it is posited that poor mental health is associated with ineffective release of monoamine neurotransmitters and brain-derived neurotrophic factor (Donaghy, 2007).

Differences in mental health symptoms have also been identified between male and female young adults, such that young adult females are more at risk to develop poor mental health, than their male counterparts (Stallman, 2010). Young adult mental health occurs on a developmental trajectory that may begin early in the life course. Life course theories note that influences in childhood affect adolescent development that in turn affect young adulthood.
Gender differences in mental health first emerge in adolescence. Male and female children report similar levels of depression, until the age of approximately 14 to 15 years (Hankin et al., 1998). Following the onset of puberty, females become twice as likely to experience depression as compared to males of the same age (Galambos, Leadbeater, & Barker, 2004). Between adolescence to young adulthood, the rates of depression onset remains higher amongst females (Hankin et al., 1998), and continue to follow the same trajectory into young adulthood, where young women are at increased risk of common mental disorders than young men (Hankin et al., 1998; Kosidou et al., 2012).

**The role of psychological factors for young adult mental health**

Apart from these biological factors, psychological factors including cognitive functioning have been implicated in the development of poor mental health (Beck, 1976). Cognitive theorists posit that depressive and anxiety symptoms occur as a result of irrational thoughts and beliefs, which follow a triad of negative thoughts regarding the self (self-esteem), the world (negative day-to-day explanations) and the future (hopelessness; Beck, 1976). These negative thoughts are exacerbated by emotional distress and maladaptive behaviour and ultimately are believed to lead to the development of anxiety and depressive symptoms (Beck, 1976; Shortt & Spence, 2006). In addition, poor self-rated health has been linked to higher rate of depression, and anxiety disorders (Zinzow et al., 2011). Research has indicated that young adults with poor mental health are more likely to experience: low self-esteem (Ryan, 2010), high levels of neuroticism (perceiving the world as dangerous or threatening; Weber et al., 2013), and to internalise their problems (Dingle et al., 2011). Conversely, a high sense of mastery may act as a protective factor for young adult mental health (Colman et al., 2014).
Young adult evaluations of interpersonal interactions are also relevant in the development of poor mental health. Theorists have suggested that young adults who explain negative life events as stable (likely to persist across time and into the future), global (likely to influence many parts of life) and due to personal factors (likely to be due to deficits internal factors), are at higher risk of developing poor mental health (Seligman et al., 1984). Further young adults with poor mental health are likely to explain positive life events as due to unstable, single events and as due to external factors that are unlikely to recur. There is considerable support for the role of negative attributions and hopelessness in the development of depression (Joiner & Wagner, 1995; Mark & Smith, 2012; Muris, Schmidt, Lambrichs, & Meesters, 2001; Pearson et al., 2015).

Young adults with poor mental health also tend to engage in maladaptive cognitive and behavioural patterns, including rumination about the negative aspects of experience (Goldstein, 2006; Spasojevic & Alloy, 2001), withdrawal from others (Katz, Conway, Hammen, Brennan, & Najman, 2011), and the use of ineffective coping strategies (Mahmoud, Staten, Lennie, & Hall, 2015; Vickers et al., 2003) including denial, self-blaming, substance use (Mahmoud, Staten, Hall, & Lennie, 2012), and tobacco use (Lenz, 2004). These factors are also important in the development of poor mental health (Conversano et al., 2010). Evidence suggests that utilising positive coping strategies (i.e., effective and direct communication) and expression of an optimistic thinking style is associated with improved mental health (Cattelino, Graziano, & Calandri, 2014; Conversano et al., 2010; Moritz et al., 2015).

Psychological factors, particularly unhelpful attitudes and perceptions, in relation to social interaction, have been implicated in the development of poor mental health. Evidence suggests that low perceived social support (Hunt & Eisenberg, 2010; Young, Berenson, Cohen, & Garcia, 2005), low parental acceptance, low
parental warmth (Alloy, 2001), low perceived quality of peer relationships (Cooney & Kurz, 1996; Pelkonen, Marttunen, & Aro, 2003), low family cohesiveness, limited ability to directly express self in the family (Wong, 2012), marital discord between parents (Cooney & Kurz, 1996) as well as greater perceived parental rejection (Bellamy & Hardy, 2015) are related to young adult poor mental health. Conversely, psychological protective factors include high intelligence, high self-esteem, low perceived parental psychological control, and high parental warmth (Pargas, Brennan, Hammen, & Le Brocque, 2010).

**The role of social factors for young adult mental health**

Social relationship risk factors relate to young adult relationships and interpersonal interaction with individuals within their environment (Engel, 1980). For example, evidence suggests that young adults who engaged with peers who expressed positive values (i.e., performing well in studies and engaging in volunteer activities) were less likely to experience poor mental health (Gutman & Sameroff, 2004). Conversely, Reinherz and colleagues (2000) found that young adults who had siblings with substance abuse problems (alcohol and drugs) were more likely to develop poor mental health. Further, one study identified increased conflict with parents amongst female young adults as a risk factor for poor mental health (Lewinsohn, Rohde, et al., 2000).

Stressful life events within the social sphere (Beardslee, Chien, & Bell, 2014) such as the breakup of romantic relationships, interpersonal conflict with parents, experiencing bullying, failure at school or university (Donald & Dower, 2002), childhood adversity (e.g. poverty, child chronic illness, parental conflict; Hazel, Hammen, Brennam, & Najman, 2008) or sexual violence (Donald & Dower, 2002; Hunt & Eisenberg, 2010) can lead to the development of poor young adult mental health. These events are especially salient if the young adult is unable to control them
(Hankin & Abela, 2005). Theory also suggests that the interplay between life events and psychological factors lead to increased risk for poor mental health. According to the diathesis-stress model, a negative style of attribution for events in interaction with negative life events is likely to increase a sense of hopelessness which leads to poor mental health (Schotte et al., 2006). This suggests that negative life events may predispose a young adult to lack hope and thereby develop poor mental health. It is also plausible that poor mental health may increase the likelihood of negative life events, which in turn exacerbate the symptoms (Sund, Larsson, & Wichstrøm, 2011).

Several researchers have indicated that socioeconomic status is a risk factor for depression in young adulthood (Donald & Dower, 2002; Hope & Henderson, 2014; Hunt & Eisenberg, 2010; Weitzman, 2004). For example, young adults who report income below the poverty line were significantly more likely to report higher depressive symptoms when compared with young adults with higher income (Child Trends Databank, 2015). In addition, young adults who reported long periods of unemployment also reported higher depressive symptoms, than those who were employed (Galambos, Barker, & Krahn, 2006). Fisher and colleagues (2010) theorise that low socioeconomic standing influences the development of poor mental health by introducing individuals to a multitude of risk factors including physical abuse, low educational attainment and living in neighbourhoods which are characterised by low social connectivity and stress.

Conversely, social protective factors include being married or in a defacto relationship, parent-reported parental support for autonomy (Gutman & Sameroff, 2004), strong sense of spirituality (Tosevski, Milovancevic, & Gajic, 2010), sense of family cohesion (Carbonell et al., 2002), adaptive parent-young adult relationship (Pargas et al., 2010), and a high level of social support (Galambos et al., 2006).
Further, evidence indicates that poor young adult mental health is associated with longer engagement in smoking (Patten, Choi, Vickers, & Pierce, 2001) and lowered involvement in healthful behaviours such as physical activities including sports participation and physical activity (Feng, Zhang, Du, Ye, & He, 2014; Patten et al., 2001). Feng and colleagues (2014) found that low engagement in physical activity was related to higher depressive symptoms controlling for age, gender, body mass index, and maternal education. Further, high engagement in sedentary activities is associated with higher depressive symptoms amongst young adults (Feng et al., 2014; Gordon, Juang, & Syed, 2007; Morgan & Cotten, 2003; Wu, Tao, Zhang, Zhang, & Tao, 2015). In addition, evidence supports the notion that peer and family participation in physical activity may benefit mental health (King, Vidourek, English, & Merianos, 2013; Trost, Owen, Bauman, Sallis, & Brown, 2002). Specifically, having peers who share physical activity pursuits and peer support for physical activity engagement have been shown to reinforce engagement in physical activity among youth (Leslie et al., 1999; Wallace, Buckworth, Kirby & Sherman, 2000) and adults (Allender, Cowburn & Foster, 2006), which in turn is related to mental health (Ball, Burton, & Brown, 2009; Feng et al., 2014; Wu et al., 2015). There is evidence to suggest that combinations of physical activity and sedentary behaviour amongst young adults are related to differential outcomes in mental health (Feng et al., 2014; Wu et al., 2015). This suggests that activity engagement including high physical activity and low sedentary behaviour may act as protective factors amongst young adults.

The Biopsychosocial model (Engel, 1980) provides a framework to identify and organise the empirically identified risk and protective factors for poor mental health amongst young adults. The theoretical and empirical evidence regarding the association between each risk and protective factor and mental health was used to
inform which factors were to be included in the multivariate analyses in the current thesis.

Life course theory

Developmental life course theory recognises that mental health changes across the lifespan (Elder, 1998). The extent of the effect of risk and protective factors is different for different life periods (Pillas, Naicker, Colman, & Hertzman, 2014), and the manner in which they impact mental health varies by the unique social, historical and cultural elements the individual experiences in different life periods (Elder, 1998; Pillas et al., 2014). Specifically, life course theory posits that risk and protective factors differ in their effect on mental health during sensitive or critical periods of development (Pillas et al., 2014). Sensitive periods are characterised by the insufficient development of key biophysical, cognitive and psychosocial competencies for optimal development. In particular, delayed or failure to develop these competencies is likely to influence an individual’s long-term mental health status (Pillas et al., 2014). As mentioned in Chapter 2, young adulthood is marked by a number of developmental tasks or processes (Schulenberg, Bryant, et al., 2004).

Evidence indicates that recent cohorts of young adults are experiencing developmental processes later in young adulthood when compared with previous generations. Specifically, since the 1970s, Australian young adults have experienced a significant change in the socio-cultural norms established in previous generations. First, current young adults report getting married later, than those of previous generations (Australian Bureau of Statistics, 2013). Specifically, the median age for marriage has increased from 26.5 years and 24.3 years for men and women in 1990 to 29.6 years and 27.9 years in 2010, respectively (Australian Bureau of Statistics, 2012a). Second, a larger proportion of current young adults engage in tertiary
education, such that only 14% reported engaging in tertiary education in 1976, reflecting almost half of those in 2011 (26%; Australian Bureau of Statistics, 2013). Third, in light of the increased engagement in tertiary education since the 1970s, young adults are more likely to stay in the family of origin home. That is, approximately 49% of young men and 45% of young women (aged 18 - 24 years) in 2012 reported choosing to stay in their family home, primarily noting financial reasons as the motivator (41%; Australian Bureau of Statistics, 2012a). Further, as there is a greater social acceptance of living with an intimate partner prior to marriage, young adults are getting married later in life. This is illustrated by the fact that 67% of 24-year-olds were married in 1976, whilst only 14% of the same age group were married in 2011 (Australian Bureau of Statistics, 2013). These large-scale changes inform the perceived socio-cultural norms of what happens and at which life stage (Elder, 1998). These trends overall place current young adults into a unique historical context, which warrants consideration. Importantly, consistent with life course theory, the delayed age for achieving mature adulthood may be increasing the risk of poor mental health of young adults as a generation.

Further, life course theory recognises that critical periods of development influence mental health, such that specific risk or protective factors may have a particularly strong influence on young adult mental health, relative to other developmental periods (Pillas et al., 2014). For example, evidence suggests that binge drinking may play a more important role in the development of poor mental health during adolescence than during young adulthood. Specifically, whilst binge drinking in adolescence predicts adolescent poor mental health (Galambos et al., 2004), young adult binge drinking may not affect mental health to the same extent (Mason-Jones & Cabieses, 2015; Mohamed & Ajmal, 2015). Therefore, while the same factors may be related to the development of poor mental health, these factors
influence the outcome to varying degrees depending on the developmental stage of the individual. For this reason, the current research program will focus on considering several risk or protective factors that are related to young adult mental health.

Theory suggests that risk and protective factors interact to influence mental health through their combined and or independent influence (Hertzman & Power, 2006). As one example, the influence of social support on young adult mental health is relative to the extent of stress experience; specifically more social support is associated with lower risk of mental disorders, but only for those who experienced stressful life events (Dalgard, Bjork, & Tambs, 1995). As a further example, the association between job boredom and depressive symptoms may be moderated by level of intrinsic job motivation, such that only amongst young adults who reported a high level of intrinsic job motivation found that high job-related boredom resulted in higher depressive symptoms (Wiesner, Windle, & Freeman, 2005). Thus, it is important to address not only the independent influences of risk and protective factors but also the interplay between them in order to understand their impact on mental health (Stokols, 1992). The current research program will address how engagement in physical activity and sedentary behaviour interact to produce their effect on mental health, within the context of multiple confounding factors.

Summary

Prevention science informs the process of identifying risk factors, which supports the building of a knowledge base for designing more effective mental health prevention interventions. As defined by the Biopsychosocial model and empirical evidence, there are many biological, psychological and social risk and protective factors. The life course theory situates these factors in a developmental context, such
that risk and protective factors unique to recent cohorts of young adults may place them at greater risk of poor mental health. Further, risk and protective factors may vary according to temporal relevance, and independence of influence to impact the development of poor mental health. Importantly, it is the interplay between factors at varying levels of the Biopsychosocial model and developmental life course that predict mental health.
Chapter 4: Physical activity, sedentary behaviour and young adult mental health

The previous sections summarised evidence that young adults have high rates of mental health problems and are facing generational changes in risk and protective factors. To reduce young adult mental health problems and their associated disease burden, it is important to identify risk and protective factors that are amenable to change (Herman et al., 2012; Mrazek & Haggerty, 1994). The current Chapter aims to describe two health behaviours; physical activity and sedentary behaviour that have been posited as influences on young adult mental health. Particularly, focus will be placed on defining physical activity and sedentary behaviour and on identifying current estimates regarding Australian young adult engagement in both. Importantly, theoretical explanations for the possible effects of physical activity and sedentary behaviour on mental health will be examined.

Physical Activity

Physical activity definition

Physical activity (PA) is defined as any bodily movement that causes an increased level of energy expended by the body (Caspersen, Powell, & Christenson, 1985). It is further characterised by three dimensions; its frequency (rate of engagement per e.g. week), duration (amount of time spent per session, measured in units of time), and intensity (Caspersen et al., 1985). Intensity can be classified as moderate intensity, which is activity that requires a moderate amount of effort, such as quickened walking, dancing, and gardening (Ainsworth et al., 2000). Vigorous physical activity involves more physical effort and involves activities such as skipping, running, aerobics, and competitive sports (Ainsworth et al., 2000). Physical activity can be a single session or ‘acute’, as well as ongoing or ‘chronic’ in nature.
(Petruzzello, Landers, Hatfield, Kubitz, & Salazar, 1991). Whilst there is an empirical focus on the extent to which acute physical activity may generate mental health benefits (Bartholomew, Morrison, & Ciccolo, 2005; Daley & Welch, 2004; Hoffman & Hoffman, 2008; Morgan, Roberts, & Feinerman, 1971; Steptoe & Cox, 1988), the current thesis will focus primarily on the possible effect of chronic physical activity on mental health.

**Rate of engagement in physical activity**

Current National guidelines recommend Australian adults engage in a minimum of 1.25 hours (75 minutes) of vigorous intensity to 2.5 hours (150 minutes) of moderate intensity physical activity, or approximately 2.5 hours of a combination of moderate to vigorous intensity activity, every week (Brown, Bauman, Bull & Burton, 2012). Evidence indicates that young adults (18 to 24 years) engage in 30 minutes to 2.9 hours of moderate intensity physical activity, and 1.9 to 3.1 hours of vigorous intensity physical activity per week (Wooden, 2014). Whilst this suggests that young adults engage in 2.4 to 6 hours of moderate to vigorous physical activity, evidence shows that most young adults (53% to 56% of 18-24-year-olds) do not engage in sufficient physical activity to meet public health recommendations (Australian Institute of Health and Welfare, 2011; Wooden, 2014). Further, from late adolescence to young adulthood, individuals tend to reduce or maintain low levels of physical activity (Gordon-Larsen, Nelson, & Popkin, 2004). Specifically, Gordon-Larsen, Nelson and Popkin (2004) found from approximately 16 to 22 years of age, most young adults either engaged in consistently low level activity (61.0% ; < 5 sessions of MVPA/ week), or reduced their engagement in activity (31.1%; changed from 5+ sessions of MVPA/ week to < 5). This evidence suggests that young adults tend to engage in insufficient physical activity to meet public health guidelines, and are on a trajectory of reduced activity.
Measurement of physical activity

Physical activity is measured either via objective methods, including accelerometers (a device that estimates energy expenditure) or pedometers (a device that counts steps walked), or self-report methods, including via self-report estimates of weekly activity (Ainsworth, Cahalin, Buman, & Ross, 2015). Most of the existing research involve the use of self-report subjective questionnaire measures (Teychenne, Ball, & Salmon, 2008), with research gaps in addressing the possible difference in health benefits associated with objectively measured physical activity (Ainsworth et al., 2015). Specifically, some evidence suggests that the relationship between physical activity and mental health may vary according to the nature of the measure. For example, Poole and colleagues (2011) found that moderate intensity physical activity as measured using accelerometers was significantly negatively associated with depressive symptoms, whilst there was no significant association between self-report moderate intensity physical activity and depressive symptoms.

Brief self-report measures of physical activity, however, continue to provide important information regarding existing rates of physical activity engagement and indeed were relied upon to establish existing public health guidelines (Colley et al., 2011). In addition, self-report physical activity measures are proposed to reflect a unique component of physical activity engagement, not otherwise captured by objective measures (Ainsworth et al., 2015; Colley et al., 2011). The relative limitations of self-report measures of physical activity will be further detailed in Chapter 8.

Correlates of physical activity

Young adults who engage in physical activity tend to be younger (Bauman et al., 2012), male (Buckworth & Nigg, 2004), report higher education (Dowda,
Ainsworth, Addy, Saunders, & Riner, 2003), and had previously engaged in physical activity (Pinto Pereira, Geoffroy, & Power, 2014). Active young adults also tend to have higher self-esteem, self-efficacy (Azar, Ball, Salmon, & Cleland, 2011), are less likely to smoke (Steptoe et al., 1997; VanKim, Laska, Ehlinger, Lust, & Story, 2010), report higher alcohol consumption (VanKim et al., 2010), and weight loss attempts (Dowda et al., 2003; Steptoe et al., 1997).

**Consequences of low physical activity**

Considerable empirical focus has been placed on the biopsychosocial outcomes of engagement in PA (Nelson, Neumark-Stzainer, Hannan, Sirard, & Story, 2006). Low levels of engagement in PA have been associated with an increased risk for health outcomes including low self-reported health status (Pedišić, Greblo, Phongsavan, Milton, & Bauman, 2015), obesity, type 2 diabetes (Penedo & Dahn, 2005), cardiovascular disease and some cancers (Hamilton, Healy, Dunstan, Zderic, & Owen, 2008; Lee, Paffenbarger, & Hsieh, 1991). Importantly, many studies have found support for the relationship between PA and positive mental health outcomes amongst young adults, including improved life satisfaction (Pedišić et al., 2015), improved general mental health (Sagatun, Søgaard, Bjertness, Selmer, & Heyerdahl, 2007; Thome & Espelage, 2004; VanKim et al., 2010), lower stress levels (Poole et al., 2011), lower anxiety symptoms (Wu et al., 2015), fewer depressive symptoms (Ball, Burton, & Brown, 2009; Feng et al., 2014; McPhie & Rawana, 2015b) and lower psychological distress (Graham, Richardson, King, Chiera, & Olds, 2014).

**Physical activity as preventive approach to mental ill-health**

Considering the high prevalence of common mental disorders and psychological distress, there has been increasing empirical attention placed on the
applicability of physical activity to treat or prevent mental ill-health (Martinsen, 2008). In the interest of understanding the extent to which physical activity can be used to prevent mental ill-health amongst the general population of young adults, the current thesis will consider the prevention of mental ill-health. In line with this, the systematic review described in Chapter 5 reflects studies of non-clinical samples, and the cross-sectional and longitudinal studies in Chapters 6 and 7 reflect a sample of community young adults.

**Mechanisms of physical activity effects on mental health**

Several hypothesised mechanisms have been proposed to explain the inverse association between PA and mental health. On a biological basis, engaging in PA may lead to a direct reduction in poor mental health symptoms through the release of biochemicals that are associated with improved wellbeing (Dinas, Koutedakis, & Flouris, 2011). In particular, evidence indicates that engaging in vigorous PA results in the release of endorphins, which facilitates a sense of wellbeing (Dinas et al., 2011), and may reduce the levels of existing poor mental health. Conversely, the monoamine hypothesis posits that poor mental health, particularly depression, is associated with insufficient and ineffective release of monoamine neurotransmitters. During physical activity, these neurotransmitters are released, which may curb depressive symptoms (Donaghy, 2007; Monteiro Peluso & Guerra de Andrade, 2005). Also, during exercise, there is an increased release of brain-derived neurotrophic factor, which is related to improved mood (Donaghy, 2007). Finally, evidence suggests that engaging in PA can directly influence some mental health symptoms including sleep quality (Brand et al., 2010), fatigue, weight reduction/increase, and appetite changes (Allgöwer, Wardle, & Steptoe, 2001).
Other explanations propose that engaging in PA may curb the effect of poor mental health among young adults by ameliorating the associated psychosocial risk and protective factors (Donaghy, 2007). For example, engagement in PA is associated with an improved sense of self-esteem, self-confidence, self-efficacy, improved body image, a sense of achievement and a potential increase in social support, which are protective against the development of poor mental health (Donaghy, 2007). It is also possible that engaging in consistent PA is likely to lead to a sense of achievement and potential mastery over the behaviour that may reduce a sense of hopelessness (Daley, 2008), thereby protecting against poor mental health. In addition, it is possible that physical activity may have a variable contribution to mental health depending on the age and life stage of the individual, consistent with the life course theory (Elder, 1998). Some researchers suggest that engagement in PA may buffer against the negative consequences of negative life events, which stress theories have associated with the development or exacerbation of poor mental health such as depressive symptoms (Harris, Cronkite, & Moos, 2006; Sund et al., 2011). Finally, engagement in PA in groups or through sports participation has the potential benefit of increasing social relationship protective factors such as a sense of social cohesion and social support, which may buffer against poor mental health (Allgöwer et al., 2001; Colarossi & Eccles, 2003; Fox, 1999).

In summary, consideration of the biological, psychological and social benefits associated with physical activity on mental health reflects the application of the biopsychosocial model. This exploration serves to elucidate potential mechanisms to support the view that positive mental health is likely to result from engagement in physical activity. The proposed research program outlined in the present thesis will investigate the extent to which physical activity is related to mental health symptoms,
(namely psychological distress) in a contemporary population of Australian young adults.

**Sedentary Behaviour**

**Sedentary behaviour definition**

Early research into sedentary behaviour (SB) defined it and PA as existing on opposite sides of the continuum of activity (Pate, O'Neill, & Lobelo, 2008). However, evidence indicates that these behaviours are more likely to be different constructs (Biddle, Gorely, & Stensel, 2004; Owen, Healy, Matthews, & Dunstan, 2010). There are several reasons for this. First, a lack of engagement in PA does not equate to increases in SB (Biddle, Gorely, Marshall, Murdey, & Cameron, 2003). In support of this proposition, evidence suggests a weak correlation between SB and PA (Biddle et al., 2003; Biddle, Gorely, et al., 2004). As one example it is possible for those engaging in 30 minutes of moderate to vigorous activity over three days to also engage in long periods of sitting time (Tremblay, Colley, Saunders, Healy, & Owen, 2010). Second, some correlates of PA are not significantly related to SBs. For example, King and colleagues (2011) found that availability of safe places for play, parental use of active transport method were associated with sedentary behaviour but not physical activity. Third, SB physical health consequences are distinct from those associated with PA. Engaging in sufficient PA relates to increased lipoprotein lipase (LPL) release, which in turn reduces blood triglycerides and reduces the risk of cardiovascular disease, whilst longer SB is associated with lower LPL, higher blood triglycerides and thus risk of cardiovascular disease (Tremblay et al., 2010). The change in LPL activity due to sedentary behaviour primarily occurs in oxidative muscle fibres, whilst physical activity-induced changes to LPL occur primarily in glycolytic fibres (Tremblay et al., 2010). In addition, other research shows reduced
bone mineral density as a result of prolonged periods of SB, even amongst those engaging in daily moderate to vigorous PA (Tremblay et al., 2010). For these reasons, physical activity and sedentary behaviour need to be addressed independently and equally in relation to mental health.

Sedentary behaviour involves sitting or lying down in which there is little increase in energy expenditure above the resting state (≤ 1.5 Metabolic Equivalent of Task – a physiological measure of physical activity) in activities across contexts including leisure (sitting whilst socialising, television viewing, computer use, video game use), inactive transport (sitting in cars, buses), and work related sitting (Owen et al., 2010; Pate et al., 2008). Whilst some research focusses only on the limited energy expenditure component, recent research suggests that engaging in standing may reflect low energy expenditure, but be associated with better health outcomes, than SB during lying down or sitting (Gibbs, Hergenroeder, Katzmarzyk, Lee, & Jakicic, 2015). As a result, research requires measurement of SB recognising the postural element of the definition (Tremblay et al., 2010). The majority of recent SB research has focused on components of sitting time such as leisure time TV viewing, computer use or work related sitting (Hamilton et al., 2008). However, these are proxy measures of total sitting time, conclusions regarding health outcomes are thus limited to those specific behaviours (Tremblay et al., 2010). In order for research to provide sufficient evidence regarding the dose-effect of SB, from which SB guidelines for adults can be developed, further empirical focus is required on total sitting time (Owen et al., 2010). As a result, the current thesis program will address the association between sitting time and mental health.
Rate of engagement in sedentary behaviour

Evidence indicates that adults engage in approximately 5.4 hours of daily sitting (38.8 hours/week), whilst working or in leisure time (Australian Bureau of Statistics, 2012d). Young adults engage in a comparable 5.5 daily hours (38.5 hours/week) of sitting time, which is largely accounted for by TV viewing (9.0 hours/week or 1.3 hours/day), computer or internet use (8.8 hours/week or 1.3 hours/day), work related sitting (7.2 hours/week or 1.0 hour/day), telephone use and computer games (4.4 hours/week or 0.6 hours/day) and passive commuting (4.0 hours/week or 0.6 hours/day; Australian Bureau of Statistics, 2012d). Further, evidence suggests that in the transition from late adolescence to young adulthood, there is an increasing or consistently high level of sedentary behaviour. Specifically, from 16 to 22 years, individuals tended to engage in either consistently high screen time (37.0%; 14+ hours of screen time/week), or increased their screen exposure (22.2%; changed from < 14 hours/week to 14 or more hours/week; Gordon-Larsen et al., 2004). National guidelines recommend Australian adults engage in limited sitting time, with frequent breaks (Brown, Bauman, Bull & Burton, 2012), but there is no current time/day recommendation in light of insufficient research regarding the dose relative to health consequences of prolonged sitting amongst adults.

Measurement of sedentary behaviour

Measurement of sedentary behaviour involves consideration of three foci including overall time in sedentary pursuits (/day), time engaged in sedentary behaviour within a specific domain of activity (e.g. work-related, leisure, or transport), or the amount of time spent engaging in specific sedentary behaviours (e.g. TV viewing, computer use) (Healy et al., 2011). Self-report measures include activity diaries and questionnaires whilst objective methods include an accelerometer.
or Actigraph (a device that estimates bodily movement) (Healy et al., 2011). A significant proportion of the existing research investigating the effect of sedentary behaviour on health has utilised self-report questionnaires (Healy et al., 2011). Examples include the Bouchard Physical Activity Questionnaire (Bouchard et al., 1983), SIT-Q (Lynch et al., 2014), Sedentary Behaviour Questionnaire (Rosenberg et al., 2010) and the International Physical Activity Questionnaire Short form (IPAQ-S) sitting item (IPAQ Research Committee, 2005).

Evidence indicates that the IPAQ-S form sitting item reflects appropriate psychometric properties. Specifically, Papathanasiou et al., (2009) indicated Inter Class Correlation (ICC) = 0.72 (Day 1 to 9), and ICC = 0.66 (Day 1 to 30), whilst a review conducted by Healy et al., (2011) indicated ICC = 0.80 – 0.97 (3 days – 3 weeks). This evidence suggests good test retest reliability. In addition, Wanner et al., (2016) and Craig et al. (2003) reported that the IPAQ sitting time was correlated with the Actigraph ($r = .72$ and $r= .61$ respectively), suggesting good criterion validity. This overall suggests that the IPAQ short form sitting item holds adequate psychometric properties.

**Sedentary behaviour: is there a dose response?**

Of the available research, particular attention has been placed on the Australian Diabetes, Obesity and Lifestyle Study (AusDiab; Owen et al., 2010). The study involved data gathering regarding health and lifestyle factors including TV viewing as related to health markers including metabolism of glucose, gathered at three time points; 1999/2000, 2005, and 2012. It was found that adults who engaged in 4 or more hours of daily TV viewing were at risk of abnormal blood glucose tolerance, an indicator of diabetes risk (Dunstan et al., 2007). Analysis of the Scottish Health Survey indicated that 4 or more hours of daily TV viewing or screen time was associated with increased risk of mortality (Stamatakis, Hamer, & Dunstan, 2011).
From the Australian 45 and Up study, males who engaged in 6 or more hours of sitting time daily were more likely to report any chronic illness, than those who engaged in less than 4 hours/day (George, Rosenkranz, & Kolt, 2013). Further, adults who reported engaging in 8 or more hours of sitting time/day were at increased risk of mortality, compared to those who engaged in less than 4 hours/day, controlling for covariates including physical activity (van der Ploeg, Chey, Korda, Banks, & Bauman, 2012). Overall this evidence suggests that there may be a dose-response effect of sedentary behaviours on older adult health. Little current evidence exists regarding SB dose-response for young adult health. In light of the trend toward increasing sedentariness amongst youth (Gordon-Larsen et al., 2004), developing an understanding regarding a potential SB dose-response effect in this age group, warrants analysis. As a result, the current thesis program will identify the extent to which young adults at different sedentary behaviour rates report differing levels of psychological distress.

**Correlates of sedentary behaviour**

Those who engage in high levels of sedentary behaviour tend to report being unemployed, higher BMI, engage in smoking, being male, lower physical activity, and higher rates of depression or anxiety symptoms (Rhodes, Mark, & Temmel, 2012). This indicates that many of the correlates of sedentary behaviour are similar to the correlates of poor mental health.

**Consequences of sedentary behaviour**

The literature indicates that engaging in sedentary behaviour is associated with negative biopsychosocial consequences (Brown, Bauman, Bull, & Burton, 2012; Owen et al., 2010; Tremblay et al., 2010). In particular, sedentary behaviour is related to decreased insulin sensitivity that may reflect increases/decreases in body
weight (Tremblay et al., 2010), which is a depressive symptom (American Psychiatric Association, 2013). Further, it was found that per hour of TV viewing, there was a reduced life expectancy by 22 minutes (Veerman et al., 2012). Also, there is also evidence to suggest that high levels of SB are associated with poorer emotional and peer functioning (Page et al., 2014). For example, some suggest that engagement in high levels of SB is associated with a decreased mood, and increased loneliness and sense of isolation (Martin, 2011). However, relative to the empirical evidence for PA and mental health outcomes, there has been less research focus on SB. For this reason, and the associated negative outcomes, it is important to address SB as a potential risk factor for young adult mental health.

**Mechanisms of sedentary behaviour effect on mental health**

There are several mechanisms through which sedentary behaviour engagement could impact mental health. First, the social withdrawal hypothesis posits that through prolonged sedentary behaviour, there is a reduction of social contact, as a result of which poor mental health results (Hamer, Stamatakis, & Mishra, 2009). Second, it is suggested that via its effect on physiological changes including increased central nervous system arousal and abnormal metabolic health, that sedentary behaviour may be related to increased anxiety symptoms (Teychenne, Costigan, & Parker, 2015). Third, several studies have found that sedentary behaviour, particularly TV viewing and screen use, can negatively impact sleep quality (Mesquita & Reimão, 2010; Paavonen, Pennonen, Roine, Valkonen, & Lahikainen, 2006; Teychenne et al., 2015), which is a depressive symptom (American Psychiatric Association, 2013). Fourth, TV viewing is said to indirectly relate to poor mental health, through its association with higher food consumption (Must & Parisi, 2009), which in turn increases the risk of obesity (Thomson, Spence, Raine, & Laing, 2008). Obesity, in turn, is related to increased risk of poor mental
Finally, researchers suggest that as a result of the negative association between physical activity and sedentary behaviour that prolonged engagement in sedentary behaviour displaces engagement in physical activity, which in turn prevents the individual from reaping the associated psychobiological benefits (Teychenne, Ball, & Salmon, 2010).

Therefore, though its potential influence on central nervous system arousal, social interaction, food consumption habits, sleep and deleterious effect on the relationship between physical activity and mental health, sedentary behaviour appears to have several biopsychosocial mechanisms through which it may relate to poor mental health. Given that relatively few studies have investigated whether sedentary behaviour is associated with poorer physical and mental health independently of physical activity, the extent to which the physical activity displacement hypothesis is true, is unclear. Further research thus requires consideration of both PA and SB in order to elucidate the extent to which both exert independent and synergistic influences on mental health.

**Confounding variables of physical activity, sedentary behaviour and mental health**

To understand the nature of the associations between sedentary behaviour, physical activity and mental health (Teychenne et al., 2008, 2010), and to develop informed interventions (Steptoe et al., 1997), it is important to control for inter-related psychosocial correlates. Factors that have been identified to influence physical activity and sedentary behaviour and mental health include; gender (Buckworth & Nigg, 2004); income (Arredondo et al., 2013); employment (Asztalos et al., 2009); health status (Cerin, Leslie, Sugiyama, & Owen, 2009); smoking
(Rhodes et al., 2012); and social factors such as peer and family participation in physical activity (King et al., 2013; Trost et al., 2002).

Several studies suggest that physical activity-related social support is associated with higher engagement in physical activity (Dowda et al., 2003; Steptoe et al., 1997; Treiber et al., 1991). One study found that social support indirectly predicted physical activity through its effect on self-efficacy (Rovniak, Anderson, Winett, & Stephens, 2002). However, few studies have controlled for the effect of social support for physical activity (Arredondo et al., 2013). The current thesis program will, therefore, consider the associations between physical activity, sedentary behaviour and mental health symptoms whilst controlling for psychosocial correlates including measures of physical activity social support.

Summary

Young adults tend to engage in insufficient physical activity to meet public health guidelines, and engage in prolonged periods of sedentary behaviour. The evidence is pointing towards a trajectory from early adulthood involving stability or increases in low levels of physical activity and in high levels of sedentary behaviour. Further, evidence suggests that there may be a dose-response effect of sedentary behaviour on mental health that has as yet been unexamined amongst young adults. Correlates of physical activity and sedentary behaviour and mental health support the need for their inclusion in multivariate analyses of effects on mental health. In addition, a growing body of evidence shows that low-level physical activity and prolonged periods of sedentary behaviour have unique biopsychosocial consequences. The evidence indicates that physical activity and sedentary behaviour may influence young adult mental health directly but may also help to indirectly limit mental health by targeting other risk and protective factors. The current research
program will address the extent to which physical activity and sedentary behaviour are independently and interactive influences on young adult mental health.
Chapter 5: Effects of physical activity and sedentary behaviour on common mental health problems in young adults: A systematic review

What follows is a systematic review of observational studies of the mental health effect of physical activity and sedentary behaviour, amongst young adults. The literature review is the first empirical component of the current thesis. It reflects a discussion of overall findings from the existing literature, and importantly, a consideration of methodological limitations that may restrict the drawing of strong conclusions. The review informs the methodology of the following cross-sectional and longitudinal studies, described thereafter. The review that follows has been written in a form suitable to be developed into a journal article submission. For this reason, some of the concepts included in the earlier sections of this thesis are summarised in what follows.

Abstract

**Background.** Previous reviews have investigated the effect of physical activity or sedentary behaviour on common mental health disorders but focused on youth or general adult samples. **Objectives.** The current review aimed to identify the association between physical activity and sedentary behaviour (including screen time as a proxy for SB) on common mental health disorders (anxiety and depression) in young adults (aged 18 to 29). **Method.** Reviewed databases were searched for observational (cross-sectional and longitudinal) studies that investigated physical activity and mental health, or sedentary behaviour and mental health or both. The majority of the sample age were required to be within the young adult age range. Only studies that analysed these relationships in normative (community sample) with multivariate control of confounding factors were included. A total of 26 studies were
included for the current review. Identified studies were reviewed for methodological quality using a modified version of the QualSyst assessment tool for quantitative studies (Kmet, Lee, & Cook, 2004). **Results.** 16 cross-sectional and 10 longitudinal studies were included. Most found an inverse association between physical activity and mental health symptoms. Only seven studies, 6 cross-sectional and 1 longitudinal, investigated the role of sedentary behaviour on young adult mental health. Most studies found a positive association between sedentary activities and mental health symptoms. Four studies investigated both PA and SB and two cross-sectional studies investigated and found evidence for interactions. Amongst those who engaged in less than 3 days of physical activity per week, young adults that engaged in less than 2 hours of sedentary screen time were at a reduced risk of depression than those engaging in 2 or more hours of daily screen time. **Conclusions & implications of key findings.** Physical activity was associated with better mental health and sedentary behaviour with worse mental health and there was evidence of interacting associations with mental health in young adult samples. Further research is required with measures of better methodological quality and further investigate potential the interaction effects of sedentary behaviour and physical activity on mental health.

**Introduction**

Anxiety and mood disorders represent two of the most common sets of mental disorders amongst adults, worldwide (Kessler et al., 2009). Adults report a life time prevalence rate of 16% and 12% for anxiety and mood disorders, respectively, with prevalence rates tending to be highest within developed countries (Kessler et al., 2009). These disorders tend to onset during adulthood (Kessler et al., 2009), of which young adulthood is a sensitive developmental period. Mental
disorders are the second leading cause of Disability-Adjusted Life Years (DALYs) lost during young adulthood (years of life lost due to premature death and disability associated with mental ill health; Begg et al., 2008). This disability manifests in long-term difficulties meeting employment and educational responsibilities, and reduced engagement with peers and family (Wittchen et al., 1998). In particular, poor mental health is related to two times the risk of never being married and almost three times the risk of long-term (≥ 12 months) unemployment (Andrews, Henderson, & Hall, 2001). Further, young adults with mental health concerns are less likely to seek help for their concerns (Armando et al., 2012), and more likely to complete suicide (Page et al., 2014).

To reduce this burden, and to advance prevention efforts, it is important to understand the effect of specific risk and protective factors that are amenable to change. There are a number of biological, psychological and social risk and protective factors that have been found to predict mental health symptoms. The current review will investigate the influence of physical activity and sedentary behaviour on young adult mental health.

Young adulthood is a transitional developmental period, in which many healthful life habits are formed and developed (Schulenberg, Sameroff, et al., 2004). Compared to previous generations, young adults are now more likely to engage in higher education and increasingly entering industries that involve sedentary activities (Australian Bureau of Statistics, 2012b). Studies suggest that there is a significant reduction in their level of physical activity during adolescence, and into young adulthood (Nelson et al., 2006; Tammelin, Näyhä, Laitinen, Rintamäki, & Järvelin, 2003). Lifestyle patterns during young adulthood, such as those involved in sedentary behaviour and physical activity influence mental health (Pinto Pereira et al., 2014). In light of the changing nature of health behaviour patterns in young
adults, and the effect of physical activity and sedentary behaviour on mental health, further analysis is warranted among this age group.

**Physical activity**

Physical activity is posited as an important predictor of mental health. Physical activity is defined as any bodily movement that causes a level of bodily energy expenditure above resting level (Caspersen et al., 1985). The international public health guidelines recommend that adults engage in a minimum of 150 minutes of moderate to vigorous physical activity per week (Brown, Bauman, Bull & Burton, 2012). Evidence indicates that the majority of Australian young adults (18 - 24 years) engage in 2.4 to 6 hours of moderate to vigorous physical activity (Wooden, 2014), the majority do not meet the public health guidelines (Australian Institute of Health and Welfare, 2011).

Reviews that have investigated the relationship, suggest that higher levels of physical activity are associated with improved mental health in adult samples (Mammen & Faulkner, 2013; Stanton, Happell, & Reaburn, 2014; Ströhle, 2009; Teychenne et al., 2008). For example, a recent review conducted by Stanton and colleagues (2014) indicated long-term engagement in moderate to vigorous physical activity predicted lower risk of depression. Similarly, Mammen and Faulkner (2013) conducted a systematic review regarding the effect of physical activity on depression risk in community samples and found that physical activity engagement predicted lowered risk of depression. Reviews involving child and adolescent samples indicate similar findings (Biddle & Asare, 2011; Larun, Nordheim, Ekeland, Hagen, & Heian, 2006). Importantly, Larun and colleagues (2006) found that the small effect identified in their review was associated with high heterogeneity across study methodologies. In addition, Cooney and colleagues (2013) conducted a systematic review and meta-analysis on the treatment effect of exercise on clinical-level
depression. Across all 37 randomised controlled trials, they found a moderate effect of exercise, compared to no treatment. However, when only high-quality studies were considered, the difference between exercise and no treatment was not conclusive. Overall, the evidence suggests that longer engagement in physical activity predicts reduced mental health problems. The relationship between physical activity and mental health amongst young adults is unclear.

**Sedentary behaviour**

Sedentary behaviour is defined as any activity conducted whilst sitting, or lying down, and thus requires low energy expenditure (Owen et al., 2010). Initially, sedentary behaviour was defined as low-level physical activity (Pate et al., 2008). However, alternative evidence indicated that these behaviours are different constructs (Biddle, Gorely, et al., 2004). As a result, sedentary behaviour is recognised as requiring separate investigation.

Relative to physical activity, less empirical focus has been placed on the association between sedentary behaviour and mental health (Teychenne et al., 2010; Teychenne et al., 2015). This paucity of studies that have considered the prospective effect of sedentary behaviour on mental health amongst young adults is remiss given that predictors of mental health are likely to vary across developmental life-stage, age and cohorts (Elder, 1998).

There are currently no guidelines regarding appropriate levels of sedentary behaviour for adults (Brown et al., 2012). Hence, identifying the levels of sedentary behaviour that are associated with mental health problems will support the development of guidelines that can be disseminated in future mental health preventative initiatives.
One recent review was conducted to determine the effect of sedentary behaviour on depression amongst adults (Teychenne et al., 2010), and a systematic review was conducted to determine the effect of sedentary behaviour on the risk of anxiety disorders (Teychenne et al., 2015). Both reviews suggested increased sedentary behaviour related to poorer mental health. However, no review has addressed the effects of physical activity and sedentary behaviour on mental health amongst young adults exclusively.

Whilst physical activity and sedentary behaviour may independently have an effect on mental health, it is also likely that they interact in their influence. Recent research has found that adults who engage in five or fewer hours of sedentary behaviour per week and were active reported a lower risk of psychological distress, as compared to those who engaged in 10 or more hours of sedentary behaviour per week and were inactive (Sloan et al., 2013). In addition, it was found that people who were active and engaged in ten hours of sedentary behaviour reported comparable psychological distress rates to adults who were inactive and engaged in the same level of sedentary behaviour (Sloan et al., 2013). This suggests that there may be a threshold at which physical activity may not be associated with a mental health benefit, depending on the extent of sedentary behaviour engagement. The potential interaction effect between physical activity and sedentary behaviour has received limited research attention. The current review will also identify studies that have investigated the interactive effect of physical activity and sedentary behaviour on young adult mental health.

A recent search of the literature identified 14 reviews, which have been previously conducted to determine the effect of either physical activity or sedentary behaviour on mental health symptoms (Cooney et al., 2013; Dale, Brassington, & King, 2014; Johnson & Taliaferro, 2011, 2012; Larun et al., 2006; Mammen &
Faulkner, 2013; Morgan, Parker, Alvarez-Jimenez, & Jorm, 2013; Proper, Singh, van Mechelen, & Chinapaw, 2011; Rebar et al., 2015; Teychenne et al., 2008, 2010; Teychenne et al., 2015; Van Andel & Austin, 1984; Warburton, Nicol, & Bredin, 2006). The reviews focused on children, adolescents or general adult populations. No previous reviews have considered young adults exclusively.

To gain an understanding of the current literature amongst young adults, cross-sectional and longitudinal studies that have examined the association between physical activity, sedentary behaviour and mental health symptoms will be included. The present review will not include studies that sampled solely those with diagnosed mental health concerns. By ensuring that only normative samples are reviewed, the present study sought to maximise implications for population health.

The aims of the current review were fourfold. The aim was first, to determine the mental health effect of moderate to vigorous physical activity on mental health. The hypothesis was that there will be an inverse association between physical activity and common mental health symptoms. Second, to determine the influence of sedentary behaviour on mental health. A positive association is predicted between sedentary behaviour and mental health symptoms. Third, to explore the extent to which there is an interaction effect of physical activity and sedentary behaviour on mental health. Finally, to determine the extent to which the literature indicates a dose-response association between sedentary behaviour and mental health. The current review focused on young adults, in order to determine the potentially unique mental health effect associated with physical activity and sedentary behaviour during this developmental life stage.
Methods

To ensure rigorous methodology, the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines were followed in the current review.

Search strategy and search terms

Databases including CINAHL, PsychINFO, PsychARTICLES, ScienceDirect, and MEDLINE (via PubMed) were searched over 23rd October 2015 to 25th October 2015. No publication date limit was set, in order to ensure comprehensive coverage of relevant studies.

Search terms for mental health, based on key synonyms were identified in key articles during preliminary searches. These terms along with equivalent key terms/subject headings (including MeSHheadings) and indexes found for each database were entered into the search terms. This was repeated for each key component of the review including; physical activity and sedentary behaviour and mental health search terms (e.g., key component “mental health”, included keywords such as “depressive symptoms” or “anxiety symptoms”).

Search terms for mental health were entered into the database search panel in ‘batches’ where each search term was separated by Boolean “OR” between terms (e.g., batch; “mental health” OR “anxiety symptoms” OR “depressive symptoms”). These search terms ‘batches’ for each key component were also created for physical activity and for sedentary behaviour. Mental health search terms along with physical activity search terms were entered into database searches using Boolean “AND” term (e.g. (“depressive symptoms” OR “anxiety symptoms”) AND (“physical activity” OR “exercise”). Where available, search limiters for age, human participants, journal article sources, and observational studies were selected. Where limiters were
unavailable, equivalent search terms were entered (e.g. Young adult: 18 -29 years
limiter was picked or search terms including; “young adult” or “university student” etc.). This process was repeated separately again including mental health and sedentary behaviour search terms, with relevant limiters or equivalent search terms. The search for physical activity and mental health, and then sedentary behaviour and mental health were repeated for each database.

Resulting records were then transferred to Endnote. Search terms for each database and the number of studies found in each database are included in Appendix Table 1. Studies identified as relevant and not identified through the systematic search process were found through analysis of references in key articles, and reviews.

**Study selection**

The studies found via systematic methods were initially screened by title to determine if any studies were either not a journal article, did not hold key components for review (including journal title, authors) or duplicates, and were excluded accordingly. The remaining studies were reviewed by abstract, where only studies that met inclusion and exclusion criteria were included. The remaining studies and those found from previous studies or reviews were then reviewed by full text, of which those that did not meet the selection criteria were excluded (see Figure 1 PRISMA diagram for details; Liberati et al., 2009). Twelve studies were found to be potentially relevant through the search but could not be accessed within the time limits that were set for the review to be conducted (Berger & Owen, 1987, 1988; Dittmar, 1994; Hayden & Allen, 1984; He & Xu, 2002; Jiang & Zhu, 1997; Paffenbarger, Blair, Lee, & Hyde, 1993; Reiter, 1975; Situ & Zeng, 1997; Sungwoon & Jingu, 2007; Tang, Wang, & Zheng, 2007; Weyerer, 1992).
**Inclusion criteria**

Studies identified by abstract and by full text were reviewed according to the inclusion criteria, described herein. First, as many previous studies included young adults in larger, adult samples (e.g., 18 – 89 years) or with adolescent samples (e.g., 16 - 30 years), it was important to ensure that the data reported in the review reflected largely a young adult sample. As a result, studies were retained if more than 50% of the study sample were within the young adult age range (18 - 29 years).

Second, predictors of mental health were either physical activity and/or sedentary behaviour, and outcomes were common mental health symptoms (stress/ psychological distress/ depressive symptoms/ anxiety symptoms or diagnosis of depression or anxiety disorders).

These criteria were important, to prevent inclusion of studies focussed on the effect of mental health on physical activity and sedentary behaviour. Studies also had to be observational in nature (cross-sectional or longitudinal). Of the studies reviewed by title and abstract, no population-level physical activity or sedentary behaviour interventions that evaluated effects on young adult mental health, were identified. Finally, there is considerable evidence to suggest bivariable associations between physical activity and mental health, and sedentary behaviour and mental health. However, these effects may be confounded by the influence of correlates (e.g. health status, employment, income). Hence, only studies that analysed these relationships in multivariate models, with control of confounding factors, were included in the current review.
Records identified through database searching (n = 2310)
Records after duplicates removed (n = 2214)
Records screened by abstract (n = 517)
Records excluded (n = 346)
Full-text articles assessed for eligibility (n = 171)
Full-text articles excluded (n = 145)
   Reasons:
   1. Out of age range (n=101)
   2. Not relevant (n=11)
   3. Could not obtain (n=12)
   4. Non-normative sample (n=7)
   5. Not observational study (n=7)
   6. Reported bivariable analyses only (n=7)
Studies included in qualitative synthesis (n = 26)
   Cross-sectional studies (n = 16)
   Longitudinal studies (n = 10)

Figure 5.1 PRISMA Flow Diagram
Exclusion criteria

Several exclusion criteria also determined the final studies included in the review. First, studies were excluded if they did not sample a general (normative) population. For example, samples were excluded where they focussed on women that were pregnant or had recently given birth, as pregnancy can impact physical activity, sedentary behaviour and mental health. Samples that reflected largely non-normative demographic characteristics, including patients with disability/physical illnesses such as cancer were excluded. These samples reflect a particular demographic and thus have specific needs not relevant to a general sample of young adults. Further, samples that solely reflected those with diagnosed mental illness were excluded, as again these samples are distinct from the general community samples of young adults. Finally, review articles, those that reflect only abstracts presented at conference proceeding or theses were excluded, to ensure only original articles were included.

Data extraction

Data were extracted using a template table, where relevant information for each reference was established. The data extracted from each article included study specifics (including author, year, and country of completion), sample details (including, age, gender and overall sample size), methodological characteristics (study design, sampling methodology, response rate and details of follow-up period if longitudinal), operationalisation of key variables including physical activity, sedentary behaviour, and mental health indicators, data analyses (including statistical method, covariates included in the multivariate analyses), results (including bivariable and multivariable results), and limitations of each study.
Quality assessment

Identified studies were reviewed for methodological quality using a modified version of the QualSyst assessment tool for quantitative studies (Kmet et al., 2004), previously utilised in systematic reviews of sedentary behaviour (Chastin et al., 2015; Stierlin et al., 2015). Eleven quality characteristics were defined for the following components of each study; study design, sample methodology, predictor quality, outcome measure quality, statistical methodology, and control for relevant confounding variables. The sample score reflects a total score of four components (gender distribution, sample size, response rate and sampling methodology). The measured predictors (physical activity or sedentary behaviour) were scored such that studies where physical activity was measured for two or more qualities (intensity, duration and frequency) were scored highly (1), and those that only recognised one or none of these qualities received a low rating (0). As limited research has indicated overall quality ratings for sedentary behaviour and because an aim of the current study was to identify dose-response of sedentary behaviour, the measure in the current study was required to reflect a total sedentary time value per day or per week to receive a high rating (1). Studies that did not measure both physical activity and sedentary behaviour were not scored for physical activity or sedentary behaviour, respectively. As several studies included more than one mental health indicator, it was important that the quality rating score did not reflect a ‘favouring’ of those with more than one measure of mental health. As such, so long as at least one analysis was based on a measure with adequate psychometric properties and was described adequately in the study, the study overall received a high-quality rating for the outcome measure (1). Psychometric properties of the mental health measures were determined by the provision of reliability estimates. This included; Cronbach’s alpha for self-report measures gathered cross-sectionally and inter-rater reliability
estimates for clinician-reported data by the studies reviewed. If none of the outcome measures met both psychometric quality and adequate description of the measure, the study received a low rating (0). The statistical analysis methodology received a high rating where studies provided sufficient detail for the reader to understand the approach taken, which covariates were controlled for, and why this method was applied. Considering the literature has identified common predictors of both mental health and sedentary behaviour or physical activity, studies that included the control (or considered the moderating/mediating effect) of at least two of those covariates (i.e., age, gender, education, income, some measure of health). As research has identified the independent and inter-related role of physical activity and sedentary behaviour on mental health, studies that considered the effect of one behaviour (e.g., physical activity), and controlled for the effect of the other (e.g., sedentary behaviour) in their relation to mental health, received a high rating (1). For each of the components, where studies did not provide any information, that particular component was rated -1. Where methodological details are not provided, it brings doubts regarding the overall quality of a study. Ideally, contact with the corresponding author would be made to obtain the necessary details (Ryan, Hill, Prictor, & McKenzie, 2013). In light of time constraints and because the coding method is recommended elsewhere (Child Care & Early Education Research Connections, 2013), it was adapted into the quality assessment process for the current review. Further details of how each component was scored are provided in Appendix Table 2.

Each of the ratings was summed to produce a total score, ranging from -11 to 11; higher scores reflecting higher quality. The total score was then categorised according to the level of quality; low (-11 to 4), moderate (5 to 6), and high quality (7+). These quality ratings were decided based on summing the component quality
scores for each study, as done in previous systematic reviews (e.g. Mammen & Faulkner, 2013). The quality ratings were used to describe the overall quality of the literature, and to guide the conclusions based on possibly conflicting findings across studies.

Results

**Study identification and selection**

The initial search provided 2310 studies, as well as 50 studies identified through other sources. Following removal of duplicates ($n = 120$), and studies without sufficient information for further review ($n = 26$), a total of 2214 were reviewed by title. Studies found across database included; 455 from CINAHL, 26 through PsychARTICLES, 74 through PsychINFO, 95 through PubMed and 1560 through SPORTDiscus. A total of 517 were screened by abstract, from which 171 were checked for full text. A total of 144 studies were excluded based on exclusion criteria (see Figure 5.1 PRISMA flow diagram for details). Studies were excluded as they reflected non-normative samples (e.g. only those with clinical disorder, cancer patients etc.) or did not provide sufficient detail regarding age or sample was largely (>50%) out of age range. Studies considered not relevant ($n = 11$; indicated in Figure 5.1) were those that reported prevalence data only for physical activity, sedentary behaviour or mental health ($n = 5$; Adams & Moore, 2007; Greenwood & Fleshner, 2011; KaradaĞ & Yildirim, 2010; Montgomery, Chellappan, Kotikalapudi, Wunsch Ii & Lutzen, 2013; Tekbas, Ceylan, Hamzaoglu & Hasde, 2003), reported on studies where physical activity or sedentary behaviour was the outcome ($n = 3$; Bhochhibhoya, Branscum, Taylor & Hofford, 2014; El Ansari et al., 2011; Raffaelli, Andrade, Poppe, Sanchez-Armass, Vidal & Garcia, 2013), physical activity was defined as physical fitness according to physiological markers ($n = 2$; Becofsky, Sui, Lee, Wilcox, Zhang & Blair, 2015; Dishman, Xuemei, Church, Kline, Youngstedt &
Blair, 2015), or one of the constructs was utilised as a moderator of an irrelevant relationship (Lee & Jeong, 2014). A final of 26 studies were thus included in the analyses.

**Study characteristics**

**General description**

Overall, sixteen cross-sectional and ten longitudinal studies were included as part of this review. Most \( n = 10 \) of the cross-sectional study samples reflected young adults recruited from university or colleges and were primarily gained using convenience sampling. Five cross-sectional studies reflected university or community samples gained through random sampling methodology, whilst two studies did not provide sufficient detail to indicate sampling methodology (Bray & Kwan, 2006; Sidney et al., 1996). Sample sizes ranged from 40 (Poole et al., 2011) to over 43,000 (Taliaferro, Rienzo, Pigg, Miller, & Dodd, 2009). The longitudinal studies reflected community samples gained through random sampling methods, of samples ranging from 853 (Jewett et al., 2014) to over 11,000 (Pinto Pereira et al., 2014), and follow-up periods ranged from one year (Thomée, Härenstam, & Hagberg, 2012) to 27 years (Pinto Pereira et al., 2014). Studies were conducted largely in the US, then followed by UK, China, Canada, Australia, Austria, Switzerland, Finland, Croatia, Germany and Sweden.

**Operationalisation of mental health**

Studies assessed mental health using a variety of measures. Most studies assessed mental health through the presence of depressive symptoms, utilising well validated and reliable questionnaires including the Center for Epidemiologic Studies-Depression Scale ((CES-D; Ball et al., 2009; Gordon et al., 2007; McPhie & Rawana, 2015b; Morgan & Cotten, 2003; Poole et al., 2011; Sidney et al., 1996;
Thome & Espelage, 2004; Wu et al., 2015), Beck Depression Inventory (Gerber, Brand, Herrmann, et al., 2014), Depression Scale (Gerber, Brand, Elliot, Holsboer-Trachsler, & Puhse, 2014), Self-Rating Depression Scale (Feng et al., 2014), 7-item Depressed Mood Inventory (Birkeland, Torsheim, & Wold, 2009), and the Major Depression Inventory (Brunet et al., 2013; Henchoz et al., 2014; Jewett et al., 2014). Several studies utilised single item measures of depressive symptom (Harbour, Behrens, Kim, & Kitchens, 2008; Taliaferro et al., 2009; Thomée et al., 2012), and stress symptoms (Thomée et al., 2012). One study utilised a standardised diagnostic tool to determine a diagnosis of Major Depressive Episode using the University of Michigan Composite International Diagnostic Interview Short Form (Haarasilta, Marttunen, Kaprio, & Aro, 2004). Anxiety symptoms were assessed using the Self-Rating Anxiety Scale (Feng et al., 2014; Wu et al., 2015), Social Anxiety Scale (Gordon et al., 2007), State-Trait Anxiety Inventory (Thome & Espelage, 2004), and two assessed the presence of anxiety disorders using the Psychiatric Diagnostic Screening Questionnaire (PDSQ; Herring, O’Connor, & Dishman, 2014), and the Munich-CIDI (Ströhle et al., 2007). Perceived Stress Scale (Gerber, Brand, Elliot, et al., 2014; Gerber, Brand, Herrmann, et al., 2014), Cohen Perceived Stress Scale (VanKim & Nelson, 2013) were used to assess stress symptoms, whilst one study assessed salivary cortisol levels as indication of the stress response (Poole et al., 2011). Two studies considered psychological distress by measurement of the General Health Questionnaire (GHQ; Bray & Kwan, 2006; Fang, Zhang, Lai Man Poon, Lun Alan Fung, & Katakia, 2014), whilst others considered general mood and mental health symptoms through the use of the Profile of Mood States (POMS; Poole et al., 2011), Positive and Negative Affect Schedule (PANAS; Thome & Espelage, 2004), Mental Health Scale from SF-36 (VanKim & Nelson, 2013), Multidimensional sub-Health Questionnaire of Adolescents (Wu et al., 2015), Psychological subscale of
Malaise Inventory (Pinto Pereira et al., 2014) and the Strengths and Difficulties Questionnaire (Sagatun et al., 2007).

**Operationalisation of physical activity**

Overall, most studies utilised self-report measures of physical activity (e.g. Bray & Kwan, 2006; Feng et al., 2014; Gerber, Brand, Elliot, et al., 2014; Haarasilta et al., 2004), whilst few considered objectively measured physical activity (Gerber, Brand, Herrmann, et al., 2014; Poole et al., 2011). Several studies considered multiple methods of defining physical activity (e.g. Gerber, Brand, Elliot, et al., 2014; Henchoz et al., 2014; Poole et al., 2011; Taliaferro et al., 2009; Wu et al., 2015). Most studies considered self-report physical activity across vigorous and moderate intensity, sports engagement (Gerber, Brand, Elliot, et al., 2014), or strengthening exercises (Gerber, Brand, Elliot, et al., 2014; Taliaferro et al., 2009).

**Operationalisation of sedentary behaviour**

Sedentary behaviour was operationalised according to one or more forms of screen-based activities, including overall screen time (Fang et al., 2014; Feng et al., 2014; Thomée et al., 2012), internet use (Gordon et al., 2007; Morgan & Cotten, 2003), or TV viewing (Sidney et al., 1996; Wu et al., 2015). No studies reported on overall sitting time. Of the 26 studies, only six cross-sectional and one longitudinal study considered the association of sedentary behaviour and mental health (Fang et al., 2014; Feng et al., 2014; Gordon et al., 2007; Morgan & Cotten, 2003; Sidney et al., 1996; Thomée et al., 2012; Wu et al., 2015).

**Physical activity and mental health**

Out of the 26 studies, 23 studies, 14 cross-sectional and 9 longitudinal, investigated the role of physical activity in relation to mental health symptoms. Most studies identified an inverse relationship between physical activity and mental health.
Seven studies considered the effect of physical activity on two or more mental health indicators.

Studies that investigated the association between physical activity and mental health considered mental health indicators including depressive symptoms (see Tables 5.1 and 5.2 for full list, e.g. Ball et al., 2009; Birkeland et al., 2009; Fang et al., 2014; Feng et al., 2014; Gerber, Brand, Elliot, et al., 2014; Gerber, Brand, Herrmann, et al., 2014; Haarasilta et al., 2004), anxiety symptoms (Feng et al., 2014; Herring et al., 2014; Ströhle et al., 2007; Thome & Espelage, 2004; Wu et al., 2015), psychological distress (Brunet et al., 2013; Fang et al., 2014) and general mental health (Poole et al., 2011; Sagatun et al., 2007; Thome & Espelage, 2004; VanKim & Nelson, 2013; Wu et al., 2015).
Table 5.1
Cross-sectional studies that have investigated association between physical activity/ sedentary behaviour and mental health amongst young adults

<table>
<thead>
<tr>
<th>Authors, (Year), Country</th>
<th>Study participants</th>
<th>Predictor variable: Physical Activity (PA)</th>
<th>Predictor variable: Sedentary Behaviour (SB)</th>
<th>Correlates Controlled in multivariate analyses</th>
<th>Outcome variable: mental health symptoms</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bray, Matthew &amp; Kwan (2006), Canada</td>
<td>N = 175, $M_{age}$ = 17.8 ($SD = 0.5$), Age range = 17 – 19 years, 65.7% female, longitudinal study, recruitment method details not provided.</td>
<td>Subjective measure: 1) No. of PA sessions /week 2) Duration of vigorous PA in previous 7 months; based on interview schedule of Behavior Risk Factor Surveillance System. Sufficiently PA = 3+ sessions of 20+mins.</td>
<td>Not measured</td>
<td>Self-reported frequency of cold/ flu.</td>
<td>General Health Questionnaire (GHQ) 2 subscales; somatic symptoms subscale and anxiety-insomnia symptoms subscale (scores range 0 to 21).</td>
<td>Those who engaged in sufficient PA reported lower somatic symptoms ($M=5.5, SD=3.2$) than those who engaged in insufficient PA ($M=6.7, SD=3.7; F=5.34, p =.02$).</td>
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<tr>
<td>Fang et al., (2014), Canada</td>
<td>N = 152, Age range = 17 – 24 years, 43.4% female, convenience sample part of community action research of Chinese-Canadian young adults.</td>
<td>Subjective measure: No. of hours spent in PA on a typical day in previous 7 days.</td>
<td>Subjective measures: 1) No. of hours / day on computer, television viewing, 2) Screen time for school-related tasks and 3) Screen time for non-school related tasks in previous 7 days.</td>
<td>Dietary habits.</td>
<td>General health questionnaire (GHQ) – measures depressed mood.</td>
<td>Total no. of hours in PA inversely was associated with depressed mood and only non-school related screen time predicted higher depressed mood. Screen time for school-related tasks and hours of computer/Television viewing were not related to depressed mood.</td>
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Table 5.1 Continued...

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<tr>
<td>Feng et al., (2014), China</td>
<td>N = 1106, $M_{age}$ = 18.9 ($SD$ = 0.9), Age range = 16 - 24 years, 42.6% female, university sample through two stage random cluster sampling.</td>
<td>Subjective measure: Frequency of PA/week (of 30+mins per session). High PA = 3+ days/week.</td>
<td>Subjective measure: Screen Time (ST; hours/day) on usual weekend and weekdays. High ST&gt;2 hours/day.</td>
<td>Gender, age, BMI, maternal education.</td>
<td>1) Self-Rating Depression Scale - measures depressive symptoms = 53+ indicated depression. 2) Self-Rating anxiety scale - measures anxiety symptoms = 50+ indicated anxiety.</td>
<td>Those who engaged in low ST were significantly less likely to report depression scores above cut-off ($OR = 0.67$, $95%$ CIs [0.44, 0.89]), than those who engage in high ST. PA was not significantly related to depression. ST and PA were not significantly related to anxiety.</td>
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Table 5.1 Continued…

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<tr>
<td>Gerber, Brand, Elliott et al., (2014), Switzerland</td>
<td>Total sample N = 451 of two samples; medical students n = 201, $M_{age}$ = 23.2 ($SD$ = 2.4), 67.6% female, Exercise &amp; health sciences students n = 250, $M_{age}$ = 22.3 ($SD$ = 2.2), 57.6% female, convenience sample of university students.</td>
<td><strong>Subjective measures:</strong> Frequency and duration of PA across 15 activities/ previous 2 weeks. Weekly frequency calculated for 1) aerobic exercise (e.g. jogging) 2) ball sports (e.g. basketball) 3) Weightlifting, and 4) Dancing (e.g. ballet).</td>
<td>Not measured</td>
<td>Age, gender, study discipline.</td>
<td>1) Perceived stress scale - measures stress &amp; 2) The depression Scale - measures depressive symptoms.</td>
<td>Controlling for covariates and stress, none of the exercise types remained significantly related to depressive symptoms. The significant interaction effect between dancing and stress on depressive symptoms; e.g. students who engaged in dance and who reported elevates stress reported lower depressive symptoms, compared to those who reported lower stress levels.</td>
</tr>
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<td>Authors, (Year), Country</td>
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<td>Gerber, Brand, Herrman et al., (2014), Switzerland</td>
<td>N = 42, $M_{age} = 21.2$ ($SD = 2.2$), 52.4% female, convenience sample of university students.</td>
<td><strong>Objective measure:</strong> Accelerometer utilised to measure moderate level PA (MPA), and vigorous PA (VPA). Meeting VPA recommendations = 20+mins of VPA across 3+ days / week.</td>
<td>Not measured</td>
<td>Age, gender, MPA.</td>
<td>1) Beck Depression Inventory - measures depressive symptoms &amp; 2) Perceived Stress Scale - measures stress.</td>
<td>Those who met VPA guidelines reported significantly lower depressive symptoms (met VPA $M = 2.4$, $SD = 4.2$; below VPA rec. $M = 5.9$, $SD = 6.7$, $\eta^2 = .10$) and perceived stress levels (met VPA $M = 20.5$; $SD = 4.8$; below VPA rec. $M = 24.3$, $SD = 6.1$, $\eta^2 = .18$), as compared to those who did not engage in enough VPA to meet guidelines. Only internet use for coping with personal problems was significantly related to higher depressive symptoms ($\beta = .40$, $p &lt; .001$), whilst longer total time sitting ($\beta = .12$, $p &lt; .05$) and internet use for coping with personal problems ($\beta = .39$, $p &lt; .001$) related to higher social anxiety.</td>
</tr>
<tr>
<td>Gordon et al., (2007), US</td>
<td>N = 312, $M_{age} = 21.3$ ($SD = 5.1$), Age range 18 - 49 years, 67.0% female, convenience sample from university.</td>
<td>Not measured</td>
<td><strong>Subjective measures:</strong> 1) Frequency of internet use/ week &amp; total sitting time. 2) Reasons for internet use; meeting people, information seeking, distraction, coping with personal problems, email.</td>
<td>Age, gender, place of birth, parent education level, ethnicity.</td>
<td>1) CES-D - measures depressive symptoms, 2) Social Anxiety Scale - measures social anxiety.</td>
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<td>Haarasilt et al. (2004), Finland</td>
<td>N = 433, Age range = 20 - 24 years, 51.7% female, randomly sampled through Finnish Health Care Survey.</td>
<td>Subjective measure: Frequency of PA (30+ mins per session, engaged in twice/week to twice/month or once/month).</td>
<td>Not measured</td>
<td>Age, gender, residence, marital status, working status, smoking status, frequency of drunkenness, chronic illness.</td>
<td>University of Michigan Composite International Diagnostic Interview Short form – meeting diagnostic criteria for Major Depressive Episode (MDE).</td>
<td>Those who engaged in 1 or fewer sessions of PA per month reported significantly higher odds of MDE than those who engaged in PA daily ($OR = 4.01, 95% \text{ CIs } [1.18, 14.0]$).</td>
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<td>Harbour et al., (2008), US</td>
<td>N = 8621, $M_{age} = 21.3$ ($SD = 2.7$), 53.4% female, randomly selected through Utah Higher Education Health Behavior Survey.</td>
<td>Subjective measure: No. days / week engaged in vigorous PA to the point of ‘sweating’ and ‘breathing heavily’, categorised into two groups; met VPA guidelines, and those who did not meet guidelines.</td>
<td>Not measured</td>
<td>Age, gender, race, BMI, grade point average, class level, study status, marital status, residence, employment, religious event attendance.</td>
<td>1 item “frequency of feeling downhearted or blue” over previous week – measures ‘depression’.</td>
<td>Those who engaged in VPA sufficiently to meet guidelines were more likely to report feeling downhearted and blue some of the time ($OR = 1.4, 95% \text{ CIs } [1.2, 1.5]$) and more than a good bit of the time ($OR = 1.7, 95% \text{ CIs } [1.5, 2.0], p&lt;.001$).</td>
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<td>Herring et al, (2014), US</td>
<td>N = 1036, $M_{age} = 19.7$, ($SD = 2.9$), 100% female, convenience sample of female students from University of Georgia.</td>
<td>Subjective measure: 7 Day PA Recall measure; categorised into MET-mins values for moderate, hard, and very hard types of PA activities.</td>
<td>Not measured</td>
<td>BMI, Depression (based on Major Depressive Disorder subscale from PDSQ), psychotropic medication use.</td>
<td>Psychiatric Diagnostic Screening Questionnaire (PDSQ) - measures anxiety disorders.</td>
<td>Inverse association between PA and anxiety disorders, explained by the indirect effect of self-concept and self-esteem.</td>
</tr>
<tr>
<td>Morgan et al., (2003), US</td>
<td>N=256, $M_{age} = 18.1$ ($SD = 0.5$), Age range = 16 - 22 years, 53.9% female, convenience university sample.</td>
<td>Subjective measure: No. of hours/week internet use for different purposes; 1) Email, 2) Chatting, 3) Internet surfing (shopping/ playing games, and research).</td>
<td>Not measured</td>
<td>Gender, age, and declaration of major.</td>
<td>CES-D (Iowa Version) - measures depressive symptoms in last month, categorised into none (0-8.5), Mild (9-11), Moderate (11.5-17), and Severe depression (17+).</td>
<td>Longer emailing, online chatting and internet surfing were independently related to lower depressive symptoms, whilst the gender and internet use interaction did not predict depressive symptoms.</td>
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<td>Poole et al., (2011), UK</td>
<td>N = 40, $M_{age} = 28.7$ ($SD = 6.1$), 100% female, convenience sample of university students.</td>
<td><em>Subjective measure:</em> IPAQ- Short form; total time (mins/ day) in moderate PA, vigorous PA and walking PA across the week.</td>
<td><em>Subjective measure:</em> IPAQ-Short form sitting time (mins) per weekday. Not indicated if utilised in the analyses.</td>
<td>Daily emotional states rating for anger, depression and anxiety (NES), age, BMI.</td>
<td>1) Profile of Mood States (POMS) - measures transient mood states 2) Salivary cortisol levels - measures physiological stress response (gathered 1 day at end of week), 3) 7-day self-rating of positive emotional state (PES), 4) CES-D - measures depressive symptoms.</td>
<td>PA not related to POMS or Salivary cortisol levels. The inverse association between physical activity and PES, and physical activity and CES-D remained after controlling for covariates.</td>
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<td>Sidney et al. (1996), US</td>
<td>N = 4352, Age range = 23 – 35 years, 54.0% female, sampled from prepaid health care program, as part of the Cardiovascular Risk Development in Young Adults (CARDIA) study.</td>
<td><strong>Subjective measure:</strong> Time spent in 8 PAs of heavy intensities / the previous year, categorised into those scored above/below lowest quartile of physical activity (specific cut off details not provided; results in relation to depressive symptoms not reported).</td>
<td><strong>Subjective measure:</strong> 2 items of leisure time TV viewing duration, categorised into time engaged in TV viewing (/day): 0, 1, 2, 3, ≥4 hours.</td>
<td>Age, education, BMI, physical activity, smoking, alcohol use, examination centre.</td>
<td>CES-D - measures depressive symptoms, categorised into above gender specific quartile, and those below (specific cut off details not provided).</td>
<td>Young adults who engaged in high TV viewing (≥4 hours/day) were significantly at higher risk of high depressive symptoms, but only amongst white males (OR = 2.1, 95% CIs [1.3, 3.5]).</td>
</tr>
<tr>
<td>Taliaferr o et al., (2008), US</td>
<td>N = 43499, $M_{age}$ = 20.4 ($SD = 1.8$), Age range = 18 - 25 years, 64.5% female, sampled through the National College Health Assessment.</td>
<td><strong>Subjective measures:</strong> 2 items reflects: 1) No. of days of the week in which engaged in Vigorous PA (VPA) 20+mins or Moderate PA (MPA) 30+mins, &amp; 2) No. of days did toning exercises. Each variable categorised into 0 times/ week, 1-2 times, 3-5 times, 6-7 times a week.</td>
<td>Not measured</td>
<td>Gender (moderator)</td>
<td>1) 1 item - measures 12-month experience of hopelessness, 2) 1 item - measures 12-month experience of depressed mood, &amp; 3) Suicidal ideation.</td>
<td>Males and females who engaged in 3-5 times in MPA / VPA or toning activity per week reported a lower risk of depression, lower suicidal ideation, compared to those who do no exercise.</td>
</tr>
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<td>Thome et al., (2004), US</td>
<td>N = 321, $M_{age}$ = 19.9 ($SD$ = 2.7), 73.2% female, convenience sampled university students.</td>
<td>Subjective measures: 1) Godin Leisure Time Exercise Questionnaire - measures frequency of (15+mins/ week) strenuous, moderate and mild exercise engagement 2) Fitness inventory that reflects type, frequency, duration and intensity of exercise participation.</td>
<td>Not measured.</td>
<td>Gender (moderator)</td>
<td>1) CES-D - measures depressive symptoms, 2) State-Trait Anxiety Inventory (STAI) - measures anxiety symptoms, 3) Satisfaction with Life Scale (SWLS) - measures life satisfaction, 4) Positive and Negative Affect Schedule (PANAS) - measures positive and negative affect.</td>
<td>Amongst males; higher weekly exercise frequency was associated with higher life satisfaction, lower state anxiety and trait anxiety and greater positive affect. Amongst females; higher exercise frequency was related to higher positive affect, higher negative affect.</td>
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<tr>
<td>Van Kim &amp; Nelson (2013), US</td>
<td>N = 14804, Majority age range = 18 - 23 years, 63.1% female, sampled from the Harvard School of Public Health Study of College Health Behaviors.</td>
<td>Subjective measure: Youth Risk Behavior Survey -measures No. of days of vigorous PA (VPA) in past 7 days, categorised into ‘meet VPA guidelines’(3+ days engaged in VPA/week) or ‘not meet VPA guidelines’.</td>
<td>Not measured</td>
<td>Response rate, sex, VPA in high school, weight status, ethnicity, SES status, and year in school. Socialising (mediator)</td>
<td>1) Mental health scale from the SF-36 - measures overall mental health 2) Cohen Perceived Stress Scale - measures stress.</td>
<td>Students who met VPA recommendations were less likely to report poor mental health ( OR = 0.79; 95% \text{ CIs} [0.69, 0.90] ) and stress ( OR = 0.75, 95% \text{ CIs} [0.67, 0.83] ) than those who did not meet VPA. Socialising partially mediates the relationships between VPA and mental health.</td>
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<td>Wu et al., (2015), China</td>
<td>N = 4747, $M_{age}$ = 19.3 ($SD$ = 1.4), 58.4% female, random cluster sampling of university students.</td>
<td>Subjective measures: 1) Youth Risk Behavior Survey - measures No. of days of strengthening exercises in past 7 days, categorised into ‘high PA’ = 3+ days/ week; 2) Physical Activity Rank Scale 3 – measures exercise intensity, time and frequency over one month, categorised into low, moderate and high PA.</td>
<td>Subjective measure: No. of hours spent on the computer (incl. playing video games), &amp; television viewing on usual weekday and weekend day; total where low ST = ≤ 2 hours, high ST = &gt;2 hours/ day.</td>
<td>Gender, age, residential background, BMI, perceived family income, perceived study burden.</td>
<td>1) Self-rating anxiety scale - measures anxiety symptoms, 2) CES-D - measures depressive symptoms = ≥16 high symptoms, 3) Multidimensional sub-health Questionnaire of Adolescents - measures psychopathological symptoms.</td>
<td>High PA was inversely associated with anxiety symptoms, depressive symptoms and psychopathological symptoms, compared to those who reported Low PA. High ST was significantly associated with increased anxiety, depressive symptoms and psychopathological symptoms, compared to those who engage in Low ST. A significant interaction effect of PA and ST on anxiety, depressive and psychopathological symptoms.</td>
</tr>
</tbody>
</table>

*Note.* Reported under ‘Findings’ reflect results from multivariate analyses only.
Nineteen studies, 13 cross-sectional and 6 longitudinal, found physical activity has an inverse effect on mental health symptoms in young adulthood. Whilst this finding is supported by previous research, the results are based on studies of variable methodological quality. Only seven studies were of high quality (Ball et al., 2009; Feng et al., 2014; Haarasilta et al., 2004; Henchoz et al., 2014; McPhie & Rawana, 2015b; Sagatun et al., 2007; Wu et al., 2015), and only one reflected a large, equally gender-distributed sample, of young adults recruited using random sampling methodology (Haarasilta et al., 2004). In addition, only seven studies included a physical activity measure that reflected all components of physical activity (intensity; duration and frequency; Ball et al., 2009; Bray & Kwan, 2006; Feng et al., 2014; Gerber, Brand, Herrmann, et al., 2014; Herring et al., 2014; Poole et al., 2011; Sagatun et al., 2007; Taliaferro et al., 2009; Thome & Espelage, 2004). Further, only two studies controlled for a measure of sedentary behaviour (Feng et al., 2014; Wu et al., 2015). A previous meta-analysis and systematic review had identified that the inverse effect of physical activity on mental health is not clear once only high-quality studies are considered (Cooney et al., 2013).

Two longitudinal studies investigated the change of physical activity (increasing, decreasing from baseline to follow-up) effect on mental health (Henchoz et al., 2014; Pinto Pereira et al., 2014). Both studies investigated the effect of changes in the frequency of physical activity on depressive symptoms, amongst large samples of adults. Amongst young adults, both studies found that those who increased in activity from one (Henchoz et al., 2014) to five years later (Pinto Pereira et al., 2014) reported significantly lower depressive symptoms, compared to those who engaged in consistently low-frequency physical activity.

Four studies, three longitudinal and one cross-sectional, reported null findings (Birkeland et al., 2009; Brunet et al., 2013; Gerber, Brand, Elliot, et al., 2014; Ströhle
et al., 2007). Gerber, Brand, Elliot, and colleagues (2014) investigated the association between four types of physical activity, namely aerobic exercise, ball sports, dancing and strengthening exercises on stress and depressive symptoms, amongst 451 university students. Controlling for the effect of age, gender, study modality and stress, none of the exercise types were significantly related to depressive symptoms. Similarly, Birkeland and colleagues (2009), and Brunet and colleagues (2013) investigated the longitudinal effect of physical activity in adolescents on young adult depressive symptoms and found no significant effect. Further, Strohle and colleagues (2007) found that physical activity did not predict risk of diagnosis of mental disorders. All three longitudinal studies reflected high-quality methodology. Specifically, the results reflect use of high-quality physical activity and mental health measures, large samples that were randomly recruited, and controlled for several confounders. All three investigated the effect of physical activity during adolescence (age approximately 12 to 14 years), on young adult mental health (age approximately 22 to 24 years). Evidence shows that from adolescence to young adulthood, physical activity reflects low stability (Birkeland et al., 2009; physical activity at 13 years and 23 years Pearson's r = .18). It is possible that adolescent physical activity is not predictive of young adult mental health.

**Sedentary behaviour and mental health**

Seven studies, 6 cross-sectional and 1 longitudinal, investigated the role of sedentary behaviour on young adult mental health (Fang et al., 2014; Feng et al., 2014; Gordon et al., 2007; Morgan & Cotten, 2003; Sidney et al., 1996; Thomée et al., 2012; Wu et al., 2015). Five studies considered the association between sedentary behaviour and two or more mental health indicators.

In general, results indicated that increased time spent engaging in sedentary behaviour was associated with higher depressive symptoms (Feng et al., 2014;
Gordon et al., 2007; Morgan & Cotten, 2003; Wu et al., 2015). Specifically, Feng and colleagues (2014) found that young adults who engaged in less than two hours of daily screen time were significantly less likely to report depression scores above cut-off ($OR = 0.67$, 95% CIs [0.44, 0.89]), than those who engaged in two or more hours of screen time. Similarly, Wu et al. (2015) found that young adults who engaged in more than two hours of screen time per day, were more likely to report increased depressive symptoms ($OR = 1.76$, 95% CIs [1.47, 2.09]), and anxiety symptoms ($OR = 1.38$, 95% CIs [1.15, 1.65]) than those who reported two or fewer hours of daily screen time. Importantly, both studies (Feng et al., 2014; Wu et al., 2015) controlled for the possible confounding effect of physical activity, and results were based on large samples that were randomly recruited. These studies suggest a possible dose-response for screen-based sedentary behaviour, such that engaging in approximately two daily hours or more of the behaviour is associated with poorer mental health. This is particularly relevant to young adults as they tend to spend long periods engaging in screen-based activities (Fang et al., 2014; Feng et al., 2014).

In light of the different activities considered, it was relevant to group the results according to the type of outcome and activity. Three studies investigated the association between screen time (computer use/ TV viewing) on depressive symptoms (Fang et al., 2014; Feng et al., 2014; Sidney et al., 1996; Wu et al., 2015), of which three found a positive association (Feng et al., 2014; Sidney et al., 1996; Wu et al., 2015). Specifically, it was found that longer engagement in screen-based sedentary behaviour, the poorer the mental health outcomes. Fang et al. (2014) uniquely found no significant association.
Table 5.2
Prospective studies that have investigated the effect of physical activity/ sedentary behaviour and mental health amongst young adults

<table>
<thead>
<tr>
<th>Authors</th>
<th>Study participants, Follow-Up period (FU) and response rate (RR)</th>
<th>Predictor variable: Physical Activity (PA)</th>
<th>Predictor variable: Sedentary Behaviour (SB)</th>
<th>Correlates in analyses</th>
<th>Outcome variable: mental health symptoms</th>
<th>Findings</th>
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<tr>
<td>Ball, Burton &amp; Brown (2009), Australia</td>
<td>N = 6677, Age range = 22-27 years, 100% female, random sampling in Australian Longitudinal Study on Women’s Health (ALSWH). FU = 4 years (2000-2003) RR = Baseline = 68%; F/U = 64%</td>
<td>Subjective measure: 2000 walking and moderate to vigorous PA/week = categories reflect MET mins; none (0 to &lt; 40), very low (40 to &lt;300), low (300 to &lt;600), moderate (600 to &lt; 1200), high (≥1200).</td>
<td>Not measured.</td>
<td>Education level, marital status, occupation, smoking status, parity status, presence of health problem/disability, BMI.</td>
<td>2003 CES-D Depressive symptoms – measures depressive symptoms where total ≥10 reflect high symptoms.</td>
<td>Those in low-level PA were significantly less likely to report depressive symptoms (OR = 0.77, 95% CIs [0.59, 0.99]), than those who reported engaging in no PA. Other levels of PA did not predict depressive symptoms. Results reported reflect those of young adult age group (18-23 years): No significant association found.</td>
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<tr>
<td>Birkeland et al., (2009), Norway</td>
<td>N = 924, Age range = 13 - 23-year-olds, 45% female, random sampling in Norwegian Longitudinal Health Behaviour Study. FU= 1990-2000 (10 years). RR= baseline= 77%, F/U = 68%.</td>
<td>Subjective measure: 1 item – measured frequency of MVPA / week.</td>
<td>Not measured.</td>
<td>Sex, SES, physical disability. Analyses separately by age group 13-17, 18-23 years.</td>
<td>7 item depressed mood inventory.</td>
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<tr>
<td>Authors</td>
<td>Study participants, Follow-Up period (FU) and response rate (RR)</td>
<td>Predictor variable: Physical Activity (PA)</td>
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<td>Brunet et al., (2013), Canada</td>
<td>N = 1293, Baseline $M_{age} = 12.7$, ($SD = 0.5$), 53.2% female, random sampling in Nicotine Dependence in Teens Study, FU = 1999 - 2008 (12 years), RR = 94% (each year).</td>
<td>Subjective measures: 1) No. of days engaged in 29 MVPAs in the previous week. 2) Sports participation in sports each year. PAs and sports measured varied across waves.</td>
<td>Not measured</td>
<td>Baseline Age, sex, depressive symptoms (Based mood subscale of Hopkins Symptom Checklist), parental education</td>
<td>Major Depression Inventory - measures depressive symptoms.</td>
<td>No significant associations between MVPAs at baseline and depressive symptoms at 2008.</td>
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<td>Henchoz et al., (2014), Switzerland</td>
<td>N = 4846, $M_{age} = 19.9$, ($SD = 1.2$), 100% male, randomly selected as part of the Cohort Study on Substance Use. FU= 4 years (2010 - 2013) RR= Baseline 45.2%, F/U= 87.2%</td>
<td>Subjective measure: 1 item - measured frequency of sports or exercise, where ‘regular engagement’ are those who reported ‘almost every day’. 2) Change in PA; Regular at 2010 but not 2013, Not regular at 2010 but regular at 2013, Regular at 2010 and 2013.</td>
<td>Not measured</td>
<td>Age, language, education, employment, community, parent education, family financial status, and army status.</td>
<td>Major Depressive Inventory - measured depressive symptoms.</td>
<td>Regularly PA at 2010 related to lower levels of depressive symptoms, than those who reported ‘a few times a year’. Regular PA at 2010 and 2013 related to lower depressive symptoms than those who did not engage in sufficient PA at 2010 or 2013.</td>
</tr>
<tr>
<td>Authors</td>
<td>Study participants, Follow-Up period (FU) and response rate (RR)</td>
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<td>Jewett et al., (2014), Canada</td>
<td>$N = 853$, 2011, $M_{age} = 20.4$ ($SD = 0.8$), 54.1% female, convenience sample as part of the Nicotine Dependence in Teens Study. FU = 12 years (1999-2011) RR: 94% (each year)</td>
<td>Subjective measure: School sports participant - ranging from no involvement across 5 years (0 years) to involvement in school sport at all 5 years of secondary school (5 years).</td>
<td>Not measured</td>
<td>2011 Gender, age, diagnosed mood disorder, 1999 parent education, each year extracurricular sports participation.</td>
<td>1) Major Depression Inventory - measured depressive symptoms 2) 1 item - measured perceived stress 3) 1 item - mental health status.</td>
<td>Those who reported engaging in school sports reported significantly lower depressive symptoms ($b = -0.36$, $SE = 0.17$, $p&lt;.05$), stress ($b = -0.05$, $SE = 0.02$, $p&lt;.05$) and improved self-rated mental health ($b = 0.05$, $SE = 0.02$, $p&lt;.05$).</td>
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<td>McPhie et al., (2015), Canada</td>
<td>$N = 3676$, 1995, $M_{age} = 15.0$ ($SD = 0.0$), 2008 $M_{age} = 27.9$ ($SD = 0.5$), 51% female, Random sampling in National longitudinal study of adolescent health. FU = 13 years (1995 – 2008). RR = not reported.</td>
<td>Subjective measure: Frequency of engaging in specific PAs (referenced PAs changed between waves) in previous 7 days.</td>
<td>Not measured</td>
<td>BMI, socioeconomic status.</td>
<td>CES-D – measured depressive symptoms.</td>
<td>Higher frequency of PA at baseline was associated with ‘stagnation’ (not significant) in depressive symptoms across time.</td>
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<tr>
<td>Authors</td>
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<td>Pinto Pereira et al., (2014), England</td>
<td>N ≈ 11000, Age range = 23 – 50 years, % female not reported, random sampling in 1958 British Birth Cohort. FU = 27 years (1981 – 2008). RR = baseline 76.1%, F/U = 61.4%.</td>
<td>Subjective measure: Frequency of PA/ month, categorised into ≥5 times/ week, 3 – 4 times/ week, 1 – 2 times/ week, 2 – 3 times in previous 4 weeks, 1 time in previous 4 weeks, 0 times in previous 4 weeks.</td>
<td>Not measured.  Sex, maternal age at birth, birth order, cognitive ability at 11 years of age, family size, concurrent BMI, social class.</td>
<td>Psychological subscale of Malaise Inventory – measured anxiety and depressive symptoms.</td>
<td>Young adults who were inactive at 23 and became active (1 time/week) 5 years later, had a lower mean symptom level by 0.07 (95% CI = -0.09 - -0.04) compared with 0.01 (95% CI = -0.04 - 0.02) that had remained inactive.</td>
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<td>Sagatun et al., (2007), Norway</td>
<td>N= 2489, Age range baseline = 15 – 16, follow-up = 18 – 19 years, 55.3% females, from the Oslo Health Study (sampling method not reported). FU = 3 years (2000 – 2003). RR = baseline = 88%, F/U = 65.3%.</td>
<td>Subjective measure: No. hours of PA per week that ‘made them sweat and/ or out of breath, categorised into 0, 1-2, 3-4, 5-7, 8-10 and 11 hours/ week.</td>
<td>Not measured.  Ethnicity, income, smoking, and alcohol use.</td>
<td>Strengths and difficulties Questionnaire (SDQ) – measured emotional, conduct, hyperactivity – inattention, and peer problems.</td>
<td>Those who engaged in 5 – 7 hours/ week in PA at 15 years reported significantly lower symptoms but was found not significant after adjustment for covariates.</td>
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<td>Strohle et al., (2007), Germany</td>
<td>N = 2548, Age range = 14 - 24 years, 49.1% female, randomly sampled, representative sample from the Early Developmental Stages of Psychopathology. FU = 8 years (1995 – 2003). RR = baseline= 74.6%, F/U = 54.3%.</td>
<td>Subjective measure: frequency of engagement in PA/ week, categorised into 3 groups: ‘regular’ (daily &amp; several times a week), ‘non-regular’ (1-4 times a month), ‘no PA’ (&lt; once a month).</td>
<td>Not measured</td>
<td>Age, gender, educational status, BMI, ‘other’ mental disorders, no. impairment days due to physical problems (in previous 4 weeks).</td>
<td>Munich-Composite International Diagnostic Interview - measured diagnosis of somatoform, anxiety, mood, substance and eating disorders.</td>
<td>Those who engaged in regular or non-regular PA had reduced the risk of ‘any mental health disorder’, compared to those who engaged in no PA. No significant association found between PA and risk of ‘Major Depressive Disorder’, ‘any anxiety disorder’.</td>
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<tr>
<td>Authors</td>
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<td>Thomée et al.,  (2012), Sweden</td>
<td>$N = 4163$, Age range $= 20 – 24$ years, 65.0% female, randomly sampled community sample. FU = 1 year (2007 – 2008) RR = baseline =36%, F/U = 74%.</td>
<td>Not measured</td>
<td>Subjective measure: Average hours/ day on computer use (each below categorised into low, medium and high use); 1) general use, 2) email/chat use, 3) Gaming, 4) frequency of computer use without breaks for ≥2 hours, 5) Frequency sleep lost due to computer use at night; 6) Mobile phone use (no. calls and text messages sent and received daily).</td>
<td>Relationship status, educational level, occupation. Gender (moderator).</td>
<td>1) 1 item measured stress 2) 1 item measured sleep disturbances 3) 2 items from Primary care Evaluation of mental disorders screening form - measured depressive symptoms 4) 2 items measured reduced performance.</td>
<td>Those who engaged in high computer use (&gt;4 hrs/ day) and email/ chat (&gt;2 hrs/day) use were more likely to experience sleep disturbance (men only). Those who engaged in high computer use were more likely to report reduced performance (men only), those who engaged in high email/ chat use were more likely to experience depressive symptoms (females only).</td>
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</table>
The other three studies (Feng et al., 2014; Sidney et al., 1996; Wu et al., 2015) were all of moderate to high quality, whilst Fang et al. (2014) reflects low methodological quality. Specifically, whilst Fang et al. (2014) did not control for relevant confounding characteristics and reflects a small sample size, the other studies largely reflect large samples randomly recruited, and controlled for relevant confounders. In light of the methodological differences, it is concluded that there is evidence to support the finding that longer engagement in screen-based activities are related to higher depressive symptoms amongst young adults.

Three studies investigated the role of internet use with depressive symptoms (Fang et al., 2014; Gordon et al., 2007; Morgan & Cotten, 2003) of which, two studies found a significant positive association (Fang et al., 2014; Morgan & Cotten, 2003). For example, Morgan and Cotten (2003) found internet surfing predicted increased depressive symptoms, whilst Fang et al. (2014) found non-school related internet searching was related to depressive symptoms. Most studies, however, were of low quality. The current review concludes there are insufficient good quality studies, to draw conclusions about this association.

Two studies investigated the association between online chatting or email use on depressive symptoms (Morgan & Cotten, 2003; Thomée et al., 2012) and both found that longer engagement in online chatting or email use was associated with higher depressive symptoms. Both studies reflect moderate methodological quality, but neither controlled for the possible confounding effect of physical activity engagement. Further research is required to address these gaps.

Notably, Thomée et al. (2012) conducted the only longitudinal study that investigated the effect of any sedentary behaviour on mental health. The authors found that higher engagement in screen-based activities predicted higher stress
symptoms. They found that the positive relationship was moderated by gender, such that longer computer use predicted poorer sleep quality amongst males, whilst longer engagement in email/chat use related to more depressive symptoms amongst females. In light of the paucity of studies, the current review was not able to explore possible dose-response effects of sedentary behaviour on mental health.

**Interaction between physical activity and sedentary behaviour effect on mental health**

Of the studies that measured both physical activity and sedentary behaviour (Fang et al., 2014; Feng et al., 2014; Sidney et al., 1996; Wu et al., 2015), two high quality cross-sectional studies investigated the interaction effect of these predictors on mental health (Feng et al., 2014; Wu et al., 2015). Both studies operationalised screen time into two categories; High Screen Time (ST) reflects > 2 hours of screen time daily, and Low ST reflects ≤ 2 hours of screen time daily. Both also defined high physical activity as 3 or more days of weekly physical activity.

Both Feng and colleagues (2014) and Wu and colleagues (2015) found that amongst those who engage in low levels of physical activity, those who engaged in Low ST were significantly at reduced risk of depressive symptoms, compared to those who engaged in High ST. Feng and colleagues (2014) found that amongst those who engage in high levels of physical activity, there were no significant differences between those who engaged in High ST and those who engaged in Low ST in their association with depressive symptoms. Conversely, Wu et al. (2015) found that those who engage in high levels of physical activity and Low ST were at the lowest risk of depressive symptoms, as compared to those who engaged in low physical activity and High ST. Whilst Feng and colleagues (2014) found no interaction effect for anxiety symptoms, Wu and colleagues (2015) reported an inverse association such that amongst those who engaged in low physical activity,
those who engaged in Low ST were at reduced risk of anxiety symptoms, as compared to those who engage in High ST. Whilst both studies are of high quality, it is possible that the differences reflect Wu and colleagues (2015) higher response rate. Specifically, both studies utilised the self-rating anxiety scale to measure anxiety symptoms, comparable quality measures of depressive symptoms and reflect large sample that were randomly recruited, and measured both physical activity and sedentary behaviour in identical ways. Regardless of the reason for this difference in results (anxiety symptoms), they suggest that there is an interaction effect between physical activity and sedentary behaviour on mental health.

Discussion

The primary aims of the current systematic review were to determine the extent to which there are independent and interacting relationships between moderate to vigorous intensity physical activity and sedentary behaviour and common mental health symptoms, amongst young adults. An additional aim was to determine the extent to which the literature suggests a dose-response association between sedentary behaviour and mental health.

Physical activity and young adult mental health

The review results suggest, in line with previous studies and reviews of general adult populations, that higher engagement in moderate to vigorous physical activity predicts better mental health. This finding was consistent across cross-sectional and longitudinal studies. This suggests that there is an inverse relationship between moderate to vigorous physical activity engagement and mental health. There are several methodological limitations in the existing literature, which limits the confidence with which a conclusion can be made. These limitations are discussed in
more detail below and include the sampling methods utilised, weaknesses in the physical activity measures utilised, and inadequate control of appropriate covariates.

First, most of the studies included university student samples, gained by convenience sampling methods, and most did not report response rates. This limits the generalisability of the study findings to primarily highly educated young adults. Further studies should seek to determine the extent to which the association between physical activity and mental health remains consistent within a randomly sampled young adult cohort from the community.

Second, the majority of studies that address the association between physical activity and mental health utilised measures of physical activity that do not assess all components of physical activity, including intensity, frequency and duration. The risks associated with utilising weak measures are twofold. First, the psychometric properties are questionable, with measurement error reducing the ability to detect real effects (Helmerhorst, Brage, Warren, Besson, & Ekelund, 2012). Second, it is difficult to compare levels of reported physical activity between studies, which limits the ability to combine studies of young adult physical activity engagement (Wooden, 2014). On the other hand, utilising measures of physical activity that reflect all components allows studies to determine the extent to which the association with mental health is accounted for by the frequency, intensity or duration of physical activity, enabling a more accurate understanding of the type of activity that is beneficial. Using standardised and sound activity measures would hasten the development of accurate physical activity engagement guidelines for mental health specific benefits. There has been sufficient attention to the mental health effects of physical activity, to require that future studies use valid and standardised physical activity measures.
Third, the majority of the studies did not adequately control for relevant predictors of physical activity and mental health, including age, gender, education, income, and health status. Specifically, only fourteen studies, out of 23 studies, controlled for two or more of the above correlates (Ball et al., 2009; Birkeland et al., 2009; Brunet et al., 2013; Feng et al., 2014; Gerber, Brand, Elliot, et al., 2014; Gerber, Brand, Herrmann, et al., 2014; Haarasilta et al., 2004; Harbour et al., 2008; Henchoz et al., 2014; Jewett et al., 2014; Sidney et al., 1996; Ströhle et al., 2007; VanKim & Nelson, 2013). Inadequate control for correlates increases the risk of finding a spurious significant effect between physical activity and mental health. This, in turn, increases the risk of performing a type I error. In light of this inadequate control, the results of prior studies are brought into question. It is recommended that future analyses of the effects of physical activity on mental health include multivariate controls for all of the above correlates that have been inadequately considered in the existing literature.

Finally, very few studies examining the effects of physical activity on mental health controlled for the effect of sedentary behaviour, which affects the veracity of the findings. This is a significant gap in the literature as there is evidence that physical activity and sedentary behaviour have independent effects on mental health (Owen et al., 2010). Evidence indicates a small negative association between physical activity and sedentary behaviour (Owen et al., 2010). Further, evidence suggests that the relationship between physical activity and mental health may be dependent upon sedentary behaviour (Feng et al., 2014; Wu et al., 2015). As a result, sedentary behaviour is a correlate, which needs to be included in multivariate analyses, in order to obtain an accurate picture of the relationship between physical activity and mental health. In light of this methodological gap, further research is
required to determine the extent to which physical activity is a predictor of mental health, controlling for sedentary behaviour.

**Sedentary behaviour and young adult mental health**

The current review overall found that longer engagement in screen-based sedentary behaviour was associated with poorer mental health outcomes, or specifically, depressive symptoms (Feng et al., 2014; Gordon et al., 2007; Morgan & Cotten, 2003; Wu et al., 2015). Most of the studies found in particular that screen time (computer use/TV viewing) influenced depressive symptoms. However, several studies indicated null findings. For example, some research suggested that the amount of time spent in screen-based sedentary behaviour (Fang et al., 2014) and frequency of internet use (/ week) and total sitting time (Gordon et al., 2007) were not significantly related to depressive symptoms. Feng et al. (2014), found that screen time was not related to anxiety symptoms. It is difficult to reach firm conclusions about the role of sedentary behaviour in young adult mental health in light of these discrepancies. In addition, and similar to the literature on the mental health effects of physical activity, there are several methodological limitations that warrant discussion. Specifically, studies were limited by the paucity of the number of studies, nature of the sedentary behaviour measurement, and lack of control for physical activity.

The literature review indicated the limited amount of research that has considered the relationship between sedentary behaviour and mental health amongst young adults. Specifically, only seven studies considered this relationship (Fang et al., 2014; Feng et al., 2014; Gordon et al., 2007; Morgan & Cotten, 2003; Sidney et al., 1996; Thomée et al., 2012; Wu et al., 2015).
The paucity of studies limited the aim to determine the extent to which the literature suggests a dose-response effect between sedentary behaviour and mental health. Two high-quality studies (Feng et al., 2014; Wu et al., 2015) found a significantly higher level of poor mental health symptoms amongst those who engaged in two or more daily hours of sedentary screen-based activities, than those who engaged in less. However, due to the paucity of studies, it was difficult to draw any strong conclusions. Future studies, particularly longitudinal studies, are required to further determine the extent to which there are mental health effects of this level of sedentary behaviour. Further research is required to provide a clearer indication of the relationship between sedentary behaviour and mental health.

Second, all included studies considered variations of proxy measures of sedentary behaviours, including TV viewing, computer use, and internet use. This limits the literature in several ways. First, it was difficult to compare the results across the measures of sedentary behaviour. Specifically, there were insufficient studies of good methodological quality to support a conclusion regarding the nature of the relationship for online chatting/ emailing and internet use. The literature also is limited as, in light of the limited amount of research, it is difficult to determine true levels of sedentary behaviour and establish a standard for future research to utilise. The current review established that more sophisticated sedentary behaviour measures were required to reflect the nature of the activity, including duration and frequency. Finally, given the focus on proxy measures of sedentary behaviour, there was insufficient consideration of the effect of overall sitting time on mental health. This is a particularly important gap in light of recent evidence that sitting time predicts increased risk of disease and mortality amongst adults (Biswas et al., 2015). Further studies investigating the effects of sitting time will help to provide age, activity and
mental health symptom specific guidelines regarding healthful sedentary behaviour engagement.

Similar to the literature on physical activity and mental health, a paucity of studies controlled for the effect of physical activity on the relationship between sedentary behaviour and mental health. There is some evidence that the effect of screen-based activities may be relative to the type of activity, and moderated by race and gender. Two of the five studies considered the extent to which screen based activities have an effect on mental health, depending on the type of activity and moderator effects (Fang et al., 2014; Sidney et al., 1996). They found that indeed TV viewing only was associated with depressive symptoms for white males (Sidney et al., 1996) and that non-school based internet use has an effect on psychological distress (Fang et al., 2014). Further research into possible moderators is warranted.

**Interaction of physical activity and sedentary behaviour on mental health**

Finally, evidence suggests that there is an interaction effect between physical activity and sedentary behaviour on mental health. Evidence from the current review suggests that interaction effects may have more influence on depressive symptoms, than for anxiety symptoms. However, in light of the limited number of studies that reported an interaction effect, further research in this area is warranted.

**Strengths and Limitations**

The current review is the first to address the effect of physical activity and sedentary behaviour on mental health, amongst young adult samples. The results reflect the analysis of studies identified through five databases, with no restriction of publication date. Only studies with multivariate analyses were included, to ensure the conclusions were based on studies with high quality. Further, a systematic quality
assessment was utilised in the current review. Further, this is the first review to date to consider the interaction effect of physical activity and sedentary behaviour on mental health amongst young adults.

There are several limitations. First, the focus on observational studies limited the quality of evidence for causal conclusions. Second, the current review excluded studies of those engaged in sports because they reflected athletes or non-normative samples. Future studies using community samples should investigate the effect of sports engagement on mental health (Eime, Young, Harvey, Charity, & Payne, 2013). In addition, a large relative proportion of papers ($n = 12$) could not be accessed in time for the submission of this thesis, the inclusion of which may have impacted the conclusions presented. Third, whilst the quality assessment measure used in the present review was systematic, it has not been validated. Finally, the fact that almost a third of the included studies were from grey literature (not peer-reviewed), and not through the systematic search suggests weaknesses in the overall quality of the available literature.

Conclusions/implications

Physical activity appears to have a mental health protective quality for young adults. However, this conclusion is based on largely cross-sectional studies of relatively low quality. In light of the less conclusive results of reviews of intervention studies (Cooney 2014), further research is warranted. The current review recommends further research to utilise measures of physical activity that have good psychometric properties. Second, as most of the literature considered depressive symptoms, and it is unclear if the relationship between physical activity and mental health is dependent on the nature of symptoms, the current review recommends consideration of other mental health symptoms as well as depressive symptoms. Third, control of sedentary behaviour and other relevant covariates is required in
future studies, to ensure a more accurate understanding of the effect of physical activity on mental health.

The current review also identified various sedentary behaviours as risk factors for young adult mental health. Given the quality of studies was generally moderate, there is significant scope for future high-quality studies. First, in light of the paucity of studies considering general sedentary behaviour (i.e., sitting), future work should consider investigating general sedentary behaviour and mental health. Second, prospective analyses of these associations should be conducted. Third, through the recognition that physical activity as an important predictor of sedentary behaviour and mental health, studies that investigate the effect of sedentary behaviour should control for the effect of physical activity. Attending to these methodological issues will improve the evidence base for developing sedentary behaviour guidelines.

Summary

The current Chapter reflects a systematic review of the existing observational research investigating the effects of physical activity or sedentary behaviour on mental health amongst young adults. The review indicated that whilst an inverse relationship between physical activity and mental health was found, the majority of the work was based on studies of relatively poor methodological qualities. This included the use of weak measures of physical activity, convenience samples of young adults, and poor control for sedentary behaviour and other covariates. Further, whilst a positive association was presented for proxy measures of sedentary behaviour and mental health, the paucity of research addressing this issue, the quality of sedentary behaviour measures, and inadequate control for relevant covariates, warrants that further research address these issues.
Chapter 6: Study 1 Physical activity, sedentary behaviour and their associations with mental health amongst young adults

The current Chapter presents a cross-sectional study of the relationship between physical activity, sedentary behaviour and young adult psychological distress that addresses the research gaps indicated in the systematic review. Specifically, the current cross-sectional study will utilise a sound physical activity and sedentary behaviour measure and include a larger number of identified covariates in the multivariate analyses, than previous research. Further, the current study will address the independent relationship between physical activity and mental health whilst controlling for sedentary behaviour and will investigate the independent relationship between sedentary behaviour and mental health whilst controlling for physical activity. In addition, it will address the interacting association between physical activity and sedentary behaviour in their association with mental health. In line with prevention science methodology, the first step to identifying the extent to which a factor may be a risk or protective predictor of mental health, is to conduct multivariate cross-sectional analyses whilst controlling for relevant covariates. This will serve to build the existing evidence base which can inform future mental health guidelines. The sections that follow have been written in a form suitable to be developed into a journal article submission. For this reason, some of the concepts included in the earlier sections of this thesis are summarised in what follows.

Abstract

Problem: Some research has examined prevalence rates of and associations between physical activity, sedentary behaviour and mental health, amongst young adults. Methods: In 2012, a state representative cohort of young adults \( (n = 2,346) \)
53.7% female, $M_{age} = 23.1, SD = 1.7$) were surveyed on physical activity, sedentary
behaviour and mental health. Negative binomial multivariate regression analyses
were utilised to investigate the associations between physical activity (meeting
moderate to vigorous physical activity public health guidelines), sedentary behaviour
(weekday sitting) and psychological distress, after controlling for psychosocial
correlates. **Results:** 30.5% of young adults engaged in 5.6 to 14 hours of sedentary
behaviour per weekday and 83.2% met physical activity public health guidelines,
whilst 28.1% reported high or very high psychological distress. The inverse bivariate
association between meeting physical activity public health guidelines and
psychological distress was not significant in the multivariate analyses ($IRR = 1.05,
95% CIs [1.00, 1.10]$). Those who engaged in 5.6 to 14 hours (High level) of
weekday sedentary behaviour were more likely to report higher psychological
distress (High SB $IRR = 1.07, 95\%$ CIs [1.03, 1.11]). Analyses suggest no interaction
effect of physical activity and sedentary behaviour on mental health. **Conclusions:**
Physical activity associations with mental health may vary according to the nature of
symptoms and are influenced by psychosocial correlates. Long periods of sedentary
behaviour are significantly associated with poorer mental health, independent of
psychosocial correlates. Further research should consider the processes by which
sedentary behaviour and physical activity influence mental health.

**Introduction**

Approximately 20 – 25% of young adults report poor mental health (Aalto-
Setälä et al., 2001; Newman et al., 1996; Suvisaari et al., 2009). Compared to the rest
of the population, young adults experience high rates of anxiety or affective disorders
(Australian Bureau of Statistics, 2009) and psychological distress, an emotional
experience marked by anxiety and depressive symptoms (Casey, 2013). Young
people with mental health problems are less likely to: successfully enter employment; complete higher education; and develop healthy peer and family relationships (Wittchen & Jacobi, 2005). Young people with mental health problems also have low rates of help-seeking for their concerns (Armando et al., 2012), and are more likely to complete suicide (Page et al., 2014).

To advance prevention efforts, it is important to understand how mental health symptoms are associated with potentially modifiable influences. It is unclear to what extent low physical activity contributes to high rates of mental health problems amongst young adults. Physical activity is defined as any bodily movement that causes a level of metabolic energy expenditure above resting level (Caspersen et al., 1985). Research that has investigated the association between physical activity and mental health suggests mixed findings. Although most studies suggest that higher levels of physical activity are associated with improved mental health in adult samples (Hamer, Coombs, & Stamatakis, 2014; Hogan, Catalino, Mata, & Fredrickson, 2015; Sloan et al., 2013; Stanton et al., 2014), some studies have reported null findings (Asztalos et al., 2009).

Current Australian public health guidelines recommend engaging in 150 minutes of moderate to vigorous physical activity per week to experience health benefits (Australian Institute of Health and Welfare, 2011). In 2011, the majority of young Australians (53% of 18 - 24-year-olds) reported engaging in insufficient physical activity to meet public health guidelines (Australian Institute of Health and Welfare, 2011). The extent to which meeting these guidelines is associated with mental health benefits amongst young adults is unclear. The few studies that have considered this association found that meeting physical activity guidelines was associated with better mental health (Hamer et al., 2014; Sloan et al., 2013; VanKim & Nelson, 2013). These findings are impacted by differences in the way that
moderate and vigorous physical activity (MVPA) guidelines are measured. Some studies focus on vigorous physical activity only (VanKim & Nelson, 2013), in other studies, Metabolic Equivalent Task-minutes of MVPA (Sloan et al., 2013) or weekly MVPA hours (Hamer et al., 2014) were measured. The majority of prior research has examined broader adult samples (e.g., 18 - 89 years; Hamer et al., 2014; Sloan et al., 2013) and there has been limited focus on young adult samples. The current study will, therefore, investigate the association between engagement in MVPA sufficient to meet public health guidelines and mental health symptoms, amongst young adults.

Relative to physical activity, less empirical focus has been placed on the association between sedentary behaviour and mental health. Previously conceptualised as low-level physical activity, sedentary behaviour is now recognised as a distinct behaviour (Atkin, Adams, Bull, & Biddle, 2012). Sedentary behaviour is defined as sitting or lying down which results in little increase in energy expenditure above the resting state (Owen et al., 2010). Studies indicate that increased engagement in sedentary behaviour is associated with increased risk of cancer and mortality over and above the effects of physical activity (Biswas et al., 2015). Whilst research between sedentary behaviour and mental health suggests a positive association (Teychenne et al., 2015), the extent to which this association exists for young adults is unclear.

Graham and colleagues (2014) investigated the association between sedentary behaviour and psychological distress in a young adult sample (majority aged between 18 and 24 years). Their results supported a positive association between sedentary behaviour and psychological distress. However, sedentary behaviour was measured in their study as low physical activity, which is inconsistent with current conceptualisations of sedentary behaviour.
Despite the recognition that sedentary behaviour and physical activity are distinct behaviours, few studies have investigated the independent contributions of physical activity and sedentary behaviour to high prevalence mental health problems such as depressive symptoms, anxiety symptoms, and psychological distress (Cerin et al., 2009; Kilpatrick, Sanderson, Blizzard, Teale, & Venn, 2013). Lack of research is particularly evident in young adult samples. One objective of the current study was therefore to estimate the association between both physical activity and sedentary behaviour and mental health symptoms in a contemporary young adult sample.

Limited work has also addressed the interactive effect of physical activity and sedentary behaviour on mental health (Sloan et al., 2013). Prior results show that adults who engage in less than five hours of sedentary behaviour per week have been found to be more likely to experience mental health benefits from physical activity than those who spend more than ten hours in sedentary behaviour per week (Sloan et al., 2013). An additional aim of the present study was, therefore, to examine whether the interaction of physical activity and sedentary behaviour was associated with common mental health symptoms.

To understand the nature of the associations between sedentary behaviour, physical activity and mental health, it is important to control for inter-related correlates (Teychenne et al., 2008, 2010). Factors that have been identified to influence physical activity and/ or sedentary behaviour and mental health include: gender (Saunders & Daly, 2001); income (Arredondo et al., 2013); employment (Asztalos et al., 2009); health status (Cerin et al., 2009); and social factors such as peer and family participation in physical activity (King et al., 2013; Trost et al., 2002). The current study will, therefore, consider the associations between physical activity, sedentary behaviour and mental health symptoms whilst controlling for psychosocial correlates.
There were several goals in the current study. First, in the current study, the rate of physical activity, sedentary behaviour engagement and mental health symptoms in a contemporary sample of Australian young adults are estimated. Second, the study aimed to determine the independent and interacting associations that physical activity and sedentary behaviour have with mental health symptoms. Third, the current study sought to investigate these associations after controlling for psychosocial correlates.

It was hypothesised that higher engagement in physical activity would be associated with lower levels of psychological distress (anxiety and depressive symptoms), whilst increases in sedentary behaviour would be associated with higher symptoms, after controlling for correlates. In addition, it was hypothesised that an interaction effect would be evident whereby physical activity would have less effect on enhancing mental health, amongst those spending longer periods in sedentary behaviour.

Method

Participants

Australian young adults ($M_{age} = 23.1, SD = 1.7$), participating in the International Youth Development Study (IYDS), a 12 year follow-up study involving 2,884 adolescent students (74.0% of approached sample), were recruited for the current sample. In 2002, three cohorts of state representative students were sampled from Victorian government and state schools (in Grades 5, 7 and 9), using a two-stage cluster sampling approach. This sample was recruited first by randomly selecting public and private schools in Victoria Australia, stratified according to geographic location, using a probability proportionate to grade level size sampling procedure. Second, one class from each target grade was randomly selected within
each school. Further details regarding recruitment can be found elsewhere
(McMorris, Hemphill, Toumbourou, Catalano, & Patton, 2007). Since 2002, a total
of \( n = 485 \) (16.8\%) were lost to follow-up by the 2012 wave (total possible sample
for 2012 \( n = 2399 \)). The current cross-sectional study sample reflected participants
who were re-surveyed in 2012 and completed the measures used in the present
analyses \( (n = 2,346; 81.4\% \text{ of sample recruited in 2002}) \).

**Ethics**

Ethics approval for the IYDS project was gained from the University of Melbourne
Human Ethics in Research Committee. Participants were contacted by the IYDS research
team, and once they provided informed consent, responded to an online survey, that took
approximately one hour to complete. Upon completion, respondents were provided with a
gift voucher. Ethics exemption was provided by Deakin University Human Research Ethics
Committee to conduct the present study using de-identified data.

**Measures**

**Demographic and psychosocial characteristics**

Respondents reported on several demographic and psychosocial variables
including; age (years), gender (female = 1), current employment status (“Are you
currently employed?” responded yes (1) / no (0)), marital status (“What is your
current marital status?”, responses recoded as married, engaged, de facto relationship
(1) / single/never married, divorced, separated, and widowed (0)), weekly income
(“What is your usual, take-home, weekly income from all sources of support?”
responded via 13-point scale ranging from 1 ($0) to 13 ($1001+)), tertiary education
(“Have you done any further study since secondary school?” responded yes (1) / no
(0)), health status (“In general would you say your health is…” with response options
coded to reflect excellent/very good/good (1) / fair/poor (0)), smoking (“Have you
smoked cigarettes in the past year?” recoded as yes (1) / no (0)), peer sports
participation (“In the past year, how many of your best friends have been involved in sports, clubs, organisations, or other activities in their community?”, with responses reported using a 5-point scale ranging from (0) none of my friends to (4) four of my friends), and family physical activity (“In the past year, how often have members of your family engaged in physical activities to improve their health such as running, aerobics, biking or other exercise?”, reported using a 5-point scale ranging from never (1) to very often (5)). The 2002 grade cohort in which the IYDS students were recruited was recorded (Grades 5 – Youngest; Grade 7 - Middle and Grade 9 - Oldest).

**Physical activity and sedentary behaviour**

Physical Activity (PA) and sitting time were assessed using the International Physical Activity Questionnaire (Short form; IPAQ-S). The 6-items measure has frequently been utilised to assess adult physical activity in population level studies (Ainsworth et al., 2006; Wooden, 2014), and holds appropriate psychometric properties (Bauman, Bull, et al., 2009). Participants reported on the number of days and the amount of time per day (for 10 minutes or longer) spent engaging in three domains of activity; walking, moderate intensity (e.g., doubles tennis) and vigorous intensity physical activity (e.g., running), during the previous 7 days. Data preparation was conducted according to the IPAQ scoring protocol (IPAQ Research Committee, 2005). The raw items were then recoded as follows.

The frequency of PA was assessed using the number of days participated in each domain, which was then summed to reflect total days of PA (Range = 0 - 21 days). The number of days multiplied by the hours spent engaging in each domain reflected time spent engaged in each domain per week (e.g., vigorous PA days * Time (hours)/ day). Each domain was summed to create total PA/ week (hours).
Consistent with previous research (Kurtze, Rangul, & Hustvedt, 2008), where participants reported engaging in zero days of vigorous, moderate or walking physical activity, the total time variable was recoded to equal zero.

The total weekly volume of PA energy expenditure was calculated for each domain, by multiplying activity domain time (minutes) with a Metabolic Equivalent of Task (METs) score relevant to that domain of activity. The MET-minute reflects an estimate of the approximate amount of energy expenditure for every minute of domain-specific activity engagement (Craig, Marshall, Sjöström, et al., 2003). The MET-minute for each domain was then multiplied by the number of days per week engaged in the domain (e.g., Vigorous PA time (mins) * 8.0 METs * Vigorous PA days/week). This produced three measures of volume in walking, moderate and vigorous intensity physical activity (MET-mins/week), respectively.

Total PA volume reflects the sum of volume across domains (i.e. summing walking, moderate and vigorous intensity MET-mins/week). According to IPAQ coding guidelines (IPAQ Research Committee, 2005), we categorised physical activity into three levels; high PA (Category = 3; equivalent to 1+ hours per day of moderate to vigorous intensity activity), moderate PA (Category = 2; equivalent to 0.5 hours of moderate to vigorous physical activity on most days) and low PA (Category = 1; those who did not meet above criteria). Moderate PA category is comparable to engagement necessary to meet public health physical activity guidelines (IPAQ Research Committee, 2005). The three-level variable was dichotomised to reflect; meeting/ exceeding PA public health guidelines (Categories 2 & 3), and not meeting physical activity guidelines (Category 1).

On the IPAQ-S, respondents reported time (minutes) they spent sitting per weekday whilst at home, work, leisure, or whilst studying (IPAQ Research
Committee, 2005). This was divided by 60 to provide a sitting time per weekday in hours.

**Psychological Distress**

The Kessler Psychological Distress Scale (K10; Kessler et al., 2002) is a 10-item scale designed to measure psychological distress (within the previous 4 weeks). Evidence indicates good internal consistency (Cronbach’s $\alpha = 0.93$; Kessler, et al., 2002 & current study) and higher discriminant validity compared to other measures of psychological distress to identify individuals with anxiety or depressive disorders (Furukawa et al., 2003). Participants responded to each item using a five-point scale ranging from "none of the time" (1) to "all of the time" (5). Items were summed to create a total score, which ranges from 10 to 50, where higher scores reflect higher psychological distress (Andrews & Slade, 2001). The Australian Bureau of Statistics categorisation system was employed in the current study to reflect increasing levels of K10 psychological distress: Low (10 - 15); Medium (16 - 21); High (22 - 29); and Very High (30 – 50) (Australian Bureau of Statistics, 2001).

**Data Preparation and Analysis**

A total of $n = 408$ (17.0% of 2012 possible sample $n = 2399$) were missing for the Sedentary Behaviour (SB) per weekday (hours) variable. Given the large group, examining those with a missing value on this variable was considered important, and thus utilised in further analyses. Total SB was categorised into a 4 level variable, where: 0 – 2.5 hours was coded as Low SB (0); 2.6 – 5.5 hours was coded as Moderate SB (1); 5.6 - 14 hours was coded as High SB (2); and missing was included as the final category (3). A further $n = 42$ (1.8%) were missing on one or more of the key variables (excluding IPAQ sedentary behaviour) and were thus excluded from the analyses. Two analyses were conducted according to Tabachnik
and Fidell (2013) recommendations. First, correlation analyses indicated that missing on the K10 was not significantly related to missing for any of the key variables (those included in the multivariate analyses), and that the Little's MCAR test was significant ($\chi^2$ distance = 824.95, $df = 95$, $p < .001$), which suggests that the data was missing at random. The final sample size included in the analyses, therefore, was $n = 2346$. In order to control for the potential bias associated with attrition, the sample was weighted to reflect the age, gender and school completion ratios within the 2011 Census for the population in Victoria aged 18 to 26 years. In addition, prevalence and associational effect estimates were also adjusted for clustering of responses associated with the original school recruitment of the samples.

Rates of physical activity and sedentary behaviour were reported using means (95% confidence intervals), and median (interquartile range) statistics whilst prevalence of psychological distress was calculated using proportions and 95% Confidence Intervals (CIs). Correlation coefficients were calculated using Pearson’s correlation.

The K10 data was severely positively skewed with the K10 psychological distress scores significantly over-dispersed relative to a Poisson distribution. The negative binomial regression analysis was selected as an appropriate statistical technique for this distribution (Katz, 2011). The independent variables in the multivariate analysis included: physical activity (IPAQ-S dichotomous variable); sedentary behaviour (IPAQ-S sedentary behaviour 4 category variable); gender; IYDS grade cohort; employment; income; health status; smoking; peer sports participation; and family physical activity engagement. Associations were evaluated using Incidence Rate Ratios (IRR). Analyses were completed to evaluate an interaction effect between physical activity and sedentary behaviour on mental
health. All data analyses were conducted using Stata Version 13 IC for Windows (StataCorp, 2013).

Results

**Demographic and personal characteristics**

The sample ($n = 2346$) comprised of 53.7% female participants. One-third (33.4%) were engaged, married, or in a de facto relationship, 82.4% reported being employed, and most earned more than $400 per week (63.7%). Most reported having completed some form of study since high school (86.1%), just over half reported smoking in the previous year (53.0%) and most reported excellent to good health (83.5%).

**Rate of physical activity, sedentary behaviour and psychological distress**

On average, participants reported engaging in approximately 3.6 to 3.9 hours of moderate to vigorous level physical activity, respectively across 2.6 days per week each, and over six hours walking across an average of five days (see Table 6.1). Most young adults reported engaging in PA sufficiently to meet public health guidelines (83.2%; 95% CIs [81.5, 84.9]). Sedentary behaviour was categorised to reflect three approximately equal sized groups. Almost one quarter of participants reported engaging in low sedentary behaviour ($\leq 2.5$ hours/weekday; 22.9%; 95% CIs [20.9, 24.9]), approximately one in three reported engaging in moderate sedentary behaviour ($2.6 – 5.5$ hours/weekday; 29.7%; CIs [27.8, 31.7]), and a similar proportion reported engaging in high levels of sedentary behaviour ($5.6 – 14$ hours/weekday; 30.5%; CIs [28.3, 32.9]). In the 4 weeks prior to completing the survey, 39.5% reported low psychological distress (95% CIs [37.5, 41.5]; K10 scores 10-15), 32.4% reported medium psychological distress (CIs [30.5, 34.3]; K10 scores 16-21), 18.8% reported high psychological distress (CIs [17.3, 20.3]; K10 scores 22-29) and
9.3% of participants reported psychological distress within the very high range (CIs [8.2, 10.5]; K10 scores 30-50).

**Correlates of mental health symptoms**

Meeting physical activity recommendations was negatively associated with K10 psychological distress (see Table 6.2). Longer weekday engagement in sedentary behaviour was associated with higher K10 psychological distress. Female gender, being unemployed, being in a lower income bracket, poorer health status, smoking in the past 12 months, low peer sports participation, and low family physical activity engagement were correlated with higher K10 psychological distress.

**Associations between physical activity, sedentary behaviour and psychological distress**

The multivariate negative binomial regression analysis indicated that the full model was statistically significant, \( F (13, 139) = 24.28, p < .001 \) with \( df = 151 \). Further, it indicated that once psychosocial correlates and sedentary behaviour were controlled for, engaging in physical activity was no longer associated with K10 psychological distress symptoms (see Table 6.3). Those who engaged in high levels of sedentary behaviour (5.6 hours +) reported significantly higher rates of psychological distress, compared to those who engaged in low levels of sedentary behaviour (\( \leq 2.5 \) hours). Independent of other independent variables, those who were female, in the middle and older cohorts, unemployed, lower weekly income, poorer health status, smoked in the previous year, fewer peers who participated in sports and lower family physical activity engagement reported a higher rate of K10 psychological distress. Importantly, analyses of imputed data indicated comparable findings to the analyses conducted on the complete data (See appendix 3).
Table 6.1
Descriptive statistics for physical activity and sedentary behaviour amongst young adults \( (n = 2,346) \).

<table>
<thead>
<tr>
<th>% missing</th>
<th>M</th>
<th>95% CI</th>
<th>Mdn</th>
<th>IQR</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>LL</td>
<td>UL</td>
<td></td>
</tr>
<tr>
<td>Physical activity/ week</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Days (Max. = 21)</td>
<td>0 %</td>
<td>10.0</td>
<td>9.8</td>
<td>10.3</td>
</tr>
<tr>
<td>Time (Hours)</td>
<td>18.2 %</td>
<td>13.9</td>
<td>13.1</td>
<td>14.6</td>
</tr>
<tr>
<td>Volume (MET-mins)</td>
<td>18.2 %</td>
<td>3931.7</td>
<td>3711.1</td>
<td>4452.2</td>
</tr>
<tr>
<td>Walking</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Days (Max. = 7)</td>
<td>0.2 %</td>
<td>4.9</td>
<td>4.8</td>
<td>5.0</td>
</tr>
<tr>
<td>Time (Hours)</td>
<td>13.2 %</td>
<td>6.3</td>
<td>6.0</td>
<td>6.7</td>
</tr>
<tr>
<td>Volume (MET-mins)</td>
<td>13.2 %</td>
<td>1255.3</td>
<td>1182.4</td>
<td>1328.1</td>
</tr>
<tr>
<td>Moderate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Days (Max. = 7)</td>
<td>0.4 %</td>
<td>2.6</td>
<td>2.5</td>
<td>2.7</td>
</tr>
<tr>
<td>Time (Hours)</td>
<td>9.9 %</td>
<td>3.9</td>
<td>3.6</td>
<td>4.2</td>
</tr>
<tr>
<td>Volume (MET-mins)</td>
<td>9.9 %</td>
<td>938.3</td>
<td>867.2</td>
<td>1009.4</td>
</tr>
<tr>
<td>Vigorous</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Days (Max. = 7)</td>
<td>0.1 %</td>
<td>2.6</td>
<td>2.4</td>
<td>2.7</td>
</tr>
<tr>
<td>Time (Hours)</td>
<td>7.4 %</td>
<td>3.6</td>
<td>3.4</td>
<td>3.9</td>
</tr>
<tr>
<td>Volume (MET-mins)</td>
<td>7.4 %</td>
<td>1739.1</td>
<td>1612.1</td>
<td>1864.1</td>
</tr>
<tr>
<td>Sedentary behaviour/ weekday</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time (Hours)</td>
<td>17.4 %</td>
<td>5.0</td>
<td>4.8</td>
<td>5.1</td>
</tr>
</tbody>
</table>

Note. CI = confidence intervals; Mdn = Median; IQR = interquartile range; LL = lower limit; UL = upper limit; Max = maximum, MET-mins = estimate of energy per minute of activity; Sedentary behaviour = sitting time per weekday (hours). Means and 95% CIs were weighted to reflect the 2011 Census age, gender and school completion rates and adjusted for response clustering in the originally recruited school samples. Median and interquartile range estimates are unweighted and unadjusted for school clustering.
Table 6.2

Correlations for K10 psychological distress, physical activity, sedentary behaviour and correlates (n = 2,346).

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3a</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. K10</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>2. PA</td>
<td>-0.06*</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. SBa</td>
<td>0.09***</td>
<td>-0.06**</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Female</td>
<td>0.13***</td>
<td>-0.11***</td>
<td>0.00</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>5. Employment</td>
<td>-0.13***</td>
<td>0.10***</td>
<td>-0.04</td>
<td>-0.04*</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Income</td>
<td>-0.15***</td>
<td>0.07***</td>
<td>-0.07**</td>
<td>-0.10***</td>
<td>0.42***</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Health status</td>
<td>-0.26***</td>
<td>0.19***</td>
<td>-0.06**</td>
<td>-0.05**</td>
<td>0.10***</td>
<td>0.07***</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Smoking</td>
<td>0.13***</td>
<td>0.01</td>
<td>-0.02</td>
<td>-0.06**</td>
<td>0.01</td>
<td>0.07***</td>
<td>-0.05**</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Peer Sports</td>
<td>-0.20***</td>
<td>0.19***</td>
<td>0.04</td>
<td>-0.19***</td>
<td>0.07***</td>
<td>0.01</td>
<td>-0.16***</td>
<td>-0.05*</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>10. Family PA</td>
<td>-0.10***</td>
<td>0.15***</td>
<td>0.08***</td>
<td>0.05*</td>
<td>0.05*</td>
<td>-0.04</td>
<td>0.10***</td>
<td>-0.02</td>
<td>-0.22***</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Note. Correlations were weighted for 2011 Census age, gender and school completion rates. K10 = Kessler-10 psychological distress; PA = IPAQ categorical (Low PA = 0, Moderate to high PA = 1); SB = categorical sitting time (hours) per weekday; Female = gender (Female = 1, Male = 0); Employment = If currently employed (Yes = 1, No = 0); Income = amount of weekly income; Health status = self-reported health (Excellent to good = 1, fair to poor = 0); Smoking = If smoking in previous 12 months (Yes = 1, No = 0); Peer Sports = Number of friends who participated in sports and/or physical activity; Family PA = Family physical activity engagement.

*a Correlations for SB exclude category 3 (missing) (n = 1949).

* p < .05, ** p < .01, *** p < .001.
Table 6.3

Results of negative binomial regression analyses of associations between K10 psychological distress, physical activity and sedentary behaviour (n = 2,346).

<table>
<thead>
<tr>
<th>Psychological distress</th>
<th>95% CI</th>
<th></th>
<th></th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>PA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SB</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low (referent)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>1.01</td>
<td>0.97</td>
<td>1.04</td>
<td>0.26</td>
<td>.80</td>
</tr>
<tr>
<td>High</td>
<td>1.07</td>
<td>1.03</td>
<td>1.11</td>
<td>3.50</td>
<td>.001</td>
</tr>
<tr>
<td>Missing</td>
<td>1.02</td>
<td>0.97</td>
<td>1.07</td>
<td>0.72</td>
<td>.47</td>
</tr>
<tr>
<td>Female</td>
<td>1.08</td>
<td>1.04</td>
<td>1.11</td>
<td>4.25</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Cohort</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Youngest (referent)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle</td>
<td>1.04</td>
<td>1.00</td>
<td>1.08</td>
<td>2.16</td>
<td>.03</td>
</tr>
<tr>
<td>Oldest</td>
<td>1.04</td>
<td>1.00</td>
<td>1.08</td>
<td>2.23</td>
<td>.04</td>
</tr>
<tr>
<td>Employment</td>
<td>0.96</td>
<td>0.92</td>
<td>1.00</td>
<td>-2.19</td>
<td>.03</td>
</tr>
<tr>
<td>Income</td>
<td>0.98</td>
<td>0.98</td>
<td>0.99</td>
<td>-6.00</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Health status</td>
<td>0.82</td>
<td>0.79</td>
<td>0.85</td>
<td>-9.98</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Smoking</td>
<td>1.11</td>
<td>1.08</td>
<td>1.14</td>
<td>7.18</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Peer sports</td>
<td>0.97</td>
<td>0.96</td>
<td>0.98</td>
<td>-6.53</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Family PA</td>
<td>0.98</td>
<td>0.97</td>
<td>0.99</td>
<td>-2.90</td>
<td>.004</td>
</tr>
</tbody>
</table>

Note. Psychological distress = K10 psychological distress; IRR = Incident Rate Ratios; CI = Confidence Intervals for IRR; LL = lower limit; UL = upper limit; PA = IPAQ categorical (Low PA = 0, Moderate to high PA = 1); SB = categorical sitting time (hours) per weekday; Female = gender (Female = 1, Male = 0); Cohort = age group of the IYDS sample (Youngest \( M_{\text{age}} = 21.1, SD = 0.5 \), Middle \( M_{\text{age}} = 23.1, SD = 0.5 \), Oldest \( M_{\text{age}} = 25.0, SD = 0.5 \); Employment = If currently employed (Yes = 1, No = 0); Income = amount of weekly income; Health status = self-reported health (Excellent to good = 1, fair to poor = 0); Smoking = smoking in previous 12 months (Yes = 1, No = 0); Peer Sports = Number of friends who participated in sports and/or physical activity; Family PA = Family physical activity engagement; \( F = F \) Ratio test; \( p \) = statistical significance (probability). The distribution for the K10 psychological distress distribution was significantly over-dispersed and adjusted using negative binomial regression.

Interaction effect of physical activity and sedentary behaviour on mental health

To test for an interaction effect between physical activity and sedentary behaviour, I first conducted a negative binomial regression with physical activity,
sedentary behaviour and the physical activity by sedentary behaviour interaction term to predict psychological distress. This analysis suggested that compared to those who engaged in Low SB, those who engaged in moderate SB (2.6 to 5.5 hours/weekday) reported higher psychological distress ($IRR = 1.13$, 95% CIs [1.00, 1.26], $t = 2.06$, $p = .04$). Those who engaged in high SB reported similar levels of psychological distress ($IRR = 1.01$, 95% CIs 0.90, 1.13], $t = 0.15$, $p = .88$) as compared to the reference group. Then, I tested the parameters to determine if there was a trend towards an interaction term, the results of which suggested that there was no significant effect, $F (3, 149) = 1.68, p = .17$.

Then, I ran the negative binomial regression, with all psychosocial covariates included in the model. Compared to the reference group (Low SB, either Low PA or High PA), there was no significant difference in psychological distress to those who engaged in moderate SB and high PA ($IRR = 1.06$, 95% CIs [0.95, 1.17], $t = 1.08$, $p = .28$), in the high SB and high PA group ($IRR = 0.98$, 95% CIs [0.88, 1.09], $t = -0.30$, $p = .76$), or the missing SB and high PA group ($IRR = 1.10$, 95% CIs [0.99, 1.23], $t = 1.72$, $p = .09$). Then, I tested the parameters to determine if there was a trend towards an interaction term, the results of which suggested that there was no significant effect, $F (3, 149) = 1.68, p = .17$.

Overall, the analyses indicate that there is no significant interaction effect of physical activity and sedentary behaviour on psychological distress of young adults. As a result, it was removed from the multivariate model.
Discussion

The current study identified the prevalence rates of psychological distress and engagement in physical activity and sedentary behaviour in a young adult sample. Also, independent associations between physical activity, sedentary behaviour, and mental health symptoms were investigated, in a state representative sample. Approximately 28% of the sample reported experiencing high to very high psychological distress, a third reported engaging in 5.6 or more hours per weekday sitting, and most young adults reported engaging in sufficient levels of physical activity to meet public health guidelines. The results supported the hypothesis that long periods of engagement in sedentary behaviour were related to poorer mental health. Contrary to the hypotheses, the negative correlation found between physical activity and mental health symptoms was non-significant in the multivariate analyses associated with K10 psychological distress.

Compared to the 2007 Household, Income and Labour Dynamic survey in Australia (HILDA) young adult data (Cvetkovski et al., 2012), young adults in the current sample reported higher rates of high to very high psychological distress, respectively (High to very high psychological distress HILDA = 20.7% vs. IYDS = 28.1%; Cvetkovski et al., 2012). This suggests that the present results are higher than the Australian national samples in observing high rates of psychological distress in young adults. These differences may be partly accounted for by differences in geographical sampling methodology (HILDA is a national representative survey, IYDS is a Victorian-based survey) and the different age range of participants (HILDA = 18 – 24 years versus IYDS = 19 – 26 years). Recent Australian Bureau of Statistics estimates of psychological distress indicate that compared to the general Australian adult, that a higher proportion
of Victorian adults present with high to very high psychological distress (K10 = 22 to 50; Australia 11.7% vs Victoria 12.5%). It is unclear why there is this discrepancy, but it presents as a plausible explanation for the differences between the IYDS and HILDA studies. In addition, as suggested by the life course theory, some mental health contributing factors may have particularly strong influences on young adult mental health, relative to other developmental periods (Pillas et al., 2014). Therefore, perhaps the differences in psychological distress levels reflect the capture of adults within two adjacent but different developmental stages. Participants who report K10 psychological distress in the very high range have been found to be at increased risk of anxiety or depressive disorders (Andrews & Slade, 2001).

Further, most young adults in the current study reported engaging in high levels of sedentary behaviour and engaging in sufficient physical activity to meet public health guidelines. The current sample reported higher rates of physical activity as compared to the HILDA sample (IYDS = 83.2% vs. HILDA 18-39 year old males = 80.2%, females = 71.5%; Wooden, 2014). There are several possible reasons to explain the high rates of physical activity engagement reported in the current study including seasonality in questionnaire administration, sample age range, and social desirability bias. These factors are detailed further in Chapter 8.

The current study examined the association between physical activity and mental health symptoms in a contemporary young adult sample. The bivariate correlations supported the stated hypotheses and previous research (Sloan et al., 2013; VanKim & Nelson, 2013) findings that engaging in physical activity sufficiently to meet minimum current public health recommendations was associated with reduced psychological distress (Hamer et al., 2014). The associations between physical activity and
psychological distress symptoms were no longer significant once the multivariate adjustment for psychosocial covariates occurred, contrary to previous research.

There are several possible reasons why physical activity was not associated with psychological distress symptoms in the multivariate model. First, the possibility that physical activity does not act independently but in interaction with sedentary behaviour was investigated. Whilst an interaction effect between physical activity and sedentary behaviour has previously been found (Sloan et al., 2013) the current results did not support this finding. The contrast with prior studies could be a result of differences in sample age, where the current study reflects a young adult sample as distinct to Sloan et al. (2013) who included older adults in their sample (18 – 79 years). However, the present study found a bivariate association of a similar magnitude to prior studies. Hence, it is concluded that the absence of a multivariate effect for physical activity was most likely related to the inclusion of a wider range of psychosocial correlates in the present study compared to previous studies. The current study reinforces previous findings that a greater rate of mental health symptoms is associated with correlates that include: female gender; poorer health status; unemployment; lower income; and those with fewer family members who engaged in physical activity; or peer members who participated in physical activity. The current finding thus supports the possibility that at least some of the association between physical activity and reduced psychological distress may be explained by other health and social factors that influence both physical activity and mental health (Teychenne et al., 2008). The processes through which the effect of physical activity on mental health symptoms is mediated by psychosocial factors warrants further study.
Consistent with previous research, the finding that higher sedentary behaviour associated with worse mental health symptoms remained significant once psychosocial covariates were included in the model (Teychenne et al., 2010; Teychenne et al., 2015). Specifically, compared to those who engaged in 2.5 or fewer hours of sedentary behaviour per weekday, young adults who engaged in 5.6 or more hours of sedentary behaviour had 7% higher psychological distress symptoms. Those who engaged in 2.6 to 5.5 hours of sedentary behaviour did not significantly differ in their psychological distress compared to those who engaged in 2.5 hours or less. This suggests that there may be a threshold level at which sedentary behaviour begins to be associated with psychologically detrimental outcomes. This is supported by Sloan and colleagues' (2013) findings, who found that those who engaged in 10 or more hours of sedentary behaviour reported significantly higher psychological distress than those who reported engaging in 2.5 or fewer hours of sedentary behaviour per weekday. The current study findings suggest that excessive sedentary behaviour (defined in the current study as 5.6 or more weekday hours) is associated with poorer mental health symptoms across a range of symptomology.

The current findings go beyond prior studies in showing that engaging in high levels of sedentary behaviour is associated with higher poor mental health symptoms after adjusting for young adult physical activity and a wide range of psychosocial correlates. The mechanism that explains the association between sedentary behaviour and higher mental health symptoms have been debated. In their systematic review (Teychenne et al., 2015) argued that possible explanations may include: biological impacts of sedentary behaviour on central nervous system arousal, sleep and metabolic health; reduced psychological benefits of physical activity; and withdrawal from social
and interpersonal relationships. The present findings suggest that the effect of sedentary behaviour is maintained after controlling for the influences of physical activity, physical health and social relationships. It remains possible that young adult mental health problems may precede higher rates of sedentary behaviour (Teychenne et al., 2015). Future research should seek to elucidate the temporal processes and mechanisms that underlie the association between sedentary behaviour and mental health symptoms.

Study strengths include the large contemporary sample of young adults selected as a state representative cohort, the use of well-validated measures and multivariate analyses. In addition, the current analysis was weighted to Census data to provide population estimates and to reduce potential bias associated with attrition. Further, relative to previous research in this field, the analyses reported in the present study controlled for a wider range of correlates. Unlike previous research, the present study examined the associations of physical activity and sedentary behaviour with prevalent mental health symptoms.

Limitations include the cross-sectional design that restricts causal inferences. Further research is required to examine the temporal processes that underlie the association between sedentary behaviour, physical activity and mental health (Sloan et al., 2013). Second, as the data was gathered via self-report, there is a potential respondent bias. It is unlikely that this is a large concern given evidence that the K10 and IPAQ-S are valid and reliable measures (Andrews & Slade, 2001; Bauman, Ainsworth, et al., 2009). Third, whilst the present study uniquely considered peer participation in sports, the measure reflected involvement in sports and other community activities, which limits the behavioural specification of this measure. As relevant to sedentary behaviour, the IPAQ-S assessed information regarding general sitting time, it
provided little information regarding the context or activity in which sedentary
behaviour occurs. Researchers suggest that context (e.g., work, transport, leisure), and
activity (TV viewing, computer use, socialising) are important to consider when
investigating the role of sitting time (Arredondo et al., 2013; Atkin et al., 2012; Sloan et
al., 2013).

The findings reveal that most Australian young adults report engaging in high
levels of sedentary behaviour while also engaging in sufficient physical activity to meet
public health guidelines. Those who report this combination of physical activity and
sedentary behaviour, named 'active couch potatoes', have been found to be at increased
risk of chronic illness (Owen et al., 2010). Contrary to previous research, the bivariable
association between physical activity and mental health was no longer significant after
controlling for sedentary behaviour and psychosocial correlates. The findings suggest
that irrespective of engaging in sufficient physical activity, age, gender, employment,
income, health status, smoking, peer and family engagement in physical activity, young
adults who engage in 5.6 or more hours of sedentary behaviour per weekday are more
likely to report poorer mental health than those who engage in less. In light of the
increasing evidence of the likely detrimental effect of sedentary behaviour (Teychenne
et al., 2015), and paucity of public health guidelines (Hamilton et al., 2008), the current
study results offer some evidence regarding the amount of sedentary behaviour
engagement that relates to poorer mental health amongst young adults. Prospective
studies will help to determine the extent to which sedentary behaviour engagement has a
longer term influence on mental health.
Summary

The current Chapter presented the findings from a cross-sectional study that investigated the independent, and interacting associations between physical activity and sedentary behaviour on young adult mental health. The methodology was stronger than that of the existing literature, in regards to the quality of physical activity and sedentary behaviour measures utilised, the sampling methodology and the covariates included in the multivariate analyses. The study findings indicate that contrary to the consensus of previous research, physical activity was not associated with young adult mental health, whilst sedentary behaviour remained relevant. The following Chapter will report an analysis of the prospective relationships between physical activity and sedentary behaviour and young adult psychological distress.
Chapter 7: Study 2 Prospective effects of sedentary behaviour and physical activity on young adult mental health

In Chapter 6, it was found that physical activity was not independently or in interaction with sedentary behaviour, associated with young adult mental health. This suggests that physical activity may have an effect on mental health that is not maintained once known correlates are controlled. The systematic literature review indicated that there were longitudinal studies that examined physical activity effects on mental health and found significant inverse relationships (Ball et al., 2009; Henchoz et al., 2014; Ströhle et al., 2007). Despite the null cross-sectional findings in the current study and in light of the previous research consensus, it is necessary to consider the extent to which physical activity may play a role in influencing long-term young adult mental health.

Chapter 6 indicated a significant multivariate association between sedentary behaviour and mental health. Only one previous study in the systematic review (Chapter 5) considered the prospective relationship between sedentary behaviour and mental health amongst young adults (Thomée et al., 2012). In light of the findings, the following Chapter will also investigate the prospective effects of sedentary behaviour and physical activity on mental health. The sections that follow have been written in a form suitable to be developed into a journal article submission. For this reason, some of the concepts included in the earlier sections of this thesis are summarised in what follows.
Abstract

**Objective:** Previous studies suggest that sedentary behaviour and physical activity are associated with mental health problems. The extent to which this is true for young adults is unclear. The current study investigated the possible prospective impact of sedentary behaviour and physical activity on psychological distress (anxiety and depressive symptoms) among young adults. **Methods:** A large, state-representative cohort of students in Victoria, Australia was recruited in 2002 using a two-stage cluster sampling approach. Participants completed an online survey at two time points in young adulthood; 2010 ($M_{age} = 21.0, SD = 1.7$) and 2012 ($M_{age} = 23.0, SD = 1.7$; 55.2% female; $n = 2206$). The International Physical Activity Questionnaire (Short form) was used to measure physical activity and sedentary behaviour, whilst the Kessler Psychological Distress Scale was used to measure psychological distress. Multivariate negative binomial regression and logistic regression analyses were conducted to predict the effect of sedentary behaviour and physical activity on mental health, controlling for baseline symptoms, gender, employment status, income, smoking status, health status, peer physical activity engagement, and family exercise engagement. **Results:** Sedentary behaviour in 2010 showed a small significant association with higher psychological distress 2-years later ($r = .06, p = .03$). However, this effect was not maintained in multivariate adjusted analyses. Physical activity in 2010 was not related to higher psychological distress 2-years later in the bivariate or multivariate analyses. Higher psychological distress, low health status, smoking and having few peers who engage in sports in 2010 predicted psychological distress 2-years later. Higher psychological distress, unemployment, low health status and having few peers who engage in sports at 2010 were prospective risk factors for high risk of mental illness at 2012. **Conclusions:**
The current study findings suggest that sedentary behaviour (defined as overall sitting time) and physical activity are not prospective and independent risk factors for young adult mental health. Future research is needed to determine the extent to which sedentary behaviour in different contexts (e.g., leisure time, work), and physical activity amongst young adults with specific psychosocial characteristics, experience different effects on mental health.

**Introduction**

Young adults experience the highest prevalence of common mental illnesses of Australian adults based on symptoms of depression, anxiety (Australian Bureau of Statistics, 2009) and psychological distress (Casey, 2013). Mental disorders account for 17.6 total Disability-Adjusted Life Years (DALYs) lost per 1000 people and is the second leading cause of DALYs lost during young adulthood (Begg et al., 2008). Mental health problems during young adulthood carry the risk of long-term difficulties in not only mental health but also career development and interpersonal relationships (Wittchen et al., 1998). To reduce this burden, Australian researchers (e.g. Jacka et al., 2013) have called for a greater focus on identifying influencing factors that are amenable to change, at the population level. The current study will investigate the prospective impact of physical activity and sedentary behaviour on mental health.

The association between sedentary behaviour and mental health has received increasing empirical attention (Atkin et al., 2012). Previously conceptualised as low-level physical activity (Pate et al., 2008), sedentary behaviour is now defined as sitting or lying down across contexts and activities such as travelling, home and during leisure.
time (Owen et al., 2010). Engagement in prolonged sedentary behaviour predicts increased risk of diabetes, cardiovascular disease and premature death (Wilmot et al., 2012). It is theorised to impact mental health via several pathways; biological impacts of sedentary behaviour on central nervous system arousal, sleep and metabolic health; reduced psychological benefits of physical activity; and withdrawal from social and interpersonal relationships (Teychenne et al., 2015).

Recent research suggests that sedentary behaviour predicts increased risk of anxiety (Teychenne et al., 2015) and depression (Teychenne et al., 2010) amongst adults. For example, van Uffelen and colleagues (2013) found that amongst 8950 middle-aged (50 – 55 years) women, those who engaged in 7 or more hours of daily sitting were at 47% increased the risk of depression, compared to those who engaged in 4 or fewer hours. Sloan and colleagues (2013) similarly investigated the association between sedentary behaviour and psychological distress in a large sample of adults (n = 4337; 18 - 79 years). They found that after controlling for confounders (including gender, physical activity, ethnic group, chronic illness, relationship status, income, and substance use), adults who engaged in 10 or more hours of sedentary behaviour experienced significantly higher psychological distress than those who engaged in 2.5 or fewer hours per day. Whilst these studies suggest a positive association between sedentary behaviour and mental health, most studies conducted thus far reflect cross-sectional findings (Teychenne et al., 2010) and are not based on young adult samples.

It is important to investigate the prospective effect of sedentary behaviour on mental health amongst young adults, given that predictors of mental health are developmental life-stage, age and cohort-specific (Pillas et al., 2014). Compared to previous generations, young Australian adults are now more likely to engage in higher
education and employment pursuits that require prolonged periods of sedentary
behaviour (Australian Bureau of Statistics, 2012b). Lifestyle patterns, including
sedentary behaviour, also begin to settle in the early twenties and their influence on
mental health is likely to be maintained from early adulthood (Pinto Pereira et al., 2014).

In the sole study prospectively examining the effects of sedentary behaviour in a
young adult sample, Thomee and colleagues (2012) considered the effects of computer
use on stress and depressive symptoms. They found that young women (20 – 24 years)
who engaged in more than 4 hours of computer use per day were at increased risk of
stress and depressive symptoms than those who engaged in less than two hours per day.
Given that efforts to develop public health guidelines have largely referenced sedentary
behaviour in terms of time spent sitting (Owen et al., 2010), there is a need to investigate
the effect of overall sitting time on mental health.

In order to determine the independent effect of sedentary behaviour on mental
health, it is important to control for factors that have been found to influence this
relationship. Factors include: gender (Saunders & Daly, 2001); income (Arredondo et
al., 2013); employment (Asztalos et al., 2009); health status (Cerin et al., 2009); and
peer and family participation in physical activity (King et al., 2013; Trost et al., 2002).

The relationships between physical activity and sedentary behaviour, and
physical activity on mental health have been widely debated. Defined as any bodily
movement that causes a level of bodily energy expenditure above resting level
(Caspersen et al., 1985), physical activity appears to lead to small but significant
improvements in mental health (Cooney et al., 2013; Josefsson, Lindwall, & Archer,
2014; Mammen & Faulkner, 2013). Physical activity holds only a small inverse
association with sedentary behaviour (Biddle et al., 2003; Biddle, Gorely, et al., 2004; Biddle, Marshall, et al., 2004).

The effects of physical activity on mental health amongst young adults remains unclear. Some prospective studies have found that increased engagement in physical activity is associated with improved mental health amongst young adults (McPhie & Rawana, 2015a; Perales, del Pozo-Cruz, & del Pozo-Cruz, 2014), whilst others found no significant association (Harris et al., 2006; Mammen & Faulkner, 2013). Null findings are likely to reflect mental health measures with poor psychometric properties (Pinto Pereira et al., 2014) and a limited operationalisation of physical activity, such as over-reliance on frequency (Mammen & Faulkner, 2013). Some studies that have considered engagement in moderate to vigorous physical activity have found significant mental health effects (Sloan et al., 2013). Recommended adult physical activity engagement is defined as 150 minutes of moderate to vigorous physical activity per week (World Health Organisation, 2011). The majority of young Australians (53% of 18-24-year-olds) report that they do not engage in sufficient physical activity to meet public health guidelines (Australian Institute of Health and Welfare, 2011). Whilst longitudinal research examining how sedentary behaviour independently affects young adult mental health is recognised as important, the majority of longitudinal work completed to date has considered physical activity (Brunet et al., 2013; Harris et al., 2006; Stavrakakis, de Jonge, Ormel, & Oldehinkel, 2012) or sedentary behaviour (Thomée, Härenstam, & Hagberg, 2012a) independent of one another. The current study will, therefore, consider the role of sedentary behaviour in predicting mental health, independently of moderate to vigorous physical activity engagement. Further, including physical activity as a prospective predictor in the multivariate analyses will also help to shed light on the
extent to which physical activity is an independent predictor of mental health amongst young adults.

Limited work has identified the extent to which engagement in sedentary behaviour is a risk factor for mental illness. In the current study, the Kessler-10 (K10) scale will be utilised as a measure of mental health. The K10 is a measure of psychological distress, which is characterised by anxiety and depressive symptoms (Kessler et al., 2002). Over three-quarters of adults who reported scores 30 or higher on the total K10 score also reported being diagnosed with a mental illness (76.3% to 87.5%; Andrews & Slade, 2001). As a result, the extent to which those who engage in sedentary behaviour and physical activity are at high risk of being diagnosed with a mental disorder in the sample (K10 total = 30+) is analysed in the current study.

The current study examines data from the young adults who participated in the International Youth Development Study (IYDS) in 2010 and 2012. As rates of engagement in 2012 physical activity and sedentary behaviour are reported in Chapter 6, herein the 2010 rates of engagement will be reported. The longitudinal relationships between sedentary behaviour, physical activity and psychosocial characteristics with mental health will be addressed. Importantly, the current study aimed to investigate the prospective independent effects of sedentary behaviour (indicated by sitting time) and physical activity (indicated by moderate to vigorous physical activity sufficient to meet public health guidelines), on mental health (indicated by psychological distress symptoms).
Methods

Participants

Australian young adults, participating in the IYDS were included in the current study. To reiterate from Chapter 6, the IYDS is an ongoing, 12 year follow up study involving 2884 adolescent students (74.0% of approached sample). Initial recruitment occurred in 2002, of a state-representative sample of Victorian school students in three cohorts, namely the youngest (Grades 5), middle (Grade 7) and oldest (Grade 9) students. Details regarding recruitment methodology are described in Chapter 6. Participating students were those who had parental and provided their own consent to enter the study. Students were followed annually for the first three years of the study and at less regular intervals thereafter.

The current study reflects two waves of data from this larger longitudinal study. The waves selected for analysis were restricted to the 2010 and 2012 follow-up surveys as the measures of interest were gathered only at these waves. In 2010, the participants were aged 18 to 25 years \((M_{\text{age}} = 21.0, SD = 1.7)\), and 19 to 26 years in 2012 \((M_{\text{age}} = 23.0, SD = 1.7)\). The sample for the current study reflects those who responded to most key measures at both waves \((n = 2206; 76.5\% \text{ of sample recruited in 2002})\). Although the results that follow are based on unimputed data, it is noted that analyses were repeated after imputing all missing data and that these analyses produced similar results.

Ethics

As indicated in Chapter 6, ethics approval for the IYDS project was gained from the University of Melbourne Human Ethics in Research Committee. Participants were contacted by the IYDS research team, and once they provided informed consent,
responded to an online survey, that took approximately one hour to complete. Upon completion, respondents were provided with a gift voucher. Ethics exemption was provided by Deakin University Human Research Ethics Committee to conduct the present study using de-identified data.

**Measures**

**Psychological distress**

The Kessler Psychological Distress Scale (K10; Kessler et al., 2002) is a 10-item scale designed to measure psychological distress (within the previous 4 weeks), and items reflect depressive and anxiety symptoms (Andrews & Slade, 2001). Evidence indicates good internal consistency (Current study K10 2010 Cronbach’s α = 0.92) and higher discriminant validity when compared with other measures of psychological distress to identify individuals with anxiety or depressive disorders (Furukawa et al., 2003). Participants responded to each item using a five-point Likert scale ranging from "none of the time" (1) to "all of the time" (5). The 10 items were summed to create a total score, ranging from 10 to 50, where higher scores reflect higher psychological distress (Andrews & Slade, 2001). The K10 total scores at 2010 and 2012 were categorised to reflect levels of psychological distress, defined by the Australian Bureau of Statistics categorisation system: Low (10 - 15); Medium (16 - 21); High (22 - 29); and Very High (30 - 50; Australian Bureau of Statistics, 2001). Further, a dichotomous variable was created where those who scored in the Very High range were coded as 1, and those who scored in the Low to High range were coded as 0.
**Sedentary behaviour**

One item from the International Physical Activity Questionnaire (Short form; IPAQ-S) was utilised to measure sedentary behaviour. Specifically, the IPAQ-S required participants to report on the amount of total time (Item total time in minutes/ weekday) that they engaged in sitting whilst at home, work, leisure or doing student course work, during a weekday. The total sedentary behaviour (mins) variables at 2010 and 2012, where higher scores reflected more time spent sitting per weekday, were divided by 60 to reflect total sitting time in hours. The IPAQ-S has frequently been utilised in population level studies (Wooden, 2014) and has appropriate psychometric properties (Bauman, Ainsworth, et al., 2009; Craig, Marshall, Sjostrom, et al., 2003).

**Physical activity**

The remaining 6 items from the IPAQ-S was also utilised to measure physical activity. The sample was assigned to three levels of physical activity based on the IPAQ scoring protocol (IPAQ Research Committee, 2005); Low, Moderate and High. The Moderate level of PA is comparable to meeting public health physical activity recommendations (IPAQ Research Committee, 2005), whilst High reflects exceeding those recommendations. The 2010 and 2012 categorical variables were dichotomised (0 = Low, 1 = Moderate to High), to reflect moderate to vigorous physical activity at 2010 and 2012.

**Psychosocial characteristics**

Respondents reported on age (years), gender, current employment status, marital status, weekly income from all sources, tertiary education, health status, smoking in previous year, peer sports participation (“In the past year, how many of your best friends
have been involved in sports, clubs, organisations, or other activities in their
community?”, with responses reported using a 5-point scale ranging from (0) none of
my friends to (4) four of my friends), and family physical activity (“In the past year,
how often have members of your family engaged in physical activities to improve their
health such as running, aerobics, biking or other exercise?”, reported using a 5-point
scale ranging from never (1) to very often (5)). The 2002 grade cohort in which the
IYDS students were recruited was recorded (Grades 5 – Youngest (0); Grade 7 - Middle
(1) and Grade 9 - Oldest (2)).

Data preparation

Missing data

The IPAQ-S required respondents to estimate how much time they had spent
engaging in Sedentary Behaviour (SB; Sitting) on average per day over the past week. A
number of respondents did not provide an estimate for this question. In 2010, \( n = 621 \)
did not answer this question (25.6% of \( n = 2423 \)), whilst in 2012, a further \( n = 360 \)
(16.1% of \( n = 2239 \)) did not answer. Given the large non-response group, a missing
value level was utilised on this variable in analyses. Those that provided estimates of
their SB were divided into three roughly equal groups, resulting in total SB being
categorised into a 4 level variable, where: 0 – 2.5 hours was coded as Low SB (0); 2.6 –
5.5 hours was coded as Moderate SB (1); 5.6 - 14 hours was coded as High SB (2); and
missing was included as the final category (3).

Statistical analyses

The prevalence rates of physical activity, sedentary behaviour and psychological
distress in 2010 were calculated, with 95% Confidence Intervals (CIs; Table 7.1). The
change in physical activity, sedentary behaviour and psychological distress were calculated by the proportion of those at 2010 that maintained, increased or decreased their activity levels at 2012 (Table 7.2). The Pearson’s correlations (and significance levels) between sedentary behaviour, physical activity, psychosocial characteristics and K10 psychological distress at 2010 and 2012 were calculated (Table 7.3).

Multivariable analyses using both negative binomial regression and logistic regression were conducted to determine the effect of sedentary behaviour on psychological distress. The K10 responses were skewed with features approximating an over-dispersed Poisson distribution (K10 total score variance = 52.10; Skew = 1.20; Likelihood-ratio test rejected the hypothesis that the distribution was Poisson, \( \chi^2 (1) = 532.40, p < .001, n = 2373 \)). Similarly to the results presented in Chapter 6, analyses were conducted using negative binomial regression (Table 7.4) as it as an appropriate statistical technique for an overly dispersed Poisson distribution (Katz, 2011). Further, this statistical technique has been used previously for analyses predicting psychological distress scores (Jorm & Reavley, 2012). To determine the role of sedentary behaviour in predicting very high psychological distress, the K10 was dichotomised, where K10 total score = 10-29 (0; referent group) & K10 total score = 30-50 (1) (Table 7.4; Australian Bureau of Statistics, 2001). The multivariate models included the following 2010 predictors: baseline psychological distress, physical activity (IPAQ-S dichotomous variable); sedentary behaviour (IPAQ-S sedentary behaviour 4 category variable); gender; IYDS grade cohort; employment; income; health status; smoking; peer sports participation; and family physical activity engagement. In order to control for the potential bias associated with attrition, the sample was weighted to reflect the age, gender and school completion ratios within the 2011 Census (ABS, 2011) for the
population in Victoria aged 18 to 26 years. Correlational effect estimates were also
adjusted for clustering of responses associated with the original school recruitment of
the samples. All data analyses were conducted using Stata 13 IC for Windows (Version
13; StataCorp, 2013).

Results

Demographic and Psychosocial Characteristics

The sample \( (n = 2206) \) comprised of 55.2\% female participants. In 2010, almost
one-quarter (23.1\%) were in a relationship (married, in a de facto relationship or
engaged), 79.1\% reported being employed, and most earned more than $300 per week
(54.3\%). Most reported having completed some form of study since completion of high
school (82.4\%), over half reported smoking in the previous year (55.9\%) and most
reported excellent to good health (82.5\%). Further, 81.5\% (95\% CIs [79.7, 83.2]) of
participants reported engaging in physical activity sufficient to meet public health
recommendations.

Rates of sedentary behaviour engagement and psychological distress are
indicated in Table 7.1. Briefly, the highest proportion of young adults engaged in a high
level physical activity (exceed public health guidelines), and one-quarter engaged in 5.6
or more hours of sedentary behaviour. In addition, approximately one in ten young
adults reported psychological distress in the very high range. Other analyses indicate that
young adults engaged on average in 3.7 hours of moderate physical activity (95\% CIs
[3.4, 4.0]), and 3.6 hours of vigorous physical activity (95\% CIs [3.3, 3.8]), over 2.4
days (95\% CIs [2.3, 2.5]) each. Young adults also spent over 4 hours sitting per day in
2010 \( (M = 4.7, 95\% CIs [4.5, 4.9]) \).
Table 7.1
Rate of psychological distress, physical activity and sedentary behaviour (n = 2206)

<table>
<thead>
<tr>
<th>K10</th>
<th>%</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low (10 – 15)</td>
<td>38.9</td>
<td>[37.0, 40.8]</td>
</tr>
<tr>
<td>Medium (16 – 21)</td>
<td>31.8</td>
<td>[30.0, 33.7]</td>
</tr>
<tr>
<td>High (22 – 29)</td>
<td>19.6</td>
<td>[18.2, 21.2]</td>
</tr>
<tr>
<td>Very high (30+)</td>
<td>9.7</td>
<td>[8.4,11.1]</td>
</tr>
<tr>
<td>Physical activity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>18.5</td>
<td>[16.8, 20.3]</td>
</tr>
<tr>
<td>Moderate</td>
<td>35.6</td>
<td>[33.8, 37.4]</td>
</tr>
<tr>
<td>High</td>
<td>45.9</td>
<td>[43.5, 48.3]</td>
</tr>
<tr>
<td>Sedentary behaviour/ weekday</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low (0 -2.5 hours)</td>
<td>21.9</td>
<td>[20.1, 23.9]</td>
</tr>
<tr>
<td>Moderate (2.6 – 5.5 hours)</td>
<td>26.7</td>
<td>[24.9, 28.6]</td>
</tr>
<tr>
<td>High (5.6+ hours)</td>
<td>25.7</td>
<td>[23.6, 27.9]</td>
</tr>
<tr>
<td>Missing</td>
<td>25.6</td>
<td>[23.7, 22.7]</td>
</tr>
</tbody>
</table>

Note. K10 = Kessler 10 total score; Physical activity = IPAQ categorical rate of physical activity engagement; Sedentary behaviour = total sitting time/weekday. CI = Confidence Interval.

Rate of change in physical activity and sedentary behaviour

Overall, most young adults at 2010 reported engaging in either a moderate level physical activity or high level of physical activity (See Table 7.2). Amongst young adults who engaged in a low level of physical activity at 2010, the majority either maintained their activity at a low level or increased sufficiently to reach a moderate level of activity in 2012. The highest proportion of young adults who engaged in a moderate level of activity at 2010 maintained their level of activity in 2012. A similar pattern was seen for those who engaged in a high level of physical activity at 2010 and 2012.

Comparatively, young adults engaged in similar levels of sedentary behaviour at both 2010 and 2012 (See Table 7.2). Specifically, of those who engaged in 0 to 2.5 hours per weekday in sitting, almost one in three remained as sedentary in 2012.
Consistently, of those who engaged in high levels of sedentary behaviour, almost half continued to engage in 5.6 or more hours of sitting time per weekday in 2012.

Further, rates of psychological distress showed some stability from 2010 to 2012. Specifically, those who reported high psychological distress largely remained at the same level of distress at 2012 or reduced to moderate level distress. However, the largest proportion of those who reported low, moderate or very high psychological distress maintained their level of psychological distress at 2012.

**Unadjusted Analyses**

Prospective correlates of psychological distress. Table 7.3 results show that higher sedentary behaviour in 2010 was associated with significantly higher psychological distress in 2012. Higher psychological distress at 2012 was also more likely to occur amongst those who engaged in low levels of moderate to vigorous physical activity, were female, unemployed, in a lower income bracket, low health status, smoker in the previous 12 months, and had fewer peers who engage in sport and lower family member exercise engagement at 2010. Further associational analyses between higher sedentary behaviour in 2010 and psychological distress at 2012, including those who did not report on the items (e.g., including missing group), showed the association remained significant ($n = 2206, r = .06, p = .003$).
Table 7.2
Proportion (95% CI) of young adult engagement in physical activity, sedentary behaviour and psychological distress across 2010 to 2012 (n = 2206)

<table>
<thead>
<tr>
<th>Physical Activity at 2012</th>
<th>Low</th>
<th>Moderate</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical activity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>411</td>
<td>38.1% (33.4 – 43.0)</td>
<td>35.0% (30.9 – 39.4)</td>
</tr>
<tr>
<td>Moderate</td>
<td>787</td>
<td>16.7% (14.3 – 19.5)</td>
<td>41.9% (38.7 – 45.2)</td>
</tr>
<tr>
<td>High</td>
<td>1008</td>
<td>8.0% (6.5 – 9.9)</td>
<td>26.7% (23.9 – 29.7)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sedentary Behaviour at 2012</th>
<th>Low</th>
<th>Moderate</th>
<th>High</th>
<th>Missing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sedentary behaviour</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>484</td>
<td>34.1% (29.9 – 38.7)</td>
<td>28.5% (24.4 – 33.0)</td>
<td>23.3% (19.9 – 27.1)</td>
</tr>
<tr>
<td>(0 - 2.5hrs)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>588</td>
<td>22.4% (19.1 – 26.2)</td>
<td>40.2% (36.5 – 44.2)</td>
<td>27.4% (23.8 – 31.3)</td>
</tr>
<tr>
<td>(2.6 – 5.5hrs)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>566</td>
<td>15.0% (11.8 – 18.7)</td>
<td>29.7% (26.0 – 33.7)</td>
<td>46.7% (41.9 – 51.7)</td>
</tr>
<tr>
<td>(5.6+hrs)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Missing</td>
<td>568</td>
<td>20.3% (16.9 – 24.0)</td>
<td>22.1% (19.2 – 25.4)</td>
<td>25.0% (21.7 – 28.6)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>K10 Psychological distress at 2012</th>
<th>Low</th>
<th>Moderate</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td>K10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>855</td>
<td>64.2% (60.9 – 67.3)</td>
<td>24.7% (21.8 – 27.7)</td>
<td>8.5% (6.6 – 10.9)</td>
</tr>
<tr>
<td>(0 - 15)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>702</td>
<td>32.3% (28.5 – 36.3)</td>
<td>43.9% (40.0 – 47.9)</td>
<td>19.4% (16.4 – 22.7)</td>
</tr>
<tr>
<td>(16 - 20)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>434</td>
<td>14.9% (11.6 – 19.1)</td>
<td>37.1% (32.9 – 41.5)</td>
<td>33.5% (29.3 – 37.8)</td>
</tr>
<tr>
<td>(21 – 29)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very High</td>
<td>215</td>
<td>11.7% (8.2 – 16.3)</td>
<td>16.3% (12.3 – 21.3)</td>
<td>29.8% (23.7 – 36.7)</td>
</tr>
<tr>
<td>(30+)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. K10 Psychological distress = Kessler 10 categorical level; Physical activity = IPAQ categorical rate of physical activity engagement; sedentary behaviour = total sitting hours/weekday. The proportions reflect the proportion of participants at 2010 who reported their rate at 2012 (e.g. n = 855 reported Low psychological distress at 2010, of which 64.2% reported low psychological distress at 2012).
Adjusted Analyses

*Prediction of total psychological distress.*

The adjusted negative binomial regression analysis indicated that the full model was statistically significant, $F(14, 138) = 88.73, p < .001$ with $df = 151$. Results indicated that neither sedentary behaviour nor physical activity were significant multivariate predictors of psychological distress (Table 7.4). Higher psychological distress at 2012 was more likely amongst participants who reported in 2010 higher psychological distress, poor health status, smoking and fewer peers who engaged in sports. Further analyses (not reported here) showed similar results when analyses were conducted with the continuous sedentary behaviour variable and when the analyses were conducted separately for males and females.

*Prediction of very high psychological distress.*

The adjusted logistic regression analysis results indicated that the full model was statistically significant, $F(14, 138) = 20.80, p < .001$ with $df = 151$. Results indicated that neither sedentary behaviour nor physical activity were significant multivariate predictors of very high psychological distress (Table 7.4). Those who were at increased risk of scoring in the very high psychological distress category at 2012 were those who reported in 2010 very high psychological distress, female gender (approaching significance), unemployment, poor health status and having fewer peers who engage in sports.
Table 7.3
Pearson correlations for 2010 and 2012 K10 total, physical activity, sedentary behaviour and correlates (n = 2206).

<table>
<thead>
<tr>
<th>2010</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. K10</td>
<td>.53***</td>
<td>-.07***</td>
<td>.07**</td>
<td>.17***</td>
<td>-.09***</td>
<td>-.11***</td>
<td>-.19***</td>
<td>.11***</td>
<td>-.19***</td>
<td>-.09***</td>
</tr>
<tr>
<td>2. PA</td>
<td>-.08***</td>
<td>.27***</td>
<td>-.06*</td>
<td>-.13***</td>
<td>.06**</td>
<td>.05*</td>
<td>.11***</td>
<td>-.01</td>
<td>.18***</td>
<td>.13***</td>
</tr>
<tr>
<td>3. SBa</td>
<td>.06*</td>
<td>-.04</td>
<td>.24***</td>
<td>-.02</td>
<td>-.01</td>
<td>-.04</td>
<td>-.07**</td>
<td>.03</td>
<td>-.02</td>
<td>.02</td>
</tr>
<tr>
<td>4. Female</td>
<td>.12***</td>
<td>-.11***</td>
<td>-.02</td>
<td>1.00</td>
<td>-.05*</td>
<td>-.10***</td>
<td>-.06**</td>
<td>-.05*</td>
<td>-.19***</td>
<td>.05*</td>
</tr>
<tr>
<td>5. Employment</td>
<td>-.11***</td>
<td>.05*</td>
<td>.00</td>
<td>-.00</td>
<td>.39***</td>
<td>.29***</td>
<td>.08***</td>
<td>.03</td>
<td>.08***</td>
<td>.07***</td>
</tr>
<tr>
<td>6. Income</td>
<td>-.07***</td>
<td>.06**</td>
<td>-.04</td>
<td>-.05*</td>
<td>.21***</td>
<td>.50***</td>
<td>.00</td>
<td>.08***</td>
<td>-.02</td>
<td>-.02</td>
</tr>
<tr>
<td>7. Health status</td>
<td>-.25***</td>
<td>.08***</td>
<td>-.04</td>
<td>-.05*</td>
<td>.11***</td>
<td>.08***</td>
<td>.39***</td>
<td>-.09***</td>
<td>.12***</td>
<td>.10***</td>
</tr>
<tr>
<td>8. Smoking</td>
<td>.12***</td>
<td>.02</td>
<td>-.02</td>
<td>-.05*</td>
<td>.01</td>
<td>.09***</td>
<td>-.06**</td>
<td>.64***</td>
<td>-.04</td>
<td>-.04</td>
</tr>
<tr>
<td>9. Peer sports</td>
<td>-.17***</td>
<td>.12***</td>
<td>.01</td>
<td>-.21***</td>
<td>.07***</td>
<td>.04*</td>
<td>.13***</td>
<td>-.05*</td>
<td>.44***</td>
<td>.16***</td>
</tr>
<tr>
<td>10. Family PA</td>
<td>-.10***</td>
<td>.11***</td>
<td>.06*</td>
<td>.02</td>
<td>.06**</td>
<td>-.00</td>
<td>.13***</td>
<td>-.02</td>
<td>.19***</td>
<td>.48***</td>
</tr>
</tbody>
</table>

Note. Correlations presented above the diagonal reflect 2012 variables with 2010 variables (e.g. K10 psychological distress at 2012, with 2010 physical activity \( r = -.09 \)), whilst the correlations below the diagonal reflect 2010 variables with 2012 variables (e.g. K10 psychological distress at 2010 with 2012 physical activity \( r = -.08 \)). K10 = Kessler-10 psychological distress; PA = IPAQ categorical (Low PA = 0, Moderate to high PA = 1); SB = categorical sitting time (hours) per weekday; Female = gender (Female = 1, Male = 0); Employment = If currently employed (Yes = 1, No = 0); Income = amount of weekly income; Health status = self-reported health (Excellent to good = 1, fair to poor = 0); Smoking = If smoking in previous 12 months (Yes = 1, No = 0); Peer Sports = Number of friends who participated in sports and/or physical activity; Family PA = Family physical activity engagement. Correlations were weighted for 2011 Census age, gender and school completion rates.

*Correlations for SB reflect data for complete cases for both waves (n = 1463).

\* p < .05, \** p < .01, \*** p < .001.
### Table 7.4
Multivariate regression analyses results of predictors of K10 psychological distress (n = 2206).

<table>
<thead>
<tr>
<th></th>
<th>Negative Binomial Regression(^a)</th>
<th>Logistic Regression(^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>95% CI</td>
<td>95% CI</td>
</tr>
<tr>
<td></td>
<td>IRR</td>
<td>LL</td>
</tr>
<tr>
<td>K10 at 2010</td>
<td>1.02</td>
<td>1.02</td>
</tr>
<tr>
<td>PA</td>
<td>0.99</td>
<td>0.95</td>
</tr>
<tr>
<td>SB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low (referent)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>1.01</td>
<td>0.97</td>
</tr>
<tr>
<td>High</td>
<td>1.01</td>
<td>0.97</td>
</tr>
<tr>
<td>Missing</td>
<td>1.02</td>
<td>0.98</td>
</tr>
<tr>
<td>Female</td>
<td>1.02</td>
<td>0.99</td>
</tr>
<tr>
<td>Cohort</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Youngest (referent)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle</td>
<td>1.01</td>
<td>0.98</td>
</tr>
<tr>
<td>Oldest</td>
<td>1.01</td>
<td>0.97</td>
</tr>
<tr>
<td>Employment</td>
<td>0.96</td>
<td>0.92</td>
</tr>
<tr>
<td>Income</td>
<td>1.00</td>
<td>0.99</td>
</tr>
<tr>
<td>Health status</td>
<td>0.93</td>
<td>0.90</td>
</tr>
<tr>
<td>Smoking</td>
<td>1.04</td>
<td>1.02</td>
</tr>
<tr>
<td>Peer sports</td>
<td>0.98</td>
<td>0.97</td>
</tr>
<tr>
<td>Family PA</td>
<td>1.00</td>
<td>0.98</td>
</tr>
</tbody>
</table>

Note. PA = IPAQ categorical (Low PA = 0, Moderate to high PA = 1); SB = categorical sitting time (hours) per weekday (Low = 0 – 2.5 hours, Moderate = 2.6 – 5.5 hours, High = 5.6+ hours); Female = gender (Female = 1, Male = 0); Cohort = age group of the IYDS sample (Youngest \(M_{age} = 21.1, SD = 0.5\), Middle \(M_{age} = 23.1, SD = 0.5\), Oldest \(M_{age} = 25.0, SD = 0.5\)); Employment = If currently employed (Yes = 1, No = 0); Income = amount of weekly income; Health status = self-reported health (Excellent to good = 1, fair to poor = 0); Smoking = smoking in previous 12 months (Yes = 1, No = 0); Peer Sports = Number of friends who participated in sports and/or physical activity; Family PA = Family physical activity engagement (Never = 1 to very often = 5); \(p\) = statistical significance (probability).

\(^a\) Under Negative Binomial Regression; K10 at 2010 = K10 total score at 2012; IRR = Incident Rate Ratios; CI = Confidence Intervals for IRR, LL = CI Lower limit, UL = CI Upper limit. The distribution for K10 psychological distress was significantly over-dispersed and adjusted using negative binomial regression.  
\(^b\) Under Logistic Regression; K10 at 2010 =
K10 total, where total score 10-29 = 0 (reference group), 30-50 =1; OR = Odds Ratio; CI = Confidence Intervals for OR, LL = CI Lower limit, UL = CI Upper limit.
Discussion

The current study is one of few to consider the longitudinal effect of sedentary behaviour in predicting mental health symptoms amongst young adults. It was found that 2010 sedentary behaviour showed small but significant correlations with 2012 psychological distress. However contrary to the hypothesis, after controlling for physical activity, baseline symptoms and correlates, sedentary behaviour was no longer a significant predictor of mental health.

Although the multivariate results showed a null effect of sedentary behaviour on psychological distress, it is proposed that this was found as a result of two possible reasons. First the relationship between sedentary behaviour and mental health may differ depending on the measure of sedentary behaviour and mental health, and second the effect was based on multivariate control for a large number of covariates. These reasons are explored in what follows.

Evidence supports the possibility that the relationship between sedentary behaviour and mental health may differ according to the type of sedentary behaviour, and type of mental health symptoms. First, other studies that have investigated the effect of sedentary behaviour on mental health have found differing associations based on the type and the context of sedentary behaviour (Atkin et al., 2012; Teychenne et al., 2010). Kilpatrick and colleagues (2013) found, across a large sample of adults \((n = 3367, M_{age} = 46.2 \text{ years})\), that increased work related sitting was associated with increased psychological distress. Further, Thomée et al. (2012) found computer use had an effect on depressive symptoms amongst women, whilst others results’ suggest that TV viewing may have no impact on mental health (Brunet et al., 2013). Sedentary behaviour
involving socialising may have a positive impact on mental health (Arredondo et al., 2013). With a paucity of longitudinal studies, further research to ascertain the extent to which the relationship between sedentary behaviour and mental health is dependent on the type and context of sedentary behaviour is warranted.

Second, some previous studies that have investigated sedentary behaviour with other indices of mental health, have found null findings. For example, Rebar, Vandelanotte, van Uffelen, Short and Duncan (2014) found that work-related sitting time was not associated with anxiety risk. Further, Sanchez-Villegas and colleagues (Sanchez-Villegas et al., 2008) investigated the prospective effect of leisure time TV and computer use on the diagnosis of a mental disorder and found no significant effect. As a measure of general anxiety and depressive symptoms, the K10 does not allow for examination of the extent to which the effect of sedentary behaviour differs depending on differing symptomology characteristics. Importantly, many mental health activities including mindfulness practice, cognitive restructuring and seeking support from mental health professionals often involve sedentary behaviour.

Third, the strong methodological quality (Craig, Marshall, Sjöström, et al., 2003), and multivariate analyses of the current study increase confidence in the accuracy of the findings. Indeed, analysis and comparison of psychometric properties of the IPAQ-short form and accelerometer data across 12-country indicated that the sitting time item included in the IPAQ-short form was not significantly different to the accelerometer estimated sitting time (Craig, Marshall, Sjöström, et al., 2003). The current study distinctly compared the predictive influence of sedentary behaviour on mental health. Well-validated measures of sedentary behaviour and psychological distress were used. Multivariate analyses were completed using data from a large state-
representative young adult sample. In particular, the sedentary behaviour measure appeared to have similar retest reliability to the more complex physical activity measure in that both indicators showed similar moderate correlations over the 2-year time-frame (Table 7.2). In addition, the data was weighted to allow for natural clustering in the original schools, and to reflect the Victorian Census age and gender population distributions. Furthermore, the finding remained consistent across analyses of both continuous and categorical sedentary behaviour. Finally, results were similar when analyses were repeated separately for males, and females. Overall, the strong methodological features of the present study increases the confidence in the finding that overall sitting time, across contexts, does not appear to have an independent effect on psychological distress amongst young adults. It remains possible that there is a positive association between sedentary behaviour and mental health, using different indices of both constructs. The present study adds to previous research to suggest that overall sitting time does not appear to relate to psychological distress, amongst young adults.

It is likely that the failure to find an effect in the multivariate analyses of sedentary behaviour on mental health may be explained by the correlated factors controlled in the present analysis. Specifically, a bivariate association between sedentary behaviour at 2010 was found with psychological distress at 2012. Further, some studies suggest an interaction effect between physical activity and sedentary behaviour on mental health (Sanchez-Villegas et al., 2008; Sloan et al., 2013). The possibility was investigated in the current study but found that the prospective results did not support this finding. Further, the analyses were also conducted separately by gender, and findings consistently found no significant effect of sedentary behaviour and
psychological distress. Further research into the moderating and mediating effects of other variables warrant further analysis.

Contrary to previous studies, the present study found that physical activity did not have a longitudinal effect on mental health in the multivariate analysis. This may be explained by a number of factors. First, there were high rates of physical activity with approximately 8 out of 10 young adults engaging in sufficient activity to meet public health guidelines in 2010. Therefore, it is likely that there was insufficient variability in the amount of physical activity to find a significant effect on mental health. Second, it is possible that physical activity has less potential to influence mental health due to the relatively stable nature of physical activity and mental health during young adulthood. This is supported by the correlational finding of moderate stability in health behaviours and mental health from 2010 to 2012 (Table 7.3). It is possible that contrary results have been found in other studies as a result of more power to measure associations with mental health in other periods of life due to greater variability in health behaviour: in the adolescent transition (Birkeland et al., 2009; Brunet et al., 2013; McPhie & Rawana, 2015b); in association with child rearing; and retirement (Panagiotakos et al., 2008; Pinto Pereira et al., 2014; Wise, Adams-Campbell, Palmer, & Rosenberg, 2006). Third, it is clear that some of the relationship between physical activity and mental health is explained by the psychosocial correlates measured in the current study. While previous reviews (Mammen & Faulkner, 2013) clearly show that physical activity has a small beneficial effect on mental health symptoms (McPhie & Rawana, 2015a; Panagiotakos et al., 2008; Pinto Pereira et al., 2014; Wise et al., 2006), the mechanisms and prospective processes remain unclear (Birkeland et al., 2009; Brunet et al., 2013).
Study limitations

Whilst the findings support a null result, there are several study limitations that require mention. First, the non-experimental design limited causal inference. Second, effects of sedentary behaviour on mental health symptoms may have been diluted by the two-year study period. Specifically, over a greater length of time between measurements, it is possible that the strength of association between sedentary behaviour and mental health may have reduced. Importantly, there was a high proportion of sedentary behaviour missing data that may have biased the results. To manage the bias associated with attrition we weighted the data according to gender, age and school data from the Victorian Census and reran analyses based on imputed data. Reanalysis based on multiple imputation of missing data produced similar results (see Appendix 3). Hence, the current findings are not explained by missing data or subject attrition. Finally, as the behavioural and mental health data were both gathered via self-report, there is a potential respondent bias, resulting for example in depressive symptoms influencing reporting of physical activity. However, there is evidence that the K10 and IPAQ-S provide valid and reliable data (Wooden, 2014).

Conclusion/ Implications

The results confirmed previous studies in identifying high rates of mental health symptoms that remained moderately stable through the early twenties. The findings did not support sedentary behaviour as a modifiable factor explaining significant changes in young adult psychological distress. Small prospective effects of sedentary behaviour on mental health observed over 2-years, were not maintained in multivariate analyses. It has been suggested that some of the association between sedentary behaviour and mental health may be explained by exogenous health and social factors (Deng, Lee, Huen Sum
Lam, & Lee, 2015). The present analyses support this view. It is concluded that amongst young adults, sitting time does not predict overall psychological distress. The current study is one of few that have longitudinally examined the effect of sedentary behaviour in predicting the risk of mental illness symptoms. The present study adds to the existing literature regarding risk factors for mental health concerns amongst Australian young adults. Multivariate analyses indicate that self-reported mental health, being unemployed, lower perceived health status and smoking status were independent risk factors for young adult psychological distress over a 2-year period. In light of evidence of increasing rates of high to very high psychological distress amongst young Australians (22 - 50 Kessler 10 total score; 1997 = 9.6% vs. 2001 = 15.3%; ABS, 2001), the current findings assist the identification of risk factors that may be targeted in young adult mental health promotion initiatives.

**Summary**

This Chapter presented the analysis of the longitudinal effects of sedentary behaviour and physical activity effects on young adult mental health. The results suggest that sedentary behaviour and physical activity are not prospective multivariate predictors of psychological distress. The following Chapter presents an integrated discussion of the thesis studies and their implications.
Chapter 8: General discussion and conclusion

The current Chapter will discuss and integrate the results presented in the previous Chapters in light of prior research findings. The thesis contribution to the existing literature will be detailed. Further, discussion of the thesis strengths and limitations will be considered. The study implications for prevention science will be addressed. Finally, a conclusion and summary will be provided.

Aims

The current thesis aims were fourfold. First, the thesis estimated young adult rates of engagement in physical activity, sedentary behaviour and prevalence of psychological distress over a two-year period. The thesis identified the extent to which young adult engagement in physical activity, sedentary behaviour and psychological distress across the 2-year period remained stable. Second, the current thesis investigated the independent associations of physical activity and sedentary behaviour on mental health amongst young adults, controlling for psychosocial sample characteristics. Third, the thesis investigated whether there was an interaction effect between physical activity and sedentary behaviour on mental health. Finally, these analyses were conducted to determine cross-sectional and longitudinal relationships between physical activity, sedentary behaviour and mental health.

Thesis hypotheses

There were several hypotheses, as supported by previous research. First, young adults would report high rates of physical activity, sedentary behaviour and psychological distress, and that these rates would be relatively stable across time. Second, there would be an independent inverse association between physical activity and mental health. Third, it was hypothesised that highly sedentary young adults would be more likely to report psychological distress. Fourth, there would be an
interaction effect between physical activity and sedentary behaviour on mental health, such that amongst those who engage in high levels of sedentary behaviour, those who meet moderate to vigorous physical activity guidelines would report significantly lower psychological distress, when compared with those who do not meet the physical activity guidelines. Conversely, it would also be shown that amongst those who engaged in sufficient physical activity to meet guidelines, those who engage in a high level of sedentary behaviour would report significantly higher psychological distress, than those who engaged in lower sedentary behaviour.

**Summary of main findings**

Consistent with previous research, young adults in the current thesis reported high rates of physical activity, sedentary behaviour and psychological distress, which remained moderately stable across a two year period. However, several of the results in the current thesis reflected findings contrary to the proposed hypotheses. Contrary to the existing empirical consensus, it was found that physical activity was not an independent predictor of young adult mental health, across cross-sectional and longitudinal analyses. Further, sedentary behaviour was highlighted as a concurrent but not a prospective independent predictor of mental health. In addition, no evidence was found for a significant interaction effect of physical activity and sedentary behaviour on mental health. The current Chapter provides a detailed exploration of these findings, relative to previous research.

**Integration of findings with previous research**

**Rate of engagement in physical activity**

Compared to previous studies, the current thesis indicated that a contemporary sample of Australian young adults engaged in high rates of moderate to vigorous physical activity. Specifically, previous national representative samples
of young adults (18 - 24 years), indicated that young adults engaged in an average
0.5 to 2.9 hours of moderate physical activity, and 1.9 to 3.1 hours of vigorous
physical activity per week (Wooden, 2014). In contrast, the present study found that
in 2010 the young adults sampled engaged on average in 3.7 hours of moderate
physical activity and 3.6 hours of vigorous physical activity per week. In 2012, the
sample reported an average of 3.9 hours of moderate physical activity, and 3.6 hours
of vigorous physical activity. Further, whilst previous studies indicated that 43.7% to
53.4% of young adults engaged in sufficient physical activity to meet public health
guidelines, the current thesis indicated 81.5% and 83.2% engaged in comparable
levels of physical activity in 2010 and 2012, respectively. There are several possible
reasons for the high level of physical activity reported for the present sample.
Specifically, these differences may be accounted for by differences in geographical
sampling methodology (HILDA is a national representative survey, IYDS is a
Victorian-based survey), and reporting a different age range of participants (HILDA
= 18 - 24 years versus IYDS = 19 - 26 years).

Further potential reasons for the high reported rate of physical activity in the
current sample, include issues associated with the psychometric properties of the
utilised measure, social desirability bias, and prosocial sampling bias. These reasons
are explored in what follows.

Specifically, evidence shows that self-report measures of physical activity
may reflect over-estimated rates of engagement (Sallis & Saelens, 2000), possibly as
a result of difficulty distinguishing between moderate and vigorous intensity physical
activity (Bauman, Bull, et al., 2009). Specifically, reporting physical activity via self-
report measures such as the IPAQ-S require the respondent to mentally calculate the
amount of physical activity engagement, and report separate amounts of time by the
intensity of activity (Wooden, 2014). Without clarity regarding the distinction
between moderate and vigorous physical activities, participants are at risk of ‘double counting’ the activities under both intensity estimates. As a result, when a total physical activity value is summed based on those amounts, participant rate of engagement appears at risk of unrealistic levels. However, this is likely a small risk in the context of the IPAQ-S measure, as the items provide examples of moderate and vigorous intensity activities, to support valid estimation of physical activity engagement. Further, the IPAQ has been utilised as the ‘golden measure’ against which validity of other self-report measures have been compared to indicate its criterion validity (Bull, Maslin, & Armstrong, 2009).

Evidence also suggests that higher rates of reported physical activity may occur when self-report measures such as the IPAQ are utilised rather than physical observations in epidemiology studies (Wooden, 2014). Previous research suggests that the IPAQ may be particularly prone to this effect (Lee, Macfarlane, Lam, & Stewart, 2011). Lee and colleagues (2011) reviewed 23 studies of the psychometric properties of the IPAQ and found that compared to the accelerometer method, there was little convergence of IPAQ physical activity rates. It is thus possible that over-reporting of physical activity is problematic in self-report questionnaires including the IPAQ. However, other findings suggest that utilising a global measure of physical activity such as the categorical variable of the IPAQ may overcome this concern. Specifically, Wooden (2014) suggested that participants tend to be placed into appropriate categories of activity (high, moderate or low) irrespective of methodology. Craig and colleagues (2003) for example found that participants were coded as meeting physical activity guidelines (category ‘Moderate’) via the IPAQ methodology at two visits (one week apart) with 80-100% similarity across 12 countries, suggesting strong reliability. Further, compared to classification of engaging in sufficient physical activity to meet physical activity guidelines by
accelerometer and IPAQ categorisation resulted in over 80% concordance (Lee, Yu, et al., 2011). As a result, it is argued that the current study reported rates may reflect unusually high rates of physical activity, commonly found amongst self-report measures. Further, as engagement was categorised into levels that reflect strong reliability, this is not likely to be a concern for the current thesis multivariate findings.

It is possible that over-estimation of physical activity in questionnaires may reflect a social desirability bias (Wooden, 2014). Specifically, it is possible that with the high social value of high rates of engagement in physical activity, participants may over-report the total amount of activity (Crutzen & Göritz, 2011). This is also unlikely, as IYDS participants responded to the data presented in the current thesis largely via an internet questionnaire. This methodology has been found not to be related to social desirability, possibly due to a greater sense of perceived privacy (Crutzen & Göritz, 2011). Other research supports that social desirability was not found to impact IPAQ self-reported physical activity amongst young adults (Loney, Standage, Thompson, Sebire, & Cumming, 2011).

It is also possible that high rates of self-reported physical activity may reflect a sample self-selected by their high engagement in physical activity (Wooden, 2014). Specifically, engagement in prosocial and health supportive behaviours tend to occur in clusters, such that participants who engage in a high level of physical activity tend also to engage in other prosocial behaviours, including volunteering time for research. However, this is unlikely to be the reason for the high proposed rate of engagement, as previous studies indicate that the IYDS samples report variable levels of prosocial behaviours including binge drinking, and substance use (Toumbourou et al., 2014). Further, the IYDS random sampling methodology
supported the selection of a representative sample of young adults and in early waves, there was no consideration to measure PA and SB.

In summary the above paragraphs suggest that the relatively high levels of physical activity observed in the present study are unlikely to arise due to measurement difficulties, social desirability bias, or prosocial sampling bias. In the section below, the stability of the IPAQ measurements is discussed, further supporting their accuracy.

**Trajectory of engagement in physical activity**

Consistent with previous studies, the current thesis indicated that physical activity engagement across young adulthood appears to be moderately stable (Gordon-Larsen et al., 2004; Telama et al., 2005). Specifically, Gordon-Larsen (2004) categorised youth from the age of approximately 16 years to 22 years, according to the extent to which they met or did not meet the criterion for ‘sufficiently active’ defined as engaging in 5 or more sessions of moderate to vigorous physical activity per week. Those who reported meeting this criterion at both 16 and 22 years were coded as ‘stable high’. Those who did not meet the threshold at 16 but met it at 22 years were coded as ‘increased’, those who met the threshold at 16 but not at 22 years were coded as ‘decreased’, and those who maintained activity under the threshold at both time points were coded as ‘stable low’. Gordon-Larsen (2004) reported that most youth reported engaging in stable low 61.0% (95% CIs [59.0, 63.0]) or decrease 31.1% (95% CIs [29.3, 32.9]), whilst some reported stable high 4.4% (95% CIs [3.9, 4.9]) or increase in activity 3.6% (95% CIs [3.0, 4.1]). Similarly, the current study found that most young adults who reported moderate or high level physical activity at 2010 tended to report engaging in the same level of activity two years later (e.g. those who reported high PA at 2010 and 2012; 65.3%, 95% CIs [61.9, 68.5]). Therefore, the current thesis findings
supported previous research, such that physical activity appears to be moderately
stable during young adulthood. The moderate stability of the IPAQ scores over 2-
years in the current study provides some evidence for the reliability of the measure.

**Rate of engagement in sedentary behaviour**

The results of the current thesis estimated rates of sedentary behaviour were
comparable to previous research. Specifically, young adults in Australia were
previously estimated as engaging in 5.5 hours of sedentary behaviour per day (ABS,
2012), whilst the current thesis indicated an average of 4.7 and 5.0 hours per
weekday in 2010 and 2012, respectively. The consistency of these estimates suggests
that overall, young Australian adults spend approximately a third of their waking
time sitting. This is a cause for concern, in light of the multitude of serious poor
health outcomes associated with prolonged periods of sedentary behaviour (Owen et
al., 2010; Veerman et al., 2012).

**Trajectory of engagement in sedentary behaviour**

The current thesis found that the engagement in sedentary behaviour was
moderately stable, a finding which is somewhat consistent with previous research (de
Cocker, van Uffelen, & Brown, 2010). Of the existing research, de Cocker and
colleagues (2010) found that across 24 to 27 years, the amount of sitting time per
weekday remained stable at 6.8 hours. This previous finding was consistent with the
present study where overall estimates of sedentary behaviour remained relatively
stable, with an approximate 20 minutes difference in rates of sedentary behaviour
engagement from age 21 to 23 years. Further, in the present study almost half of
those who engaged in 5.6 or more hours of sedentary behaviour in 2010 also tended
to engage in high level of sedentary behaviour two years later in 2012 (those who
engaged in consistently high rate of sedentary behaviour of 5.6+ hours/ weekday;
This indicates that IPAQ-S measured sedentary behaviour remained relatively high, and stable across young adulthood, consistent with prior research.

**Prevalence rate of psychological distress**

The current thesis findings indicate that approximately one in three (2010 = 29% and 2012 = 28%) young adults reported high to very high psychological distress, which is higher than other studies with representative samples. Specifically, in the National Health Survey, 15.5% of young adults (18 - 24 years) and those who engaged in the HILDA study reported 20.8% of the young adult sample with equivalent levels of high to very high psychological distress (measured using the K10, where high psychological distress = K10 scores 22 – 29, very high psychological distress = K10 scores 30+; Wooden, 2009). This difference may reflect seasonal differences in questionnaire administration. Specifically, HILDA administered the questionnaire all year whilst the IYDS administered the questionnaire primarily during the winter months (July to September). Some evidence suggests that higher rates of mood symptoms are reported during the winter months (Kasper, Wehr, Bartko, Gaist, & Rosenthal, 1989; Magnusson, 2000; Rastad, Ulfberg, & Sjödén, 2006).

**Trajectory of change in psychological distress**

Consistent with previous research, the current thesis findings indicated that psychological distress levels remained stable over time. Specifically, the rate of high to very high psychological distress increased by 1% over the two year period. The 2010 and 2012 psychological distress measures were moderately correlated ($r = 0.53$; Chapter 7, Table 7.3), and those who reported very high psychological distress at 2010 also tended to report very high psychological distress at 2012 (42.2%, 95% CIs
Similarly, the Australian Bureau of Statistics recently indicated that rates of high to very high psychological distress remained relatively stable across 2011 to 2014 amongst young adults (18 – 24 years); 11.8% to 15.2% (Australian Bureau of Statistics, 2012c, 2015). The consistency of these findings indicates that young adult psychological distress levels remain relatively stable during this developmental period. In addition, whilst results indicated that prior psychological distress was the strongest independent predictor of psychological distress, 75% of the variance can be explained by other contributing factors. This indicates that whilst relatively stable, young adult psychological distress is amenable to change.

**Independent effect of physical activity on mental health**

The primary goal of the current thesis was to identify the extent to which there was an independent effect of physical activity on young adult mental health. Through the systematic review, out of 26 studies, 19 (13 cross-sectional and 6 longitudinal) found an inverse effect of moderate to vigorous physical activity on mental health symptoms in young adulthood. Conversely, the cross-sectional study (Chapter 6) found engagement in moderate to vigorous physical activity sufficiently to meet Australia public health guidelines was a bivariable predictor of lower psychological distress, but this effect was no longer significant in the multivariate analyses. A similar pattern emerged in the longitudinal analyses, where physical activity in 2010 predicted lower psychological distress in 2012, but this effect was no longer significant after multivariate control for the effect of sedentary behaviour, gender, employment, income, health status, smoking status, peer sports and family exercise engagement.

There are several reasons why this null result was found in the present study. It is important to consider the possibility that there is no true relationship between
physical activity and mental health. Specifically, that the null hypothesis should not be rejected. This is supported by the fact that several high-quality studies found null effects in young adults (Birkeland et al., 2009; Brunet et al., 2013; Feng et al., 2014; Ströhle et al., 2007), including the current thesis multivariate findings. However, this is unlikely to reflect a true outcome, as the weight of prior studies and both the present cross-sectional and longitudinal analyses indicated a bivariable relationship between physical activity and mental health. The systematic review of the existing literature (Chapter 5) suggests that overall, engagement in physical activity predicts improved mental health. Integrating the current and previous findings suggests that the failure to find a multivariate effect in the current thesis may reflect other reasons, including; the effect of physical activity being indirect, effect differences depending on the nature of physical activity or mental health measures, effects on mental health being small. These issues are discussed in the sections that follow.

The discrepancy between bivariate and multivariate findings in the present study are likely to indicate that the effect of physical activity on mental health is an indirect one, such that it is influenced by the covariates included in the multivariate models. In other words, analyses that multivariate control for the effect of associated predictors may simultaneously control for the indirect effect of physical activity on mental health that operates through that predictor. Some previous studies indicate that the relationship between physical activity and mental health is mediated by gender, such that physical activity was related to depression amongst female, but not males (Goldfield et al., 2011; McKercher et al., 2009), which is supported by current thesis cross-sectional analyses. Specifically, ancillary analyses suggest that gender fully mediates the relationship between physical activity and psychological distress in the cross-sectional analyses (See Appendix 3).

Previous studies have also suggested that the mental health benefits of
physical activity may be mediated by other factors such as high physical activity
motivation (Scarapicchia et al., 2014) and sedentary behaviour (Wu et al., 2015).
Hogan et al. (2015) argued that the effect of physical activity on mental health was
mediated by social relationships. Hogan et al. (2015) argued that engaging in
physical activity increased personal positive emotional experiences, which supported
the building of social relationships, which in turn improved mental health and
wellbeing. Both the present findings and prior studies suggest that the moderating or
mediating roles that confounding variables play in the effect of physical activity on
mental health effect need to be carefully considered in future research (Cerin, 2010).

It is also possible that the relationship between physical activity and mental
health is influenced by the nature of the physical activity and the nature of mental
health symptoms that are measured (Ströhle et al., 2007). One study, for example,
found longer engagement in physical activity was associated with reduced anxiety,
but not depressive symptoms (Ströhle et al., 2007). Further, some research suggests
that the nature of the relationship between physical activity and mental health is
dependent on the nature of the physical activity measure (Parker, Strath, & Swartz,
2008). For example, Parker and colleagues found that self-reported physical activity
was not related to life satisfaction, whilst pedometer-derived physical activity was
related to life satisfaction. Moreover, some studies found an effect of walking
physical activity on mental health, whilst others found an effect of vigorous physical
activity (Teychenne et al., 2008). The extent to which one type of physical activity or
measure may perform differently as a predictor of mental health in young adults has
not been adequately addressed in research to date. Thus, it is recommended that
future research considers the effect of different types of physical activity on several
types of mental health symptoms.
Most studies, including the current thesis, that have found significant results between engagement in physical activity and mental health indicators reported that physical activity explains approximately 7% of the variance in mental health, which suggests that it plays an important, albeit small role in its impact on mental health. Current studies and previous research suggests that physical activity is not a major direct contributor to mental health. It is, therefore, possible that the current findings of non-significant multivariate effect may arise as a result of limited power to detect a small effect, despite the large sample size. Future studies are encouraged to combine findings across studies using meta-analysis to estimate the combined effect size and its meaningfulness for promoting young adult mental health.

It is possible that the effect of physical activity may only be evident, depending on a specific threshold of activity, such that a person needs to reach a certain amount, intensity and frequency of PA before they experience improvements in mental health. Specifically, the 7-day diary used for the IPAQ may not measure MVPA over a sufficient time span to measure the association with mental health. Hamer and colleagues (2014) measured physical activity over a 4-week period and found some positive influences on mental health. However, prior research suggests that 9 weeks of regular physical activity may be required to measurably improve mental health (Craft & Landers, 1998). This is supported by a meta-analysis, which indicated an anxiolytic effect following 10 weeks of physical activity (Petruzzello et al., 1991). It may be difficult to determine how generalisable the measure of physical activity was amongst young adults in the present study based on the 7-day recall used in the IPAQ-S. However, the IPAQ-S measure of physical activity is a sound predictor of recent physical activity engagement and the present study found it to be a moderately stable predictor over 2-years. Future research could investigate whether
longer time frames for assessing MVPA yield stronger associations with mental health.

Following consideration of the above issues, it is argued that the small effect of physical activity on mental health is likely to be moderated and mediated by other psychosocial factors included in the multivariate analyses of the current thesis. For example, previous research supports that low social support is associated with poor mental health (Hunt & Eisenberg, 2010; Young et al., 2005). The current results indicate that peer engagement in physical activity has an independent effect on young adult mental health, and is related to physical activity. It is thus possible that the effect of physical activity on mental health may be moderated by the effect of perceived peer physical activity support, as indicated by peer engagement in physical activity. Overall, consistent with the life course theory (Goodwin, Beesdo-Baum, Knappe, & Stein, 2014), the results indicate that the effect of physical activity on mental health is complex and indirect and requires ongoing research. Further analysis of these moderating and mediating relationships will support further development of physical activity guidelines for mental health promotion amongst young adults.

It is possible that there is a bi-directional between physical activity and mental health, such that physical activity may also have an effect on mental health (Roshanaei-Moghaddam, Katon, & Russo, 2009). The current thesis longitudinal analyses (Chapter 7, Table 7.3) indicated that high psychological distress at 2010 was associated with lower engagement physical activity two years later ($r = -.07$, $p < .001$). Research suggests that depression (Roshanaei-Moghaddam et al., 2009) and anxiety symptoms (O’Loughlin et al., 2013) may impact physical activity engagement. With a mental health promotive focus, the current thesis did not address the effect of mental health on physical activity. However, in light of the multitude
health benefits associated with physical activity engagement, identifying the possible
effect of mental health on young adult physical activity requires further attention.

**Independent relationship between sedentary behaviour and mental health**

The current thesis findings suggest that, consistent with previous cross-sectional studies, that prolonged periods of sedentary behaviour was associated with higher poor mental health symptoms (Feng et al., 2014; Gordon et al., 2007; Morgan & Cotten, 2003; Wu et al., 2015). In the longitudinal analyses, it was similarly found through bivariable analyses, that longer sedentary behaviour in 2010 predicted poorer mental health two years later. However, this did not remain significant in the multivariate analyses, which is inconsistent with previous findings (Thomée et al., 2012). There are several possible explanations why prospective sedentary behaviour did not predict young adult psychological distress and are presented below.

First, it is possible that the effect was ‘washed out’ by the control of relevant covariates, such as gender. The mediation effect of gender on the relationship between sedentary behaviour and mental health is supported by previous studies. Specifically, some research suggests that the effect of sedentary behaviour on mental health amongst female older adults is not significant following control of covariates (Peeters, Burton, & Brown, 2013; Van Uffelen et al., 2013). In particular, a study investigated the prospective effect of overall sitting time on depressive symptoms amongst mid-aged women (50-55 years), and found that after controlling for the effect of psychosocial characteristics and physical activity, sitting time did not have a prospective effect on depressive symptoms, 9 years later (Van Uffelen et al., 2013). Similarly, Peeters et al. (2013) found that amongst a sample of mid-aged Australian women, after multivariate control for psychosocial confounders including physical activity, total sitting time was not prospectively associated with depressive symptoms.
3 years later. Importantly, the current thesis controlled for the effect of gender. It is thus possible that the current thesis finding that sedentary behaviour was a non-significant longitudinal multivariate predictor of young adult mental health may reflect a full mediation effect of gender. Therefore, further analysis of possible mediation effect of gender would support the building of a knowledgebase of the manner in which sedentary behaviour may affect mental health.

It is also possible that the current finding is a reflection of the long period for follow-up. Specifically, previous research theorised that sedentary behaviour is a prospective predictor of mental health over a short period of time (Van Uffelen et al., 2013). This is supported by previous young adult research, as Thomee et al. (2013) considered the effect of sedentary behaviours on young adult mental health over a 1-year follow-up period, and found a significant effect. The current longitudinal follow-up period was 2-years, and thus perhaps too long to detect a significant effect. In addition, the current thesis cross-sectional multivariate analysis indicated long periods of sedentary behaviour was associated with psychological distress, after control of psychosocial covariates. This supports the theory that sedentary behaviour may be a concurrent, but not a prospective predictor of young adult mental health.

Much research debate has occurred regarding the extent to which different types of sedentary behaviours are all equally influential on mental health (Teychenne et al., 2010; Teychenne et al., 2015). As found by the current thesis systematic review, total screen time appears to have a clear negative relationship with depressive symptoms, but the effect of internet use and computer use is more mixed. Notably, Gordon et al. (2007) found a null association between sitting time and depressive symptoms. Indeed, previous research has suggested that there may not be an effect of overall sitting time on mental health (Van Uffelen et al., 2013). In addition, research suggests that the association between sedentary behaviour and
mental health may be impacted by the context of the activity (transport, occupational, 
leisure) and the activity type (screen time, sitting time; Teychenne et al., 2015). Due 
to the limited amount of research considering sitting time context amongst young 
adults, it is difficult to provide a clear conclusion. Future research, therefore, should investigate this association whilst considering the context and type of sedentary behaviour (Teychenne et al., 2015).

In light of the extent of missing sedentary behaviour data, it is possible that the current thesis findings are biased by attrition. Missing data analysis indicated that those who were missing on sedentary behaviour were significantly more likely to be unemployed, male and younger in age. The challenge with responding to sedentary behaviour overall estimates is that sedentary behaviour occurs in the background to other activities (Owen et al., 2010), and as such, participants may find it difficult to estimate the amount of time they spent reclining or sitting, as the behaviour is not as salient as the activities in which the individual participated whilst sitting (Wooden, 2014). As a result, the participant responding to one item required to estimate average sitting time, over general weekdays, could find it a challenge, as it requires them to conduct a mental calculation of times of sitting around periods of standing and physical activity (Wooden, 2014). Considering that those who are employed are likely to have a more regular routine to which they can mentally refer their activity levels, it is logical that those who are conversely unemployed were more likely not to respond to the item. However, similar findings between complete case analysis (as presented in the current thesis), and imputed data (See Appendix 3) suggest that the result is unlikely to be a reflection of the effect of missing data bias. Therefore, it is unlikely that missing data explains the present finding that sedentary behaviour is not a prospective predictor of mental health amongst young adults.
Interaction of physical activity and sedentary behaviour on mental health

The current thesis uniquely considered the possible interaction effect of physical activity and sedentary behaviour on mental health. The current thesis found no evidence for interactive effects. Contrarily, life course theory posits that some risk and protective factors interact in their effect on mental health (Hertzman & Power, 2006) and previous studies found a significant interaction effect (Feng et al., 2014; Sloan et al., 2013; Wu et al., 2015). Specifically, both previous young adult studies (Feng et al., 2014; Wu et al., 2015) found that amongst those who engage in low levels of physical activity (< 3 days/week), those who engaged in low Sedentary Time (≤ 2 hours/day) were significantly at reduced risk of depressive symptom, compared to those who engaged in high Sedentary Time. Importantly, there are several methodological differences between the current study and those reported by Feng et al. (2014) and Wu et al. (2015). Firstly, Feng et al. (2014) and Wu et al. (2015) defined sedentary behaviour as screen time (computer use & TV viewing), whilst it was defined as total weekday sitting time in the current study. Secondly, Feng et al. (2014) and Wu et al. (2015) considered depressive symptoms, whilst the current study focused on psychological distress. Whilst the constructs are related, they are independent indicators of mental health (Drapeau, Marchand, & Beaulieu-Prévost, 2012). The current findings add to the existing research as this is the first study to consider the interaction effect of sedentary behaviour and physical activity on young adult mental health, using a prospective design.

The current thesis findings suggest that overall, the effect of physical activity on mental health may not depend on the sedentary behaviour level of the young adult. Further, that the effect of sedentary behaviour on mental health may not depend on physical activity levels. This theoretically reinforces the view that
physical activity and sedentary behaviour are independent in their effect on mental health. It remains possible that the interaction effect is dependent on the type of sedentary behaviour considered. In light of the paucity of studies, no firm conclusions can be made regarding the existence of an interaction effect between physical activity and sedentary behaviour on mental health. Therefore, it is recommended that future research continues to investigate the possible interaction effect between physical activity and sedentary behaviour on mental health.

**Correlates of mental health amongst young adults**

The current thesis also considered the role of several psychosocial characteristics in predicting psychological distress. The current thesis included psychosocial covariates in the multivariate analyses. All of the bivariable covariates remained significantly associated with cross-sectional psychological distress in the multivariate analyses. The bivariable cross-sectional analyses revealed the following predictors of young adult mental health remained for both the cross-sectional and longitudinal analyses higher psychological distress amongst young adults was more likely amongst those who were; female, unemployed, older (as measured by cohort), in a lower income bracket, low self-reported health status, self-identified smoker in the previous 12 months, had fewer peers who engage in sport and lower family member exercise engagement. The longitudinal analyses revealed that only prior mental health, poor health status, smoking, and fewer peers who engage in sports remained significant and independent risk factors of psychological distress. Whilst the current thesis did not find for an interaction mental health effect between physical activity and sedentary behaviour, consistent with life course theory (Hertzman & Power, 2006), it is possible that physical activity and sedentary behaviour may interact with the covariates to impact mental health. Future research is encouraged to elucidate the extent to which this is true. In addition, the current findings have
implications for the development of preventive mental health initiatives. In particular, young adults who have elevated mental health symptoms, or report poor health, smoking in the previous 12 months, or have few peers who engage in sports may require targeted intervention prior to the onset of serious mental health concerns.

**Strengths**

The current thesis findings are based on several methodological strengths, which serve to reinforce the validity of the findings. Importantly, the IYDS sample was recruited via random sampling methodology and was a state-representative sample of adolescents. Furthermore, the questionnaire utilised at young adult follow-up was administered via the internet, which may have provided a sense of privacy, which in turn may have encouraged more accurate reporting of physical activity, sedentary behaviour and mental health symptoms. The physical activity, sedentary behaviour and mental health measures are widely considered valid self-report measures of their respective constructs (Wooden, 2009, 2014). Further, the data were weighted to reflect population profiles for Victorian census gender, age and school leaving. In addition, the independent effects of physical activity and sedentary behaviour were controlled. The current thesis is one of five studies to have reported on the effect of physical activity and sedentary behaviour on young adult mental health, independent of sedentary behaviour and physical activity, respectively (Fang et al., 2014; Feng et al., 2014; Sidney et al., 1996; Wu et al., 2015). The present study is the first to report the prospective mental health effect of young adult sitting time. The analyses also used appropriate methods for the overly-dispersed Poisson distribution of the K10 mental health data. Importantly, the current thesis multivariate analyses controlled for a wider range of psychosocial characteristics, as compared to previous research in the field. Finally, very few studies have reported
both the cross-sectional and prospective relationships between physical activity, sedentary behaviour and mental health. The current thesis thus uniquely identified the extent to which the cross-sectional and longitudinal associations are different. Overall, the current thesis reflects strong methodology from sampling to analysis, which supports the validity of the findings.

Limitations

Several limitations discussed in the earlier sections require revisiting, including controversy regarding the psychometric properties of measures utilised, sedentary behaviour categorisation, and the K10 categorisation method.

Some literature suggests that self-report measures, such as the IPAQ short-form, are inaccurate measures of physical activity (Lee, Macfarlane, et al., 2011). For example, there is evidence suggesting that young adults report significantly higher rates of physical activity using IPAQ self-report, as compared to accelerometer data (Downs, Van Hoomissen, Lafrenz, & Julka, 2014). In contrast, other studies indicate that utilising self-report measures or objectively identified measures, lead to a comparable proportion of participants being identified as engaging in physical activity sufficient to meet public health guidelines. Thus, it is possible that self-report measures may be less accurate in identifying specific details of physical activity (e.g., time in vigorous intensity activity), but may be appropriate measures of the extent to which a sufficient level of physical activity to meet public guidelines has been reached (Ainsworth et al., 2015). Thus, whilst the self-report nature of the IPAQ Short-form may not provide valid estimates of the precise level of physical activity, the findings from the bivariate and multivariate analyses are likely to be unaffected by this concern, as a global operationalisation of physical activity was utilised.
Although objective measures such as accelerometer data provide accurate measures of physical activity, they do not provide insights into the psychosocial context of physical activity. The mental health benefit of physical activity is theorised to result not only from physiological but also through psychosocial mechanisms (Berger & Motl, 2000). It is possible that the mental health benefits of physical activity engagement may be partially explained by physical activity’s effect on self-concept, enjoyment of the activity (Azar et al., 2011), taking a break from the challenges of daily living (Berger & Motl, 2000), or via the mutual experience if engaged with friends (Pickett, Yardley, & Kendrick, 2012). As a result, some research suggests that self-report measures of physical activity may provide important details regarding the psychosocial context of activity that is missed by objective measures (Ainsworth et al., 2015). As a result, it is argued that objective measures of physical activity may not be solely appropriate to determine the mental health benefits of physical activity. Thus, a combined use of self-report and objective measures in large-scale studies may be more effective in identifying the association between physical activity and mental health. In the context of large-scale studies, where it may be expensive and impractical to administer objective measures (e.g. accelerometers) to all participants, it is possible to administer them to a smaller subset of the sample.

One of the other challenges associated with the IPAQ-Short form, not reflected by its long form counterpart (IPAQ Research Committee, 2005), is that the context of physical activity is not considered. Some research suggests that the effect of physical activity on mental health may be relative to the context in which it occurs, such that physical activity during household chores is not related to mental health, but leisure time activity is (Cerin et al., 2009). In addition, ongoing research indicates the mental health benefits of engaging in physical activity outdoors versus
indoors (Thompson Coon et al., 2011). The extent to which this is true for young adults is unclear, and thus requires further exploration.

Similarly, there has been a call for the improvement in measures of sedentary behaviour (Gibbs et al., 2015), and to include both objective and subjective measures of the behaviour, to complement each other. Some literature also suggested the use specifically of accelerometer data to identify sedentary behaviour. The challenge of using an accelerometer is how to operationalise sedentary behaviour when it is not the reflection of simply a lack of energy expenditure. As a result, a combination of measures is recommended. Specifically, subjective measures offer information regarding context-specific activity (e.g. sitting during computer use, commuting etc.), whilst objective measures reduce the risk of reporting bias associated with the reporting of health behaviours (Gibbs et al., 2015).

Ultimately, all measures of physical activity and sedentary behaviour carry some measurement error (Ainsworth et al., 2015; Gibbs et al., 2015), and the selection of an appropriate measure as such, requires consideration of participant burden, budget limitations, the primary purpose of the study, and how the measure will be utilised in analysis. In the context of international, large-scale, longitudinal studies suggest as the IYDS, a short, internationally recognised and widely utilised, cost effective measure such as the IPAQ-Short form was an appropriate choice. Thus, the selection of an appropriate measure needs to be considered in the real world limitations of large-scale studies.

It has been noted that the effect of physical activity and sedentary behaviour on psychological distress may be dependent upon the manner in which the Kessler-10 scale is categorised (Kilpatrick et al., 2013). There are several methods or cut-offs utilised to determine K10 scores that reflect a high risk of mental disorder diagnosis (Kilpatrick et al., 2013). The current thesis categorisation method was selected so
that the results could be compared with national samples. Arguably, as the cut off
which reflects optimal specificity and sensitivity of a measure to select those of high
risk to mental illness, is likely to vary by each sample, it is possible that the
longitudinal findings were limited by the cut-off utilised. To provide a sensitivity
analysis (Kilpatrick et al., 2013) the current thesis presented both an analysis of
continuous data from the K10 and of a dichotomous measure and reported similar
findings. Future research is recommended to continue to conduct separate models
with variable cut-offs, as a sensitivity analysis.

Implications and contribution

The current thesis findings have theoretical, research and practical
implications. Overall, consistent with the biopsychosocial model, the results indicate
that there are many risk and protective factors that predict mental health and that the
development of prevention interventions should consider; elevated mental health
symptoms, health status, smoking and peer sports engagement of young adults. In
addition, the results suggest that sedentary behaviour may have a concurrent but not
a prospective predictor of young adult mental health. The current findings suggest
that the effect of physical activity may be indirect and operate through correlated
young adult characteristics. These findings support theories that suggest that
engaging in PA may curb the effect of poor mental health among young adults by
ameliorating the associated psychosocial risk and protective factors (Donaghy,
2007). In addition, the current thesis provides support for the theory that physical
activity and sedentary behaviour have independent effects on mental health.
Importantly, the study identifies an association albeit a small one. Empirically, the
results suggest that the relationships between sedentary behaviour, physical activity
and mental health may be impacted by moderators and or mediators (Cerin, 2010).
Importantly, the current thesis utilised improved methodology, compared to previous research and in this way has contributed to improving the quality of the available literature. Firstly, the current studies utilised psychometrically appropriate self-report measures of physical activity and sedentary behaviour, which has been done in only one prior study (Feng, 2014). Further, the multivariate models investigating the relationships between physical activity, sedentary behaviour and mental health controlled for a wider range of psychosocial correlates than previous studies. This includes four factors which have previously received limited attention among young adults; physical activity, sedentary behaviour, family physical activity and peer exercise engagement. Importantly, the current thesis considered concurrent and prospective relationships between physical activity, sedentary behaviour and mental health. Finally, the current thesis investigated a largely unaddressed interactive effects between sedentary behaviour and physical activity on the mental health of young adults.

The current research has implications for future studies of young adult mental health. The study confirms high rates of young adult mental health symptoms in a contemporary sample and shows for the first time high associations with sitting time. The study suggests specifically, that further studies of the processes that lead from sedentary behaviour to mental health problems in young adults are warranted. The current study raises questions as to whether physical activity has a direct effect on young adult mental health, suggesting instead that its effect may be mediated through factors such as sedentary behaviour, prior mental health status, physical health, smoking, peer sports engagement and gender. Mediation analyses would help determine the extent to which the relationship between physical activity and young adult mental health is accounted for by gender, health status, smoking or as a result of the social reinforcement of having peers who engage in exercise. The current
research may contribute to public health guidelines in demonstrating in a large state representative sample that engaging in more than 5.6 hours or more of weekday sitting was associated with concurrent elevations in poor young adult mental health symptoms.

Further research is required to elucidate the manner in which the relationship between physical activity and mental health is moderated/mediated by psychosocial confounders, in order to inform which young adult groups would experience the greatest mental health benefits from physical activity. In addition, exploration of the possible bi-directional relationship between physical activity and mental health is warranted. Further, research should consider controlling for the effect of physical activity, when investigating the effect of sedentary behaviour on mental health, and sedentary behaviour when investigating the effect of physical activity on mental health. Future research is required to determine the extent to which a threshold effect for sedentary behaviour is found in other studies that measure sedentary behaviour as total sitting time.

Practically, the present results suggest that engaging in 5.6 or more hours of weekday sitting may be a threshold above which young adult mental health is affected. The present findings should be confirmed in future research to establish whether there are threshold effects of sedentary behaviour on mental health after multivariate adjustment for engagement in physical activity and psychosocial correlates. If threshold effects can be established and confirmed in other areas of health, they will prove valuable in the development of public health guidelines.

Practically, the present results also suggest that physical activity may have only a small indirect effect on young adult mental health. This finding has implications for preventive interventions in suggesting that physical activity may not lead to independent improvements in young adult mental health symptoms. The
results of the present study should be combined using meta-analysis with other high-quality studies that include multivariate control for covariates in their analyses. It is possible that when this is done that physical activity has only a small effect on mental health. This brings into question the meaningfulness of the effect of physical activity as an intervention strategy to advance mental health promotion at a population level. At a minimum, the present results bring into question the existing literature ‘consensus’ that physical activity engagement carries meaningful mental health benefits at a population level for Australian young adults.

**Conclusion and summary**

Across a systematic review, and through the analysis of cross-sectional and longitudinal data, the current thesis considered the independent effect on common mental health symptoms of two health behaviours, which are amenable to change; physical activity and sedentary behaviour. The findings indicated that young adults tended to engage in long periods of sedentary behaviour, high rates of moderate to vigorous physical activity and to report high rates of symptoms of poor mental health. Mental health symptoms appeared to be relatively stable during young adulthood.

The current thesis included a novel systematic review of the existing literature investigating the effect of physical activity and or sedentary behaviour on young adult mental health. The current thesis was one of few studies to have investigated both the cross-sectional, and longitudinal effects of physical activity and sedentary behaviour on mental health, utilising a large, random sample of contemporary young adults. Further, the thesis addressed a common weakness in existing research that has used poor quality physical activity and sedentary behaviour measures, by utilising the International Physical Activity Questionnaire - Short Form; a widely utilised measure, with appropriate psychometric properties. In
addition, the analyses for the current thesis included multivariate adjustment for a wider range of psychosocial correlates, than previous studies have considered.

Through the systematic review, it was established that prior research has found physical activity to be inversely related to young adult mental health, whilst prolonged engagement in sedentary behaviour was associated with poor mental health. Contrary to previous research, the cross-sectional and longitudinal studies presented in the current thesis indicated that physical activity played a small and indirect effect on young adult mental health. Sedentary behaviour was confirmed in the present study as an independent concurrent, but not a prospective predictor of mental health. In addition, contrary to previous research, the current thesis did not identify an interaction effect between physical activity and sedentary behaviour on mental health. Young adult elevated mental health symptoms, unemployment and poor health status were all implicated as longitudinal risk factors for poor mental health. In light of the methodological qualities and strengths, the findings from the current thesis are likely to be included in future systematic reviews of high-quality studies.

The thesis findings suggested that there may be a dose-response effect of sedentary behaviour on mental health, and call into question the existing ‘consensus’ that there are direct mental health benefits for young adults associated with physical activity. Preventive initiatives may target young adults with elevated mental health symptoms, report poor health status, smoking in the previous 12 months, or those who have few peers that engage in sports, in order to reduce the high risk of mental health problems in this age group.

Future research is encouraged to investigate the effect of physical activity and sedentary behaviour as simultaneous and independent predictors of mental health, utilising large samples of young adults, gathered using rigorous methodology.
Further studies integrating both objective and subjective measures of physical activity, and sedentary behaviour are encouraged, in order to delineate the extent to which the effect on mental health differs, depending on the nature of the measure. Finally, further exploration regarding the interplay of physical activity and sedentary behaviour and the moderating and mediating role of other related psychosocial characteristics as influences on mental health would further the development of mental health theory and prevention science.
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Appendices explained

Appendix 1 reflects the Ethics exemption obtained to complete the secondary data analyses conducted with IYDS data.

The tables in Appendix 2 provide further details regarding the manner in which each study was assessed for its quality (Table 1), how each study was scored for each quality assessment criteria (Table 2), and details regarding the search engines, dates when conducted, results and search terms for each database. For publication purposes, these tables are intended as Supplementary files, to provide evidence of the systematic nature of the review.

The information in Appendix 3 provides results of the analyses conducted with data following multiple imputation, to supplement study 1 (Chapter 6). The data imputation was conducted by Steve Bowe, in preparation of a manuscript for publication (pending submission). Specifically, Table 3a reflects the negative binomial regression analyses of the cross-sectional 2012 complete cases and imputed data. On page 122, details of preliminary mediation analyses conducted to investigate the roles that gender may play in influencing the relationships between physical activity and psychological distress are provided.
Appendix I Ethics Exemption

Memorandum

To: Prof John Toumbourou
   School of Psychology

From: Deakin University Human Research Ethics Committee (DUHREC)

Date: 28 January, 2015

Subject: 2015-002

A longitudinal investigation of the roles of physical activity and sedentary behaviour on depressive symptoms among Australian adolescents and young adults

Please quote this project number in all future communications

Exemption from Ethics Review was granted for this project on 28/01/2015.

Authorisation has been given for Miss Nina Borjojevic under the supervision of Prof John Toumbourou, School of Psychology, to undertake this project for the life of the project from 28/01/2015.

This Exemption from Ethics Review is given only for the project as stated in this memo. It is your responsibility to contact the Human Research Ethics Unit immediately regarding any of the following:

- Any adverse events or events which might affect the continuing ethical acceptability of the project
- All modifications to the research relating to the data or records must be submitted to the Human Research Ethics Unit for review prior to being implemented

In addition, you will be required to report on the progress of your project at least once every year and at the conclusion of the project. You are furthermore required to retain auditable records of the project demonstrating compliance with the National Statement on Ethical Conduct in Human Research (2007) (paragraph 5.2.9) and to produce these if required.

Human Research Ethics Unit
research-ethics@deakin.edu.au
Telephone: 03 9251 7123
Appendix 2 Systematic Review

Table 1

Details of quality determined for each criterion

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Detail</th>
<th>Description of quality level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>High (1) Low (0) Poor (-1)</td>
</tr>
<tr>
<td>1. Study Design</td>
<td>Study design evident and appropriate?</td>
<td>Longitudinal Cross-sectional No information provided</td>
</tr>
<tr>
<td>Sample</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Gender distribution</td>
<td>Distribution of male/female</td>
<td>50-55% female More than 60% female No information provided</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Method</td>
<td>Sampling method</td>
<td>Random sampling Convenience sampling No information provided</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Sample size</td>
<td>Sample size</td>
<td>Size of sample (n≥200) Sample (n&lt;200) No information provided</td>
</tr>
<tr>
<td></td>
<td>What proportion of the selected sample completed the study? In longitudinal studies, what proportion of sample members participated in follow-up studies?</td>
<td></td>
</tr>
<tr>
<td>5. Response rate</td>
<td></td>
<td>&gt; 65%, or 90% for follow-up studies &lt; 65% response rate No information provided</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Predictor(s) a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Physical activity</td>
<td>Extent to which considered 3 components of activity; intensity, frequency &amp; duration</td>
<td>Two to three components of activity One or no components of activity No information provided</td>
</tr>
</tbody>
</table>


Table 1 Continued…

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Detail</th>
<th>Description of quality level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>High (1)</td>
</tr>
<tr>
<td>Predictor(s) a</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Sedentary behaviour</td>
<td>Extent to which provided time engagement/ week or day</td>
<td>Time/ week or day provided</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outcome</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Psychometric properties</td>
<td>Good validity &amp; reliability estimates (e.g. reference to Cronbach alpha levels, test-retest for longitudinal studies, etc.)</td>
<td>Adequate validity &amp; reliability estimates</td>
</tr>
<tr>
<td>9. Described adequately</td>
<td>Sufficient detail to understand the results</td>
<td>Clearly explained</td>
</tr>
<tr>
<td>10. Analytic methods</td>
<td>Analytic methods sufficiently described? Does the study explain clearly why the statistical technique was chosen?</td>
<td>Technique described and reason chosen explain adequately</td>
</tr>
<tr>
<td>11. Control for confounding</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demographic</td>
<td>Level of control for relevant confounders including: age, gender, education, income, health</td>
<td>2+ other confounders controlled</td>
</tr>
<tr>
<td></td>
<td>If study considered physical activity and mental health, was sedentary behaviour controlled in the multivariate analyses? And vice versa.</td>
<td>PA/SB controlled</td>
</tr>
</tbody>
</table>

Note. Total score ranged from -11 to 11, where quality was categorised as either low (score -11 – 4), moderate (score 5 - 6), and high (7+). a Only assessed existing predictor.
### Table 2

**Quality assessment of studies**

<table>
<thead>
<tr>
<th>First author Name (year)</th>
<th>Table</th>
<th>Study design</th>
<th>Sample</th>
<th>Predictor(s)</th>
<th>Outcome</th>
<th>Analytic methods</th>
<th>Control for confounding</th>
<th>Result</th>
<th>Quality Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Ball (2009)</td>
<td>5.2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>na</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>High</td>
</tr>
<tr>
<td>2. Birkeland (2009)</td>
<td>5.2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>na</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>High</td>
</tr>
<tr>
<td>3. Bray (2006)</td>
<td>5.1</td>
<td>0</td>
<td>-1</td>
<td>1</td>
<td>na</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>Low</td>
</tr>
<tr>
<td>4. Brunet (2013)</td>
<td>5.2</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>na</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>High</td>
</tr>
<tr>
<td>5. Fang (2014)</td>
<td>5.1</td>
<td>0</td>
<td>-1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>6. Feng (2014)</td>
<td>5.1</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>High</td>
</tr>
<tr>
<td>7. Gerber, Brand, Elliot, (2014)</td>
<td>5.1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>na</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>8. Gerber, Brand, Hermann, (2014)</td>
<td>5.1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>na</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>9. Gordon (2007)</td>
<td>5.1</td>
<td>0</td>
<td>0</td>
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Note. Table = reflects where the study details can be found (In systematic review); Sample = reflects total score of four components (gender distribution, sample size, response rate and sampling methodology); Predictors = reflects quality rating score for one or more of the physical activity or sedentary behaviour, where na (not applicable) applied when physical activity or sedentary behaviour wasn’t measured; Outcome = reflects highest quality rating score for one outcome measure in the study; analytic method = reflects the rating for overall description of statistical analysis methodology; control for confounding = reflects level of control of predetermined key confounders and extent of control of physical activity or sedentary behaviour (e.g. if assessed physical activity effect, did the study include sedentary behaviour as a control variable); result = reflects the total quality rating score. The quality rating was gained by creating three levels that are relative to the quality of studies included, where High reflects scores 7 to 8, Moderate = 5 to 6, Low reflects 4 or lower (Out of a possible total of 11).
Table 3

Details of search terms and limiters by database

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<tr>
<th>Database</th>
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<th>Limiters</th>
<th>total studies</th>
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<td>((ZE &quot;mental health&quot;) or (ZE &quot;depression&quot;) or (ZE &quot;anxiety&quot;))</td>
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<td>&quot;sitting&quot; OR sedentary* OR sedentary behaviour OR &quot;screen time&quot; OR &quot;computer use&quot; OR &quot;TV use&quot; OR &quot;sedentary screen&quot; OR &quot;media use&quot; OR &quot;internet use&quot;</td>
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<td>NOT: &quot;therapy&quot; OR &quot;RCT&quot; OR &quot;treatment&quot; OR &quot;Randomized&quot; OR &quot;intervention&quot; Academic journal articles only AB ( &quot;Young Adult&quot; OR &quot;emerging adult&quot; or &quot;emerging adulthood&quot; OR &quot;emerging adults&quot; OR &quot;university student&quot; or &quot;college student&quot; or &quot;university&quot; or &quot;college&quot; or &quot;student&quot; ) Narrow by Subject Age: - young adulthood (18-29 yrs)</td>
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Note. All databases were searched on the 23/10/2015, except for MEDLINE via PubMed which was search 23/10/2015, and Cochrane library, which was searched 6/11/2015.
Appendix 3 Study 1

Table 3a

Negative binomial regressions of the cross-sectional analyses of complete cases (n = 2206) and of imputed data (n = 2884)

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<td>Peer sports</td>
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<td>Family PA</td>
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<td>0.97</td>
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Note. Psychological distress = K10 psychological distress; IRR = Incident Rate Ratios; CI = Confidence Intervals for IRR; LL = lower limit; UL = upper limit; PA = IPAQ categorical (Low PA = 0, Moderate to high PA = 1); SB = categorical sitting time (hours) per weekday; Female = gender (Female = 1, Male = 0); Cohort = age group of the IYDS sample (Youngest Mage = 21.1, SD = 0.5, Middle Mage = 23.1, SD = 0.5, Oldest Mage = 25.0, SD = 0.5); Employment = If currently employed (Yes = 1, No = 0); Income = amount of weekly income; Health status = self-reported health (Excellent to good = 1, fair to poor = 0); Smoking = smoking in previous 12 months (Yes = 1, No = 0); Peer Sports = Number of friends who participated in sports and/or physical activity; Family PA = Family physical activity engagement; F = F Ratio test; p = statistical significance (probability). The distribution for the K10 psychological distress distribution was significantly over-dispersed and adjusted using negative binomial regression.

a these are the results reported in Chapter 6 and are included here for ease of comparison.
Preliminary mediation analyses of gender, on physical activity and psychological distress

In order to determine the extent to which gender may mediate the relationship between physical activity and psychological distress, analyses following Baron and Kenny (1986) were conducted. First, bivariate regression analyses were conducted and found significant bivariate associations between physical activity predicting psychological distress, $F(1, 151) = 5.93; IRR = 0.94, 95\% \text{ CIs} [0.90, 0.99], t = -2.43, p = .02, n = 2346$, physical activity predicting gender, $F(1, 151) = 31.87; IRR = 0.90, 95\% \text{ CIs} [0.87, 0.94], t = -5.65, p < .001, n = 2346$, and gender predicting psychological distress, $F(1, 151) = 30.04; IRR = 1.10, 95\% \text{ CIs} [1.06, 1.14], t = 5.48, p < .001, n = 2346$. Second, regression analyses were conducted to determine the associations between physical activity and psychological distress, controlling for gender. The results indicated that following control of gender, the association between physical activity and psychological distress was no longer significant ($IRR = 0.96, 95\% \text{ CIs} [0.91, 1.00], t = -1.82, p = .07$). This suggests that, according to Baron and Kenny (1986) guidelines, that gender fully mediates the effect of physical activity on psychological distress.