Associations between Positive Psychological Well-Being, Psychological Distress, and Physical Activity among Adults with Diabetes

by

Sasha Gunpat

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Carleton University

Ottawa, Ontario

Abstract

Positive psychological well-being (PPWB) is associated with physical activity above and beyond psychological distress among adults. The purpose of this study was to determine if this association holds among people with diabetes. Data came from a subset of participants in the Whitehall 2 study who participated in an accelerometer sub-study and self reported having diabetes (n = 112). Baseline data (2007-2009) of PPWB, psychological distress, and diabetes status were self-reported; physical activity was directly measured via accelerometer at follow-up (2012-2013). In adjusted models, PPWB was not associated with physical activity among people with diabetes, $\beta = 1.73$, $p = .098$. Exploratory analyses indicated that diabetes status did not moderate associations between PPWB and physical activity. Results suggest that PPWB may not play a role in physical activity among adults with diabetes. Future research should test other positive psychological factors that are associated with physical activity among adults with diabetes.

Keywords: Diabetes; Positive psychological well-being; Psychological distress; Physical activity

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Associations between Positive Psychological Well-Being, Psychological Distress, and Physical Activity among Adults with Diabetes

Diabetes mellitus is a chronic health condition that occurs when the pancreas does not produce enough insulin or the body cannot effectively use the insulin it produces (Pelletier et al., 2012; Dimeglio, Evans-Molina, & Oram, 2018; World Health Organization, 2020). Currently, over 422 million people around the world are living with diabetes, in addition to 30 to 50% of cases that remain undiagnosed (Beagley, Guariguata, Weil, & Motala, 2014; World Health Organization, 2016; Chan, Gregg, Sargent, & Horton, 2016). Diabetes can lead to the development of diabetes-related health complications, which include cardiovascular problems, amputation, and stroke, and have been linked to decreased quality of life and shorter life expectancy (Chatterjee et al., 2017; Sarwar et al., 2010; Tancredi et al., 2015). As there is no cure for diabetes, physicians and health care providers mainly focus treatment strategies on diabetes management to reduce the risk of developing diabetes-related health complications and improve health outcomes (Zhuo, Zhang, & Hoerger, 2013). Performing health behaviours, such as regular physical activity, is an effective approach to reducing the health impacts of diabetes (Vluggen, Hoving, Schaper, & Vries, 2018). Guidelines from Diabetes Canada and the American Diabetes Association recommend that adults should consistently participate in at least 150 minutes of moderate-to-vigorous physical activity per week (Chen, Sloan, & Yashkin, 2015; Colberg et al., 2016; Sigal et al., 2013; Sigal et al., 2018).

Among people with diabetes, regular physical activity is associated with reduced incidence of major cardiovascular events (e.g., death from cardiovascular disease), stroke, and risk of early mortality (Blomster et al., 2013; Tikkanen-Dolenc et al., 2017; Glenn et al., 2015; Tikkanen-Dolenc et al., 2017; Hu et al., 2001; Wei, Gibbons, Kampert, Nichaman, & Blair, 2000). Additional health benefits of physical activity in this population include improved glycemic control, improved blood pressure, and maintenance of weight loss (Sigal et al., 2018; Chimen et al., 2012; Dempsey et al., 2016; Duvivier et al., 2017; Sigal et al., 2006; Rossen et al., 2017; Chudyk & Petrella, 2011; Jelleyman et al., 2015; Bohn et al., 2015; Sigal et al., 2018). Health benefits from physical activity also persist over time. For example, a 27-year longitudinal study showed that participating in any duration of moderate-to-vigorous physical activity was associated with lower all-cause mortality in people with diabetes (Yerramalla et al., 2020).

Despite the health gains from physical activity, most people with diabetes do not meet physical activity guidelines (Chen et al., 2015; Colberg et al., 2010; Colberg et al., 2016; Plotnokoff et al., 2010; Sigal et al., 2013; Sigal et al., 2018; Vanden Bosch, Robbins, & Anderson, 2015). Researchers examining physical activity adherence suggest that about 30% of people with diabetes are insufficiently active (Basmah et al., 2019; Castonguay, Miquelon, & Boudreau, 2018; Kennerly & Kirk, 2018; Kelly et al., 2016; Salman et al., 2019). However, some cross-sectional studies report even lower physical activity attainment (e.g., Mendes, Martins, & Fernandes, 2019). For instance, Pizzol and colleagues (2019) showed that only 19.8% of participants with diabetes attained sufficient physical activity levels to meet recommended guidelines. Physical activity levels also seem to differ between those who have been diagnosed with diabetes and those who meet the criteria for diabetes but have not yet been diagnosed, though results are mixed (Pierce, Zaninotto, Steel, & Mindell, 2009; Rosella, Lebenbaum, Fitzpatrick, Zuk, & Booth, 2015; Russell, Oh, & Zhao, 2019). For instance, among older adults with either prediabetes, undiagnosed diabetes, or self-reported diabetes, regular physical activity was least likely to occur among undiagnosed diabetes (i.e., 18%; Kumar et al., 2016). In contrast, a different study found that more older adults with undiagnosed diabetes reported being physically active than older adults with prediabetes or known diabetes (Dankner, Olmer, Kaplan, & Chetrit, 2016). Given that many people with diabetes are not meeting physical activity guidelines and are at higher risk of developing health complications, there is a need to identify correlates of physical activity in people with diabetes. Research examining the psychological health of people with diabetes suggests that mental health, including psychological distress, is linked to physical activity outcomes among diabetes populations (Bansal et al., 2018; Ducat, Philipson, & Anderson, 2014; Robinson et al., 2018; Sears & Schmitz, 2016).

Psychological Distress and Physical Activity Among People with Diabetes

People with diabetes are more likely to experience increased psychological distress compared to people without diabetes (e.g., Burns, Deschênes, & Schmitz, 2015; Deschênes, Burns, & Schmitz, 2015; Egede & Dismuke, 2012); specifically, psychological distress (i.e., clinically relevant depression, depressive symptoms, severe psychological distress) is approximately twice as likely to occur in people with diabetes compared to the general population (Anderson et al., 2001; Ali et al., 2006; Li et al., 2009). Psychological distress (i.e., the subclinical experience of depressive and anxiety symptoms) is inversely associated with physical activity in people with diabetes (Johnson et al., 2016; Palakodeti et al., 2015; Ramadhan et al., 2019; Swardfager & MacIntosh, 2015). In their review, Lysy, Da Costa, and Dasgupta (2008) reported that people with diabetes and elevated depressed mood were 22 to 90% less likely to participate in physical activity. Similarly, Koopmans et al. (2009) showed that among people with diabetes and elevated symptoms of depression (i.e., 14%), there was a 70% increased likelihood of being physically inactive than if depressive symptoms were below the elevated threshold. More recently, a cross-sectional study demonstrated comparable findings, in which 83% of people with diabetes reporting depressive symptoms also reported low levels of physical activity compared to people not experiencing depressive symptoms (Rizvi, Khan, & Rizvi, 2019). Associations between psychological distress and physical activity in people with diabetes have also been demonstrated over time (e.g., Katon et al., 2010). For instance, a recent two-year longitudinal study showed that people with diabetes and co-morbid depressive symptoms engaged in decreased physical activity (Ivanova, Burns, Deschênes, Knäuper, & Schmitz, 2017). However, given that moderate psychological distress accounts for 32.6% of the variance in physical activity among people with diabetes (Pandit et al., 2014), other psychological processes that contribute to physical activity should also be considered.

Keyes Two-Continua Model

Historically, one's state of well-being was understood as either the presence or absence of psychological distress (Westerhof & Keyes, 2010). Hence, if one scored low on psychological distress measures, it was inferred that one is functioning well in life. However, according to Keyes' Two-Continua model (2002), well-being is composed of two related yet distinct continuums of psychological processes: positive psychological well-being and psychological distress. Positive psychological well-being (PPWB) can be understood as a broad construct that involves various positive psychological states (Huppert, 2009). Some of these positive psychological states include positive thoughts and feelings, being satisfied with one's life, and meaningful life pursuits (Boehm, Trudel-Fitzgerald, Kivimaki, & Kubzansky, 2015).

Research has empirically supported Keyes' (2002) theory with findings that suggest PPWB and psychological distress are correlated yet distinct constructs. Specifically, PPWB is inversely related to psychological distress (Keyes, 2005), such that as one well-being construct increases, the other may, in turn, decrease. Further, correlations between PPWB and psychological distress are moderate in strength (e.g., $r = -.50$; Hides et al., 2020; $r = -.41$; Rao, Wallace, Theou, & Rockwood, 2017), suggesting that changes in PPWB or psychological distress are not fully explained by one another. Given that PPWB and psychological distress are moderately correlated, differences between PPWB and psychological distress in predicting health behaviour outcomes have been investigated. For instance, after adjusting for the effects of psychological distress, PPWB (i.e., positive affect and optimism) was associated with a reduced likelihood of cigarette smoking in the general population (Carvajal et al., 2000; Leventhal et al., 2005; Boehm & Kubzansky, 2012). Similarly, after accounting for depressive symptoms, PPWB (i.e., control, autonomy, satisfaction, and pleasure) was prospectively associated with an 11% reduced risk of not meeting recommendations to consume daily amounts of five or more servings of fruits and vegetables at the seven-year follow-up in the general population (Boehm et al., 2018).

Consistent with Keyes' (2002) theory that PPWB and psychological distress are distinct constructs (Ryff et al., 2006; Ryff & Singer, 1998), PPWB and psychological distress have unique associations with physical activity (Keyes, 2005; Ryff & Singer, 1998). In the general population, greater PPWB is consistently associated with increased physical activity above and beyond psychological distress (e.g., Baruth et al., 2011; Diener, Pressman, Hunter, & Delgadillo-Chase, 2017). For instance, meaning in life is associated with self-reported physical activity after accounting for depressive symptoms in non-clinical older adults (Ruuskanen, Ruoppila, & Ruuskanen, 1995). Specifically, women who reported higher levels of meaningfulness in life also practiced more intensive exercise after controlling for depressive symptoms (Ruuskanen et al., 1995). Similarly, a prospective study that followed a large representative sample of older adults over 11 years indicated that PPWB was associated with attaining and maintaining self-reported physical activity levels over time after adjusting for baseline psychological distress (Kim, Kubzansky, Soo, & Boehm, 2017). Similar associations have been observed in chronic disease populations, including people with cardiovascular disease (Boehm & Kubzansky, 2012), cancer, and those reporting having experienced a stroke (Kim, Hagan, Grodstein, Dawn, Immaculata De Vivo, & Kubzansky, 2017).

A well-being perspective from the self-determination theory may explain the unique associations between physical activity and PPWB (Saunders, Huta, & Sweet, 2018). This perspective suggests that well-being facilitates health behaviour performance by increasing positive experiences that lead to the intrinsic pursuit of life goals (Ryan, Huta, & Deci, 2008). If life goal pursuits become increasingly intrinsic, then it can be expected that an individual will become autonomously regulated (i.e., feeling fully volitional) towards performing health behaviours (Ryan et al., 2008; Patrick & Williams, 2012; Koponen, Simonsen, & Suominen, 2018). Consistent with these notions, PPWB is associated with physical activity among various populations (Boehm & Kubzansky, 2012; Grant, Wardle, & Steptoe, 2009; Cotter & Lachman, 2010). Although most studies examining this association have considered physical activity a predictor of PPWB (e.g., Lee & Howard, 2019; Veldema & Jansen, 2018; Sapranaviciute-Zabazlajeva et al., 2017), there is some evidence to suggest that PPWB predicts physical activity. For instance, in a longitudinal study examining associations between PPWB and self-reported physical activity among an inactive non-clinical population, men reporting higher positive emotional outlook on life at baseline were associated with increased physical activity at the two-year follow-up. Further, men who reported mainly being happy at the baseline assessment increased their physical activity more than men who reported being happy on fewer occasions (Baruth et al., 2011). Additionally, in a study examining the effects of positive psychology interventions on medical adherence in cardiac patients, greater improvements in self-reported physical activity were found among people reporting higher levels of positive affect (Huffman et al., 2019).

Facets of Positive Psychological Well-Being and Physical Activity among Older Adults

Under the broad construct of PPWB, hedonic and eudaimonic well-being are the main theoretical perspectives that describe various positive psychological states (Ryan & Deci, 2001). Hedonic well-being is often characterized as the experience of pleasure, which includes feelings of happiness, high levels of positive affect and being satisfied with one's life (Diener, Pressman, Hunter, & Delgadillo-Chase, 2017). Eudaimonic well-being is usually conceptualized as the experience of meaning and includes dimensions of purpose in life, personal growth, self-acceptance, meaningful relationships with others, environmental mastery and autonomy (Ryff & Singer, 2008). Hedonic and eudaimonic well-being have been characterized as conceptually distinct yet correlated facets of PPWB (Keyes, Shmotkin, & Ryff, 2002).

The Control, Autonomy, Self-Realization, and Pleasure (CASP-19) is a theory-driven measure of PPWB that considers hedonic and eudaimonic domains of well-being in the context of older adults (Hyde et al., 2003). Similar to Keyes' Two Continua model (2002) suggesting that well-being exists on a continuum, the CASP-19 measure is based on well-being models that suggest poor health does not equate to low PPWB. Instead, despite being in poor health, one can have a good quality of life and experience PPWB (Hyde et al., 2003). The CASP-19 aims to and has previously been used to assess the more positive dimensions of ageing (Hyde et al., 2003; Blane, Higgs, Hyde, & Wiggins, 2004; Clarke, Fisher, House, Smith, & Weir, 2008; Higgs, Hyde, Wiggins, & Blane, 2003; Kim et al., 2014; Stoner, Orrell, & Spector, 2019; Wiggins, Higgs, Hyde, & Blane, 2004). The CASP-19 domains (i.e., control, autonomy, self-realization, and pleasure) have been individually linked to health behaviours (Hyde et al., 2003).

Sense of control can be described as the ability to involve oneself within their environment (Patrick et al., 1993; Higgs et al., 2003) and has been linked with self-management behaviours (Surgenor, Horn, Hudson, Lunt, & Tennent, 2000; Surgenor, Horn, & Hudson, 2002). Autonomy refers to experiencing freedom from unwanted interference from others (Higgs et al., 2003) and is proposed to be necessary for well-being (Deci & Ryan, 1985). Autonomy is linked with health behaviours, such that individuals are more likely to participate in health behaviours when autonomy is promoted (Chatzisarantis, Hagger, Kamarova, & Kawabata, 2012). Self-realization involves a continual process of developing one's potential by pursuing activities that make one happy regardless of age (Hyde et al., 2003; Ryff & Waterman, 2013). Theory linking PPWB to health explains that self-realization, also known as personal growth, likely contributes to practicing health behaviours and greater health benefits (Ryff & Singer, 1998; Ryff et al., 2004; Ryff & Waterman, 2013). Finally, pleasure can be described as a motivator for human action that promotes and maintains health behaviours (Kahneman, Diener, & Schwarz, 1999; Phoenix & Orr, 2014).

Sense of control, autonomy, self-realization, and pleasure has been linked to physical activity outcomes. For example, in a cross-sectional study, perceiving more control was positively associated with more frequent self-reported physical activity in a nationwide sample of older adults (Infurna & Gerstof, 2014). The authors suggested that a higher sense of control may provide individuals with the motivation necessary to engage in more health-promoting behaviours, such as physical activity (Infurna & Gerstof, 2014). Similarly, autonomy was cross-sectionally associated with self-reported physical activity in a sample of predominantly older adults with diabetes. In fact, of all measured factors (i.e., felt energy, perceived health, age, social support), autonomous motivation was directly and most strongly associated with engagement in physical activity (Koponen et al., 2018). Further, autonomy-support has been identified as the most useful behavioural change technique to facilitate regular physical activity (Arnautovska, O' Callaghan, & Hamilton, 2018). The authors proposed that reinforcing a person's sense of autonomy is key for facilitating change in physical activity among older adults.

Self-realization has also been shown to be associated with physical activity. Self-realization, often described as personal growth, was positively associated with self-reported physical activity among a group of women in early midlife (Holahan et al., 2011). The authors highlight the findings as support for theoretic assertions explaining that individuals can contribute to their own development. Finally, it has been theoretically proposed that the concept of pleasure is associated with physical activity (Higgins, 1997; Phoenix & Orr, 2014). For example, varying types of pleasure were qualitatively identified as key themes of engagement in physical activity among older adults (Phoenix & Orr, 2014). Similar findings were demonstrated in a study investigating associations between self-reported pleasure and both self-reported and objectively measured physical activity (i.e., via heart rate monitor) among a small sample of people with diabetes. In comparing an exercise treatment (i.e., 20-minute walk at a brisk speed) to a control group (i.e., sitting passively for 20 minutes), results suggested that participating in brisk walking led to increased pleasure (Kopp et al., 2012).

Current Study

Although PPWB is associated with physical activity above and beyond psychological distress in various populations (Ruuskanen, Ruoppila, & Ruuskanen, 1995; Kim, Kubzansky, Soo, & Boehm, 2017), it is unknown if this association extends to people with diabetes. Therefore, the main objective of this study is to determine if PPWB is associated with physical activity in people with diabetes above and beyond psychological distress. It is hypothesized that higher PPWB will be positively associated with physical activity above and beyond psychological distress in adults with diabetes. To contextualize this association, the strength of the association between PPWB and physical activity among people with diabetes will be compared to that of people without diabetes. This study also has two secondary exploratory objectives. First, given that evidence of physical activity participation among people with undiagnosed diabetes is conflicting (Mainous, Tanner, Anton, Jo, & Luetke, 2017), and that many studies examining correlates of physical activity in people with diabetes do not consider undiagnosed cases of diabetes, the present study aims to explore comparisons of the strength of associations between PPWB and physical activity in people with diagnosed and undiagnosed diabetes. Additionally, associations between the sub-scale domains of the CASP-19 and physical activity in people with and without diabetes will be explored.

Methods

Data Source

The current study will use data from the Whitehall 2 study, a longitudinal population-based cohort study that was established to explore associations between socioeconomic status, stress, and cardiovascular disease (Marmot & Brunner, 2005). The Whitehall 2 study protocol was approved by the ethics committee of the University College London Hospital committee. In 1985, 10,308 individuals aged 35 to 55 years were recruited from the British civil service for the study. Baseline data collection occurred from 1985 to 1988, at which time written full informed consent was obtained from all participants. To date, the Whitehall 2 study has collected data during 13 waves of data collection (i.e., 1985 to 2020). At each wave (i.e., every 1 to 2 years), participants complete mailed self-report questionnaires on demographic characteristics, health, lifestyle factors, work characteristics, social support, and life events, as well as measures of positive psychological well-being, psychological distress, and physical activity. In addition to the self-report questionnaires, clinical data (e.g., direct measure physical activity, height, weight, blood pressure reactivity) were collected every five years from 1985 to 2011. Clinical data were collected at a research clinic; home visits by nurses were offered to participants who were unwilling or unable to travel to the clinical as of phase 7 (i.e., 2003-2004). As of 2012, the follow-up interval for clinical data was reduced to every three years. Participants who declined clinic and full questionnaire participation were administered a brief telephone questionnaire. Attrition rates (i.e., formal withdrawal from the study and non-response) of clinical and self-report data are reported as low; of the 10,012 participants that provided baseline data in 1985, the attrition rate over 11 phases (i.e., 2012-2013) of data collection ranged between 13% and 34% (Akasaki, Kivimaki, & Steptoe, 2020).

Accelerometer measurement was added to the collection of clinical data at phase 11 (i.e., 2012-2013). Only participants who were seen at the central London clinic or were living in the South-Eastern regions of England and provided clinical data at home were invited to wear an accelerometer (Menai et al., 2017). Participants who lived in other parts of the United Kingdom, reported contraindications (e.g., allergies to plastic or metal), or had plans to travel abroad the following week, were not invited to participate in the accelerometer measurement. Participants who provided consent and reported no contraindications wore an accelerometer on their non-dominant wrist for nine consecutive 24-hour days. In addition to wearing the accelerometer, participants were asked to complete a diary to record overnight sleep periods, non-wear time, and cycling. Cycling time was recorded because it is poorly measured by accelerometers (Slootmaker et al., 2009; Sabia et al., 2014).

The present study will analyze data from phase 9 (i.e., 2007-2009) because positive psychological well-being was measured during this phase; data from phase 11 will also be analyzed because accelerometer measurement was added to clinical data collection as of phase 11 (i.e., 2012-2013). Accelerometers were given to 4880 participants. Of these participants, 388 people did not provide consent to wear the accelerometer, 42 people reported contraindications (i.e., 40 people were allergic to plastic or metal; 2 people reported the wrist strap as too short or cognitive impairment), 168 people were travelling abroad, 15 accelerometers were lost in the mail, and 238 people provided accelerometer data that was not valid (i.e., 166 people had technical issues with the accelerometer; 72 people did not provide data with daily accelerometer wear time of at least 16 hours per day, for at least two weekdays and two weekend days). Thus, 4029 people provided valid accelerometer data (Sabia et al., 2014).

Eligibility Criteria

Main Objective

Is PPWB associated with physical activity in people with diabetes above and beyond psychological distress? To be included in the analyses for the main objective, participants will have to provide valid accelerometer data. Additionally, to be included, participants must have completed the measures of positive psychological well-being and psychological distress at phase 9. Given that people with diabetes will be compared to people without diabetes, participants must have provided information on diabetes status (i.e., since January of 2006 have you been told by a doctor that you have, or have had, diabetes?; 1 = *yes*; 2 = *no*) to be included in the present study.

Exploratory Objectives

First exploratory objective - compare the strength of association between PPWB and physical activity in people with diagnosed and undiagnosed diabetes. To be included in the analysis for the first exploratory objective, participants will have to provide valid accelerometer data. Additionally, to be included, participants must have completed the measures of positive psychological well-being and psychological distress at phase 9. Given that people with undiagnosed diabetes will be compared to people with diagnosed diabetes, participants must have provided self-report information on diabetes status (i.e., since January of 2006 have you been told by a doctor that you have, or have had, diabetes?; 1 = *yes*; 2 = *no*) and completed a blood sample at baseline that yielded a glycated hemoglobin A1c value (HbA1c). An HbA1c value of 6.5 or higher is the cut-off for diagnosing diabetes in the United Kingdom (British Diabetic Association, 2020; John, 2012; World Health Organization, 2011; Zhang et al., 2011), so only participants with HbA1c values of $\geq 6.5\%$ will be included in the first exploratory objective. Participants who respond 'yes' to the self-report item, " have you been told by a doctor that you have, or have had, diabetes" will be classified as having diagnosed diabetes, whereas participants who respond 'no' to the self-report item and has HbA1c levels of $\geq 6.5\%$ will be classified as having undiagnosed diabetes.

Second exploratory objective - explore associations between the sub-scale domains of the CASP and physical activity in people with and without diabetes. To be included in the analysis for the second exploratory objective, participants will have to provide valid accelerometer data. Additionally, to be included, participants must have completed the measures of positive psychological well-being and psychological distress at phase 9. As people with diabetes will be compared to people without diabetes, participants must have provided self-report information on diabetes status (i.e., have you been told by a doctor that you have, or have had diabetes?; 1 = *yes*; 2 = *no*).

Measures

Physical Activity

Direct measurements of physical activity were obtained during phase 11 via a wrist-worn triaxial accelerometer (i.e., GENEActiv Original). An accelerometer is a device that measures non-gravitational acceleration and is frequently used to feasibly collect direct measures of physical activity (Lee, 2015; Migueles et al., 2017; Shiroma et al., 2015). Accelerometers also provide data on "counts", an aggregate measure of the intensity and magnitude of accelerations over a given time epoch (Evenson & Terry, 2009). Acceleration was recorded at 85.7 Hz and expressed in gravity units (g = 9.81 m/second^2) to reflect the calibrated sensors relative to gravity. Calibration error was estimated based on static periods in the data and was corrected if necessary (i.e., calibration correction range = 0.8 to 10.0 mg, mean correction = 2.5 mg; Van Hees et al., 2014). The Euclidean Norm Minus One (i.e., ENMO; monitor-specific wrist threshold for accurately discriminating between sedentary behaviours and motion-based light-intensity physical activities) was used to quantify the acceleration related to movement registered in milligravity (mg, 1 mg = .00981 meters squared; Van Hees et al., 2013). Negative values were rounded to zero, and ENMO values averaged over 5-second epochs.

Among those with valid data, accelerometer non-wear time was estimated on the basis of standard deviation and value range of each accelerometer axis, calculated for moving windows of 60 minutes with 15-minute increments (Sabia et al., 2017). A time window was classified as non-wear time if for at least two out of the three axes, the standard deviation was less than 13.0 mg (1 mg = 0.00981 m/second^2) or if the value range was less than 50 mg. For each 15-minute period detected as non-wear time, data were replaced by each participant own mean value measured from the same time of day on other days (Catellier et al., 2005; Mehdi et al., 2017; Sabia et al., 2014; Sabia et al., 2015; van Hees et al., 2011; van Hees et al., 2013).

If a participant had three weekend days or six weekdays, the wrist accelerations of the first and last full days of measurement were averaged to represent one day (Sabia et al., 2014). The average of the wrist acceleration over weekdays was calculated to represent daily weekday physical activity level, and the same was done for weekend days (Sabia et al., 2014). The weekly mean accelerometer-assessed total physical activity (mg) was calculated as: [(5 x mean daily weekday wrist acceleration + 2 x mean daily weekend wrist acceleration)]/7 (Sabia et al., 2015). Accelerometer data were analyzed using SPSS 26.0 statistical software.

Positive Psychological Well-being

Positive psychological well-being was measured at phase 9 via 19-items from the Control, Autonomy, Pleasure, Self-Realisation scale (CASP-19; Hyde et al., 2003). The CASP-19 was developed to capture four theoretically derived domains of positive psychological well-being (i.e., control, autonomy, pleasure, self-realization) in older populations, independent of factors that influence quality of life, such as physical health and financial circumstances. Participants were asked, “how often, if at all, you think they apply to you” (e.g., *I look forward* *to each day*). Responses were made on a 4-point scale (1 = *often*, 2 = *sometimes*, 3 = *not often*, 4 = *never*). Items that are negatively worded were reverse scored; a final psychological well-being score was calculated by summing responses. Additionally, a total score for each domain of the CASP (i.e., Control, Autonomy, Pleasure, Self-Realisation) was calculated by summing responses to domain-respective items. Higher scores indicate greater psychological well-being. The CASP-19 has acceptable levels of reliability and concurrent validity (i.e., r =.63; Hyde et al., 2003) for use among older British adults (Bowling, 2010; Hyde, Higgs, Wiggins, & Blane, 2015). Cronbach's alpha for the CASP-19 in the present study was .84.

Diabetes Status

Diagnosed diabetes status was measured at phase 9 with the self-report item, "have you been told by a doctor that you have, or have had, diabetes". Participants who responded affirmatively were classified as having diagnosed diabetes.

Undiagnosed diabetes status was measured at phase 9 with the self-report item, "have you been told by a doctor that you have, or have had, diabetes" and glycated hemoglobin A1c (HbA1c), which was also measured at phase 9. Measuring HbA1c is an efficient way to indicate average blood glucose levels over time and is frequently used as a tool to diagnose diabetes (Wang et al., 2016). Participants either had a nurse come to their home or presented to a clinic to provide the blood samples (Marmot & Steptoe, 2008). Blood samples for HbA1c were measured in whole blood and drawn into Vacutainers using the validated Tosoh G8 high-performance ion-exchange liquid chromatography platform. Collected blood samples were shipped to TDL laboratory for analysis, and then results were shipped back to Whitehall II. Participants who responded 'no' to the self-report item and had HbA1c levels of $\geq 6.5\%$ were classified as having undiagnosed diabetes (American Diabetes Association, 2018; Mannarino, Tonelli, & Allan, 2013; World Health Organization, 2011; Zemlin, Matsha, Hassan, & Erasmus, 2011).

Psychological Distress

Psychological distress was measured at phase 9 via 30 items from the General Health Questionnaire (GHQ; Goldberg, 1972). The 30-item GHQ is the most validated version and is widely used to detect non-psychotic psychological distress, in which each item refers to a specific common psychological symptom (e.g., depression, anxiety). The GHQ is a screening self-report questionnaire that measures experiences of psychological distress that are linked to the inability to carry out normal functions over a short period of time. Participants were asked to rate items (e.g., *have you recently found everything getting on top of you*) according to how their health has been over the past few weeks. Responses were made on a 4-point scale (e.g., 0 = *not at all*, 1 = *no more than usual*, 2 = *rather more than usual*, 3 = *much more than usual*). A final psychological distress score was calculated by summing responses. Higher scores indicate greater psychological distress. Cronbach's alpha for the GHQ in the present study was .94. The GHQ has good criterion validity (Head et al., 2013) and been validated for use among the general population and non-psychiatric clinical settings (Goldberg, 1972). Additionally, the GHQ has been used to assess mental health status among diabetes populations (e.g., Kumari, Head, & Marmot, 2004; Pena et al., 2010).

Covariates

Covariates were identified following a review of previous literature of factors that may confound associations between PPWB, or psychological distress, and physical activity (Ametz et al., 2014; Chitttleborough et al., 2011; Galler et al., 2011; Glover et al., 2019; Indelicato et al., 2018; Ivanova et al., 2017; Kim et al., 2017; Naqvi et al., 2020; Shiroma & Lee, 2010; Trief et al., 2003). Demographic covariates were assessed at phase 1. Demographic covariates that were considered in the present study include age, (i.e., age at questionnaire completion) sex (0 = *male*, 1 = *female*), years of education as a proxy for socioeconomic status (i.e., education level; 1 = *up to 16*, 2 = *17-18*, 3 = *over 18*), and ethnicity (i.e., 0 = *non-white*, 1 = *white*). Health-related covariates were assessed at phase 9. Health-related covariates included smoking status (i.e., do you smoke now – including cigarettes, cigars, or a pipe? 0 = *no; social/occasional smoker*, 1 = *yes*), body mass index (i.e., to be calculated from weight measured in kilograms using electronic scales and height measured in centimetres using a stadiometer during clinical data collection; calculated as weight in kilograms divided by height in meters squared), diabetes duration in years (i.e., what year was diabetes diagnosed?), and self-reported insulin use.

Statistical Plan

Prior to conducting analyses, data were cleaned and checked for impossible values and error codes. Histograms and boxplots were run to visualize extreme data points and outliers (i.e., standardized values greater than 3.29 were considered outliers). Preliminary analyses were conducted to identify characteristics of the samples and determine normality (e.g., examine skewness, kurtosis) of data distributions for psychological distress, PPWB and physical activity. Linearity assumptions, as well as normality of residuals, were checked using histograms and P-P plots. Additionally, multicollinearity was checked using collinearity diagnostics (i.e., variance inflation factor and tolerance statistics) to assess the degree to which the predictor variables may have been correlated with one another. Variance inflation factors of 10 or greater and tolerance statistics less than .2 were considered problematic. Participants who did not have complete data on covariates were excluded from adjusted regression models. Pearson correlation coefficients were calculated to assess associations amongst continuous variables of interest. Point-biserial correlation coefficients were calculated to assess associations amongst continuous and dichotomous variables of interest. Separate regression analyses addressed each research objective. Regression beta coefficients were interpreted as measures of effect size; the proportion of variance accounted for (R^2) by each model was also examined.

Main Objective

Is PPWB associated with physical activity in people with diabetes above and beyond psychological distress? Two separate linear regression analyses were conducted. The first analysis only included participants with diagnosed diabetes. Psychological distress was entered into the first step, and PPWB was entered into the second step. An unadjusted model and a model that adjusts for covariates in the first step of the model were conducted.

The second analysis included participants with diagnosed diabetes and without diabetes. Psychological distress was entered into the first step. In the second step, diabetes status, PPWB, and the PPWB x diabetes status interaction were entered. The interaction term assessed if diabetes status moderated the association between PPWB and physical activity. An unadjusted model and a model that adjusts for covariates in the first step of the model was conducted.

Exploratory Objectives

First exploratory objective – is the strength of association between PPWB and physical activity above and beyond psychological distress greater in people with diagnosed diabetes or in people with undiagnosed diabetes? One linear regression analysis was conducted and included participants with diagnosed diabetes and undiagnosed diabetes. In this model, psychological distress was entered in the first step. In the second step, diabetes status, PPWB, and the PPWB x diabetes status interaction were entered. The interaction term assessed if diabetes status moderated the association between PPWB and physical activity. An unadjusted model and a model that adjusts for covariates in the first step of the model were conducted.

Second exploratory objective – is the strength of association between the sub-scale domains of the CASP and physical activity above and beyond psychological distress greater in people with diabetes or in people without diabetes? Five separate linear regression analyses were conducted and included participants with diagnosed diabetes and without diabetes. The first analysis included psychological distress entered into the first step. In the second step, diabetes status was entered. In the third step, the control domain was entered. In the fourth step, the control domain x diabetes status interaction was entered. The second analysis included psychological distress entered into the first step. In the second step, diabetes status was entered. In the third step, the autonomy domain was entered. In the fourth step, the autonomy domain x diabetes status interaction was entered. The third analysis included psychological distress entered into the first step. In the second step, diabetes status was entered. In the third step, the self-realization domain was entered. In the fourth step, the self-realization domain x diabetes status interaction was entered. The fourth analysis included psychological distress entered into the first step. In the second step, diabetes status was entered. In the third step, the pleasure domain was entered. In the fourth step, the pleasure domain x diabetes status interaction was entered. The fifth analysis included psychological distress entered into the first step. In the second step, diabetes status was entered. In the third step, the control, autonomy, self-realization, and pleasure domains were entered. In the fourth step, the control domain x diabetes status interaction, the autonomy x diabetes status interaction, the self-realization x diabetes status interaction, and the pleasure x diabetes status interaction were entered. This model assessed if diabetes status moderated the association between domains of PPWB and physical activity. For each analysis, an unadjusted model and a model that adjusts for covariates in the first step of the model were conducted.

Sensitivity Analyses

Given that previous accelerometer research has found that accelerometers are poor at measuring cycling time (Sabia et al., 2014; Shiroma et al., 2015), all analyses will be repeated using data only from participants who did not report cycling in the diary to assess whether cycling may influence accelerometer findings.

Results

Main Objective

Is PPWB Associated with Physical Activity in People with Diagnosed Diabetes Above and Beyond Psychological Distress?

This sample included 112 participants who had diagnosed diabetes. They were on average 67.50 years old (*SD* = 5.77), identified mostly as White (71.40%), male (70.50%), had high education (55.40%), had an average body mass index of 29.38 (*SD* = 5.63), and did not smoke (92.70%). Participants reported an average score of 39.70 (*SD* = 6.48) on the CASP-19, an average score of 22.65 (*SD* = 8.66) on the GHQ-30, and a mean accelerometry score of 134.44 (*SD* = 38.83). Pearson and point-biserial correlations between PPWB, psychological distress, physical activity, and covariates among people with diabetes are presented in table 1. Neither PPWB, r (110) = .01, p =.916, nor psychological distress, r (110) = .14, p = .134, were correlated with physical activity. Positive psychological well-being was inversely correlated with psychological distress, *r* (110) = -.59, *p* <.001.

Table 1

Pearson and Point-Biserial Correlations between Positive Psychological Well-Being, Psychological Distress, Physical Activity, and Covariates among People With Diabetes

	Positive Psychological Well-being	Psychological Distress	Physical Activity
Psychological Distress	-.592**	-	-
Physical Activity	0.010	0.142	-
Biological Sex	-0.073	.308**	-0.091
Age	-0.052	-0.029	-.200*
Ethnicity	.240*	-0.126	0.008
Smoking status	-0.103	0.051	-0.146
Body Mass Index	-0.057	-0.085	-.220*
Diabetes Duration In Years			
Insulin Use	-0.157	0.159	-0.048

Note. Biological sex coded as 0=male, 1=female. Ethnicity coded as 0=non-white, 1=white. Education coded as low education, medium education, high education. Smoking status coded as 0=non-smoker, 1=smoker. Insulin use coded as 0=no, 1=yes. All other variables are continuous. *indicates p ≤ .05, two-tailed. ** indicates p ≤ .01, two-tailed.

Results from linear regression models testing associations between PPWB, psychological distress, physical activity and covariates are presented in the first column of Table 2. In the unadjusted model, neither PPWB, β = .87, *p* = .217, nor psychological distress, β = 1.02, *p* = .053, were associated with physical activity. After adjusting for covariates, PPWB was not significantly associated with physical activity β = 1.73, *p* = .098, however, psychological distress was inversely associated with physical activity, β = 1.53, *p* = .040.

Table 2

Regression Coefficients for Associations Between Positive Psychological Well-being, Psychological Distress, and Physical Activity

	Participants with diabetes only			Moderation by diabetes status		
	B(SE)	*p*	95% CI	*B*(SE)	*p*	95%CI
Unadjusted for covariates						
Psychological distress	1.02 (.52)	0.053	-.02, 2.06	0.14(.10)	0.179	-.06, .34
Diabetes status	-	-	-	-29.57(4.58)	<.001	-38.55, -20.60
PPWB	.87 (.70)	0.217	-.52, 2.26	.76(.14)	<.001	.49, 1.02
PPWB x diabetes status	-	-	-	-.59(.69)	0.397	-.1.94, .77
Adjusted for covariates						
Psychological distress	1.53 (.73)	0.04	.08, 2.99	-0.02(.12)	0.836	-.25, .21
Diabetes status	-	-	-	-12.82(5.21)	0.014	-23.03, -2.61
PPWB	1.73 (1.03)	0.098	-.33, 3.79	.60(.15)	<.001	.31, .89
PPWB x diabetes status	-	-	-	-.18(.84)	0.834	-1.82, 1.47

Note. PPWB, positive psychological well-being. For the sample of participants with diabetes (not adjusted for covariates: $n = 112$; adjusted for covariates: $n = 72$), models were adjusted for biological sex, age, ethnicity, level of education, smoking status, body mass index, diabetes duration in years, and insulin use. For the sample with and without diabetes (not adjusted for covariates: $n = 3862$; adjusted for covariates: $n = 2823$), models were adjusted for biological sex, age, ethnicity, level of education, smoking status, and body mass index.

An exploratory analysis was conducted to evaluate whether diabetes status moderated the association between PPWB and physical activity. To achieve this, individuals who did not self-report a diagnosis of diabetes, but met all other inclusion criteria, were added to the sample of 112 individuals with diagnosed diabetes. Individuals without diabetes ($n = 3866$), were on average 65.32 years old ($SD = 5.70$). The majority of the sample identified as White (92.7%), male (74.3%), had high education (45.00%), had an average body mass index of 26.54 ($SD = 4.24$), and did not smoke (95.00%). Table 3 compares people with and without diabetes on the main variables of interest and sociodemographic characteristics. Chi-square tests of independence among categorical variables revealed that ethnicity differed by diabetes status, X^2 (1, *n* = 3978) = 77.95, *p* <.001; people with diabetes were more likely to be White than people without diabetes. Independent sample t-tests conducted among continuous variables revealed a significant difference for age, *t*(3864) = -4.12, *p* <.001, in which people with diabetes (*M* = 67.50, *SD* = 5.77) were older than people without diabetes (*M* = 65.32, *SD* = 5.70); a significant difference for BMI, *t*(3864) = -7.15, *p* <.001, in which people with diabetes (*M* = 29.38, *SD* = 5.63) had a higher BMI than people without diabetes (*M* = 26.54, *SD* = 4.24); and a significant difference for physical activity, *t*(3864) = 6.61, *p* = .046, in which people with diabetes (*M* = 134.44, *SD* = 38.83) engaged in less physical activity than people without diabetes (*M* = 163.29, *SD* = 47.15).

Table 3

Participant Characteristics by Diabetes Status

	Diabetes (*n*=112)	No Diabetes (*n*=3866)	Difference test
Age, years, *M*(*SD*)	67.50(5.77)	65.32(5.70)	$t(3864)=-4.12$, $p<.001$
Biological sex, %			$X^2(1)=.85$, $p=.356$
Male	70.5	74	
Ethnicity, %			$X^2(1)=77.95$, $p<.001$
White	71.4	93	
Education level, %			$X^2(2)=5.09$, $p=.079$
Low	28.9	29	
Medium	15.7	26	
High	55.4	46	
Smoking status, %			$X^2(1)=1.24$, $p=.266$
Non-smoker	92.7	95	
Insulin use, %			-
No insulin	95.5	-	
Diabetes duration, years, *M(SD)*	2.04(2.17)	-	-
BMI, *M*(*SD*)	29.38(5.63)	26.54(4.24)	$t(3864)=-7.15$, $p<.001$
Psychological Distress, *M*(*SD*)	22.65(8.66)	21.74(9.32)	$t(3864)=-1.06$, $p=.925$
PPWB, *M*(*SD*)	39.70(6.48)	41.10(7.17)	$t(3864)=2.10$, $p=.310$
Physical Activity, *M*(SD)	134.44(38.83)	163.29(47.15)	$t(3864)=6.61$, $p=.046$

Note. M, mean; *SD*, standard deviation; *BMI*, body mass index; *PPWB*, positive psychological well-being.

Regression models testing associations between PPWB, psychological distress, diabetes status and physical activity are presented in Table 2. In the unadjusted model, PPWB was positively associated with physical activity, $\beta = .76$, $p < .001$, however, psychological distress was not associated with physical activity, $\beta = .14$, $p = .179$. Diabetes status was inversely associated with physical activity, $\beta = 29.57$, $p < .001$; those with diabetes reported less physical activity than those without diabetes. Diabetes status did not moderate the association between PPWB and physical activity, $\beta = -.59$, $p = .397$. In the adjusted model, PPWB was positively associated with physical activity, $\beta = .60$, $p < .001$, whereas psychological distress was not associated with physical activity, $\beta = -.02$, $p = .836$. Diabetes status was inversely associated with physical activity, β = -12.82, p = .014; those with diabetes reported less physical activity than those without diabetes. Diabetes status did not moderate the association between PPWB and physical activity, β = -.18, p = .834.

Sensitivity Analysis. Participants who reported cycling for more than ten minutes per day were removed in a sensitivity analysis to evaluate whether cycling influenced the association between PPWB and physical activity. Of the 112 participants with diabetes, 7 were excluded from the sensitivity analysis (n = 105); of the 3866 participants without diabetes, 587 were excluded from the sensitivity analysis (n = 3279). Table 4 does not include individuals who reported cycling and compares people with and without diabetes on the main variables of interest and sociodemographic characteristics. In contrast to findings that included cycling data, an independent sample t-test revealed a significant difference for PPWB, $t(3382) = 2.09$, p = .037, in which people with diabetes (*M* = 39.47, *SD* = 6.40) had lower scores of PPWB than people without diabetes (*M* = 40.93, *SD* = 7.28).

Table 4

Participant Characteristics by Diabetes Status with Cycling Data not Included

Variable	Cycling data not included		
	Diabetes (*n*=105)	No Diabetes (*n*=3279)	Difference test
Age, years, *M*(SD)	67.42(5.69)	65.49(5.73)	*t*(3382=-3.50, *p*=<.001
Biological sex, %			X^2(1)=.38, *p*=.537
Male	70.5	0.73	
Ethnicity, %			X^2(1)=72.25, *p*=<.001
White	70.5	0.92	
Education level, %			X^2(2)=4.67, *p*=.097
Low	28.7	0.3	
Medium	16.3	0.25	
High	55	0.45	
Smoking status, %			X^2(1)=.52,*p*=.469
Non-smoker	93.2	0.95	
Insulin use, %			-
No insulin	95.2	-	
Diabetes, *M*(SD)	2.09(2.20)	-	-
BMI, *M*(SD)	29.45(5.73)	26.63(4.31)	*t*(3382)=-6.75, *p*=<.001
Psychological Distress, *M*(SD)	22.60(8.52)	21.88(9.51)	*t*(3382)=-.79, *p*=.432
PPWB, *M*(SD)	39.47(6.40)	40.93(7.28)	*t*(3382)=2.09, *p*=.037
Physical Activity, *M*(SD)	134.78(39.47)	160.79(45.27)	*t*(3382)=6.01, *p*=<.001

Note. M, mean; *SD*, standard deviation; *BMI*, body mass index; *PPWB*, positive psychological well-being.

Among people with diabetes, the unadjusted model (n = 105) revealed that PPWB was not associated with physical activity, β = 1.17, p = .124; however, psychological distress was inversely associated with physical activity, β = 1.23, p = .032. After adjusting for covariates (n = 69), neither PPWB, β = 1.79, p = .103, nor psychological distress, β = 1.46, p = .058, were associated with physical activity,.

Regression models were tested to determine if PPWB was associated with physical activity among people with and without diabetes. The unadjusted model revealed that PPWB was positively associated with physical activity, β = .65, p <.001; however, psychological distress was not associated with physical activity, $\beta = .10$, $p = .349$. Diabetes status was inversely associated with physical activity, $\beta = -26.60$, $p = <.001$; those with diabetes reported less physical activity than those without diabetes. Diabetes status did not moderate the association between PPWB and physical activity, $\beta = -.41$, $p = .560$. After adjusting for covariates (n = 2472), PPWB was positively associated with physical activity, $\beta = .49$, $p = .001$; however, psychological distress was not associated with physical activity, $\beta = -.08$, $p = .524$. Diabetes status was inversely associated with physical activity, $\beta = -11.38$, $p = .028$; those with diabetes reported less physical activity than those without diabetes. Diabetes status did not moderate the association between PPWB and physical activity, $\beta = .001$, $p = .999$.

Exploratory Analysis: Comparing the Strength of Association Between PPWB and Physical Activity Among People with Diagnosed and Undiagnosed Diabetes

An exploratory analysis was conducted to evaluate whether diagnosed versus undiagnosed diabetes moderated the association between PPWB and physical activity. To achieve this, individuals with HbA1c levels of $\geq 6.5\%$, did not self-report a diagnosis of diabetes, and did meet all other inclusion criteria, were added to the sample of 112 individuals with diagnosed diabetes. Individuals with diagnosed and undiagnosed diabetes (n = 310), were on average 66.84 years old (*SD* = 5.80). The majority of the sample identified as White (76.1%), male (71.9%), had high education (45.50%), had an average body mass index of 29.00 (*SD* = 5.11), and did not smoke (92.1%). Table 5 compares people with diagnosed and undiagnosed diabetes on the main variables of interest and sociodemographic characteristics. Chi-square tests of independence among categorical variables revealed that education differed between diabetes status, X^2 (2, n = 310) = 6.19, $p = .045$; people with diagnosed diabetes were more likely to have high education than people with undiagnosed diabetes. Independent sample t-tests conducted among continuous variables revealed no significant differences between people with diagnosed diabetes and undiagnosed diabetes.

Table 5

Participant Characteristics by Diagnosed Diabetes vs Undiagnosed Diabetes

Variable	Diagnosed Diabetes (*n*=112)	Undiagnosed Diabetes (*n*=198)	Difference test
Age, years, *M*(*SD*)	67.50(5.77)	66.46(5.80)	*t*(308)=-1.31, *p*=.190
Biological sex, %			X^2(1)=.19, *p*=.661
Male	70.50	72.7	
Ethnicity, %			X^2(1)=2.16, *p*=.14
White	71.4	78.8	
Education level, %			X^2(2)=6.19, *p*=.045
Low	28.9	32.8	
Medium	15.7	28.1	
High	55.4	39.1	
Smoking status, %			X^2(1)=.25, *p*=.617
Non-smoker	92.7	91.8	
Insulin use, %			-
No insulin	95.5	-	
Diabetes duration, *M*(*SD*)	2.04(2.17)	-	-
BMI, *M*(*SD*)	29.38(5.63)	28.79(4.79)	*t*(308)=-.97, *p*=.333
Psychological Distress, *M*(*SD*)	22.65(8.66)	21.28(8.78)	*t*(308)=-1.33, *p*=.186
PPWB, *M*(*SD*)	39.70(6.48)	39.81(7.54)	*t*(308)=.14, *p*=.891
Physical Activity, *M*(*SD*)	134.44(38.83)	143.81(41.71)	*t*(308)=1.95, *p*=.052

Note. M, mean; *SD*, standard deviation; *BMI*, body mass index; *PPWB*, positive psychological well-being.

Regression results testing associations between PPWB, psychological distress, diabetes status and physical activity are presented in table 6. In the unadjusted model, PPWB was positively associated with physical activity, $\beta = 1.04$, $p = .024$, however, psychological distress was not associated with physical activity, $\beta = .57$, $p = .092$. Diabetes status was inversely associated with physical activity, $\beta = -11.75$, $p = .018$; those with diagnosed diabetes reported less physical activity than those with undiagnosed diabetes. Diabetes status did not moderate the association between PPWB and physical activity, β = -.64, p = .369. In the adjusted model, PPWB was not associated with physical activity, β = 1.03, p = .057, whereas psychological distress was inversely associated with physical activity, β = .88, p = .031. Diabetes status was not associated with physical activity, β = -6.09, p = .297, and diabetes status did not moderate the association between PPWB and physical activity, β = .15, p = .864.

Table 6

Regression Coefficients for Associations Between Positive Psychological Well-being, Psychological Distress, and Physical Activity among People With Diagnosed and Undiagnosed Diabetes.

Predictor Variable	*B*(SE)	*p*	95% CI
Unadjusted for covariates			
Psychological distress	.57 (.34)	0.092	-.10, 1.24
Diabetes status	-11.75 (4.94)	0.018	-21.46, -2.03
Positive psychological well-being	1.04 (.46)	0.024	.14, 1.94
Diabetes status X Positive psychological well-being	-.64 (.71)	0.369	-2.03, .76
Adjusted for covariates			
Psychological distress	.88(.41)	0.031	.08, 1.68
Diabetes status	-6.09 (5.83)	0.297	-17.59, 5.41
Positive psychological well-being	1.03 (.54)	0.057	-.03, 2.08
Diabetes status X Positive psychological well-being	.15 (.87)	0.864	-1.56, 1.86

Note. Unadjusted for covariates: n = 310. Adjusted for covariates: n = 205. Models were adjusted for biological sex, age, ethnicity, level of education, smoking status, and body mass index.

Sensitivity Analysis. Participants who reported cycling for more than ten minutes per day were removed in a sensitivity analysis to evaluate whether cycling influenced the association between PPWB and physical activity (n = 291). Of the 112 participants with diagnosed diabetes, 7 were excluded from the sensitivity analysis (n = 105); of the 198 participants undiagnosed diabetes, 12 were excluded from the sensitivity analysis (n = 186). Table 7 does not include individuals who reported cycling and compares people with diagnosed and undiagnosed diabetes on the main variables of interest and sociodemographic characteristics. In contrast to findings that included cycling data, chi-square and independent sample t-tests conducted among categorical and continuous variables revealed no significant differences between people with diagnosed diabetes and undiagnosed diabetes.

Table 7

Participant Characteristics by Diagnosed Diabetes and Undiagnosed Diabetes

Variable	Cycling data not included		
	Diagnosed Diabetes (*n*=105)	Undiagnosed Diabetes (*n*=186)	Difference test
Age, years, *M*(*SD*)	67.42(5.69)	66.45(5.83)	$t(289)=-1.15, p=.252$
Biological sex, %			$X^2(1)=.10, p=.755$
Male	70.50	72.00	
Ethnicity, %			$X^2(1)=2.39, p=.122$
White	70.50	78.50	
Education level, %			$X^2(2)=5.79, p=.055$
Low	28.70	34.70	
Medium	16.30	27.30	
High	55.00	38.00	
Smoking status, %			$X^2(1)=.64, p=.423$
Non-smoker	93.20	91.30	
Insulin use, %			-
No insulin	95.20	-	
Diabetes duration, *M*(*SD*)	2.09(2.20)	-	-
BMI, *M*(*SD*)	29.45(5.73)	28.81(4.87)	$t(289)=-.97, p=.320$
Psychological Distress, *M*(*SD*)	22.60(8.52)	21.40(8.78)	$t(289)=-1.14, p=.255$
PPWB, *M*(*SD*)	39.47(6.40)	39.57(7.63)	$t(289)=.12, p=.907$
Physical Activity, *M*(*SD*)	134.78(39.47)	144.07(41.68)	$t(289)=1.86, p=.064$

Note. M, mean; *SD*, standard deviation; *BMI*, body mass index; *PPWB*, positive psychological well-being.

In people with diabetes, the unadjusted model ($n = 291$) revealed that PPWB was positively associated with physical activity, $\beta = 1.05$, $p = .027$, and psychological distress was inversely associated with physical activity, $\beta = .76$, $p = .033$. Diabetes status was inversely associated with physical activity, $\beta = -11.05$, $p = .029$; those with diagnosed diabetes reported less physical activity than those with undiagnosed diabetes. Diabetes status did not moderate the association between PPWB and physical activity, $\beta = -.38$, $p = .603$. In the adjusted model (n = 196), PPWB was not associated with physical activity, $\beta = 1.00$, $p = .071$; however, psychological distress was inversely associated with physical activity, $\beta = .96$, $p = .024$. Diabetes status (i.e., diagnosed diabetes/undiagnosed diabetes) was not associated with physical activity, $\beta = -6.11$, $p = .302$, and diabetes status (i.e., diagnosed diabetes/undiagnosed diabetes) did not moderate the association between PPWB and physical activity, $\beta = .40$, $p = .663$.

Exploratory Analysis - Is the Strength of Association Between the CASP-19 Domains and Physical Activity Greater Among People with Diabetes or People Without Diabetes?

Control

An exploratory analysis was conducted to evaluate the strength of association between the CASP-19 domains and physical activity among people with diabetes and without diabetes. Regression results are presented in Table 8. In the unadjusted model, control was positively associated with physical activity, $\beta = 2.44$, $p <.001$, however, psychological distress was not associated with physical activity, $\beta = .08$, $p = .384$. Diabetes status was inversely associated with physical activity, $\beta = -29.24$, $p <.001$; those with diabetes reported less physical activity than those without diabetes. Diabetes status did not moderate the association between control and physical activity, $\beta = -.75$, $p = .719$. In the adjusted model, control was positively associated with physical activity, $\beta = 1.46$, $p = .002$, whereas psychological distress was not associated with physical activity, $\beta = -.13$, $p = .223$. Diabetes status was inversely associated with physical activity, $\beta = -12.66$, $p = .014$; those with diabetes reported less physical activity than those without diabetes. Diabetes status did not moderate the association between control and physical activity, $\beta = .13$, $p = .954$.

Table 8

Regression Coefficients for Associations between Control, Psychological Distress, and Physical Activity Among People With and Without Diabetes.

Predictor Variable	*B*(SE)	*p*	95% CI
Unadjusted for covariates			
Psychological distress	.08 (.10)	0.384	-.11, .27
Diabetes status	-29.24 (4.55)	<.001	-38.15, -20.32
Control	2.44 (.42)	<.001	1.61, 3.26
Diabetes status X Control	-.75 (2.10)	0.719	-4.86, 3.36
Adjusted for covariates			
Psychological distress	-.13 (.11)	0.223	-.35, .08
Diabetes status	-12.69 (5.16)	0.014	-22.78, -2.53
Control	1.46 (.47)	.002	.54, 2.38
Diabetes status X Control	.13 (2.30)	0.954	-4.38, 4.64

Note. Unadjusted for covariates: $n = 3863$. Adjusted for covariates: $n = 2821$. Models were adjusted for biological sex, age, ethnicity, level of education, smoking status, and body mass index.

Sensitivity Analysis. Participants who reported cycling for more than ten minutes per day were removed in a sensitivity analysis to evaluate whether cycling influenced the association between control and physical activity. In the unadjusted model ($n = 3381$), control was positively associated with physical activity, $\beta = 2.51$, $p < .001$, however, psychological distress was not associated with physical activity, $\beta = .10$, $p = .297$. Diabetes status was inversely associated with physical activity, $\beta = -26.20$, $p < .001$; those with diabetes reported less physical activity than those without diabetes. Diabetes status did not moderate the association between control and physical activity, $\beta = -.42$, $p = .842$. In the adjusted model ($n = 2470$), control was positively associated with physical activity, $\beta = 1.56$, $p = .001$, whereas psychological distress was not associated with physical activity, $\beta = -.12$, $p = .282$. Diabetes status was inversely associated with physical activity, $\beta = -11.10$, $p = .030$, those with diabetes reported less physical activity than those without diabetes. Diabetes status did not moderate the association between control and physical activity, $\beta = .53$, $p = .818$.

Autonomy

Regression results are presented in Table 9. In the unadjusted model ($n = 3863$), autonomy domain positively associated with physical activity, $\beta = 1.51$, $p <.001$, however, psychological distress was not associated with physical activity, $\beta = -.05$, $p = .616$. Diabetes status was inversely associated with physical activity, $\beta = -31.04$, $p <.001$; those with diabetes reported less physical activity than those without diabetes. Diabetes status did not moderate the association between autonomy and physical activity, $\beta = -.3.07$, $p = .063$. In the adjusted model ($n = 2820$), autonomy was positively associated with physical activity, $\beta = .85$, $p = .028$, and psychological distress was inversely associated with physical activity, $\beta = -.22$, $p = .038$. Diabetes status was inversely associated with physical activity, $\beta = -14.56$, $p = .006$; those with diabetes reported less physical activity than those without diabetes. Diabetes status did not moderate the association between autonomy and physical activity, $\beta = -2.40$, $p = .212$.

Table 9

Regression Coefficients for Associations between Autonomy, Psychological Distress, and Physical Activity Among People With and Without Diabetes

Predictor Variable	*B*(SE)	*p*	95% CI
Unadjusted for covariates			
Psychological distress	-.05 (.09)	0.61	-.22, .13
Diabetes status	-31.04 (4.72)	<.001	-40.29, -21.78
Autonomy	1.51 (.35)	<.001	.83, 2.18
Diabetes status X Autonomy	-3.07 (1.65)	0.063	-6.31, .17
Adjusted for covariates			
Psychological distress	-.22 (.10)	0.038	-.42, -.01
Diabetes status	-14.56 (5.33)	0.006	-25.05, -4.16
Autonomy	.85 (.39)	0.028	.09, 1.60
Diabetes status X Autonomy	-2.40 (1.92)	0.212	-6.18, 1.36

Note. Unadjusted for covariates: $n = 3381$. Adjusted for covariates: $n = 2469$. Models were adjusted for biological sex, age, ethnicity, level of education, smoking status, and body mass index.

Sensitivity Analysis. Participants who reported cycling for more than ten minutes per day were removed in a sensitivity analysis to evaluate whether cycling influenced the association between autonomy and physical activity. In the unadjusted model ($n = 3381$), autonomy was positively associated with physical activity, $\beta = 1.28$, $p < .001$, however, psychological distress was not associated with physical activity, $\beta = -.06$, $p = .498$. Diabetes status was inversely associated with physical activity, $\beta = -28.21$, $p < .001$; those with diabetes reported less physical activity than those without diabetes. Diabetes status did not moderate the association between autonomy and physical activity, $\beta = -.2.76$, $p = .096$. In the adjusted model ($n = 2469$), autonomy was not associated with physical activity, $\beta = .63$, $p = .110$, whereas psychological distress was inversely associated with physical activity, $\beta = -.24$, $p = .024$. Diabetes status was inversely associated with physical activity, $\beta = -13.38$, $p = .012$; those with diabetes reported less physical activity than those without diabetes. Diabetes status did not moderate the association between autonomy and physical activity, $\beta = -2.18$, $p = .261$.

Self-realisation

Regression results are presented in Table 10. In the unadjusted model (*n* = 3862), self-realisation was positively associated with physical activity, $\beta = 2.06$, $p < .001$, however, psychological distress was not associated with physical activity, $\beta = .12$, $p = .225$. Diabetes status was inversely associated with physical activity, $\beta = -29.64$, $p < .001$; those with diabetes reported less physical activity than those without diabetes. Diabetes status did not moderate the association between self-realisation and physical activity, $\beta = -1.38$, $p = .473$. In the adjusted model (*n* = 2819), self-realisation was positively associated with physical activity, $\beta = 1.75$, $p < .001$, whereas psychological distress was not associated with physical activity, $\beta = -.02$, $p = .878$. Diabetes status was inversely associated with physical activity, $\beta = -12.67$, $p = .014$; those with diabetes reported less physical activity than those without diabetes. Diabetes status did not moderate the association between self-realization and physical activity, $\beta = -.39$, $p = .860$.

Table 10

Regression Coefficients for Associations between Self-realisation, Psychological Distress, and Physical Activity Among People With and Without Diabetes.

Predictor Variable	*B*(SE)	*p*	95% CI
Unadjusted for covariates			
Psychological distress	.12 (.11)	0.225	-.07, .31
Diabetes status	-29.64 (4.50)	<.001	-38.45, -20.82
Self-realisation	2.06 (.34)	<.001	1.39, 2.78
Diabetes status X Self-realisation	-1.38 (1.92)	0.473	-5.13, 2.38
Adjusted for covariates			
Psychological distress	-.02 (.11)	0.878	-.24, .20
Diabetes status	-12.73 (5.14)	0.014	-22.81, -2.66
Self-realisation	1.75 (.38)	<.001	1.02, 2.49
Diabetes status X Self-realisation	-.40 (2.21)	0.860	-4.74, 3.94

Note. Unadjusted for covariates: *n* = 3862. Adjusted for covariates: *n* = 2819. Models were adjusted for biological sex, age, ethnicity, level of education, smoking status, and body mass index.

Sensitivity Analysis. Participants who reported cycling for more than ten minutes per day were removed in a sensitivity analysis to evaluate whether cycling influenced the association between self-realization and physical activity. In the unadjusted model (n = 3380), self-realisation was positively associated with physical activity, β = 1.66, p <.001, however, psychological distress was not associated with physical activity, β = .06, p = .523. Diabetes status was inversely associated with physical activity, β = -26.69, p <.001; those with diabetes reported less physical activity than those without diabetes. Diabetes status did not moderate the association between the self-realization domain and physical activity, β = -.77, p = .681. In the adjusted model (n = 2468), self-realisation was positively associated with physical activity, β = 1.38, p <.001, whereas psychological distress was not associated with physical activity, β = -.08, p = .497. Diabetes status was inversely associated with physical activity, β = -11.46, p = .023; those with diabetes reported less physical activity than those without diabetes. Diabetes status did not moderate the association between self-realization and physical activity, β = -.11, p = .959.

Pleasure

Regression results are presented in Table 11. In the unadjusted model (n = 3863), pleasure domain was associated with physical activity, β = -.49, p = .383, however, psychological distress was inversely associated with physical activity, β = -.25, p = .005. Diabetes status was inversely associated with physical activity, β = -29.64, p <.001; those with diabetes reported less physical activity than those without diabetes. Diabetes status did not moderate the association between the pleasure domain and physical activity, β = 1.94, p = .492. In the adjusted model (n = 2820), pleasure was positively associated with physical activity, β = 1.36, p = .031, and psychological distress was inversely associated with physical activity, β = -.23, p = .023. Diabetes status was inversely associated with physical activity, β = -14.14, p = .006; those with diabetes reported less physical activity than those without diabetes. Diabetes status did not moderate the association between pleasure and physical activity, $\beta = 5.40$, $p = .230$.

Table 11

Regression Coefficients for Associations between Pleasure, Psychological Distress, and Physical Activity among People With Diagnosed Diabetes and Without Diabetes

Predictor Variable	*B*(SE)	*p*	95% CI
Unadjusted for covariates			
Psychological distress	.25 (.09)	0.005	-.42, -.07
Diabetes status	-29.64 (4.51)	<.001	-38.48, -20.81
Pleasure	-.49 (.57)	0.383	-1.60, .61
Diabetes status X Pleasure	1.94 (2.82)	0.492	-3.59, 7.46
Adjusted for covariates			
Psychological distress	-.23 (.10)	0.023	-.43, -.03
Diabetes status	-14.18 (5.17)	0.006	-24.31, -4.05
Pleasure	1.35 (.63)	0.031	.12, 2.59
Diabetes status X Pleasure	5.36 (4.49)	0.230	-3.46, 14.17

Note. Unadjusted for covariates: $n = 3863$. Adjusted for covariates: $n = 2820$. Models were adjusted for biological sex, age, ethnicity, level of education, smoking status, and body mass index.

Sensitivity Analysis. Participants who reported cycling for more than ten minutes per day were removed in a sensitivity analysis to evaluate whether cycling influenced the association between pleasure and physical activity. In the unadjusted model ($n = 3381$), pleasure was not associated with physical activity, $\beta = -.63$, $p = .271$, however, psychological distress was inversely associated with physical activity, $\beta = -.25$, $p = .006$. Diabetes status was inversely associated with physical activity, $\beta = -26.81$, $p < .001$; those with diabetes reported less physical activity than those without diabetes. Diabetes status did not moderate the association between the pleasure domain and physical activity, $\beta = -2.05$, $p = .462$. In the adjusted model ($n = 2469$), pleasure was not associated with physical activity, $\beta = 5.95$, $p = .146$, whereas psychological distress was inversely associated with physical activity, $\beta = -.25$, $p = .014$. Diabetes status was inversely associated with physical activity, $\beta = -13.00$, $p = .011$; those with diabetes reported less physical activity than those without diabetes. Diabetes status did not moderate the association between pleasure and physical activity, $\beta = 5.95$, $p = .171$.

Control, Autonomy, Self-realisation, and Pleasure

Regression models were tested to determine if the strength of association between the domains of the CASP-19 and physical activity among people with and without diabetes. Regression results are presented in table 12. In the unadjusted model ($n = 3859$), control, $\beta = 1.25$, $p = .015$, self-realisation, $\beta = 2.14$, $p <.001$, and pleasure were positively associated with physical activity, $\beta = -2.79$, $p <.001$; however, physical activity was not associated with autonomy, $\beta = .72$, $p = .069$. Diabetes status was inversely associated with physical activity, $\beta = -31.44$, $p <.001$; those with diabetes reported less physical activity than those without diabetes. Further, diabetes status did not moderate the associations between physical activity and control , $\beta = 2.01$, $p = .435$; autonomy, $\beta = -3.57$, $p = .076$; self-realisation, $\beta = -2.37$, $p = .307$; or pleasure, $\beta = 5.23$, $p = .084$. In the adjusted model ($n = 2817$), control, $\beta = .39$, $p = .504$, autonomy, $\beta = .23$, $p = .599$, and pleasure were not associated with physical activity, $\beta = -.14$, $p = .850$; however, self-realisation was positively associated with physical activity, $\beta = 1.59$, $p <.001$. Diabetes status was inversely associated with physical activity, $\beta = -16.09$, $p = .003$; those with diabetes reported less physical activity than those without diabetes. Further, diabetes status did not moderate the association between physical activity and control, $\beta = 2.92$, $p = .316$; autonomy, $\beta = -3.34$, $p = .138$; self-realisation, $\beta = -2.14$, $p = .428$; or pleasure, $\beta = 7.75$, $p = .115$.

Table 12

Regression Coefficients for Associations between Control, Autonomy, Self-realisation, Pleasure, Psychological Distress, and Physical Activity Among People With and Without Diabetes

Predictor Variable	*B*(SE)	*p*	95% CI
Unadjusted for covariates			
Psychological distress	.19 (.10)	0.065	-.01, -.40
Diabetes status	-31.44 (4.74)	<.001	-40.73, -22.15
Control	1.25 (.51)	0.015	.25, 2.26
Autonomy	.72 (.40)	0.069	-.06, 1.50
Self-realisation	2.14 (.42)	<.001	1.31, 2.97
Pleasure	-2.79 (.63)	<.001	-4.03, -1.55
Diabetes status X Control	2.01 (2.57)	0.435	-3.04, 7.05
Diabetes status X Autonomy	-3.58 (2.01)	0.076	-7.51, .37
Diabetes status X Self-realisation	-2.37 (2.32)	0.307	-6.91, 2.18
Diabetes status X Pleasure	5.23 (3.03)	0.084	-.71, 11.17
Adjusted for covariates			
Psychological distress	.02 (.12)	0.869	-.21, .25
Diabetes status	-16.15 (5.48)	.003	-26.89, -5.42
Control	.39 (.88)	0.504	-.74, 1.52
Autonomy	.23 (.45)	0.599	-.64, 1.11
Self-realisation	1.58 (.47)	0.001	.66, 2.50
Pleasure	-.13 (.71)	0.850	-1.53, 1.27
Diabetes status X Control	2.89 (2.92)	0.316	-2.82, 8.61
Diabetes status X Autonomy	-3.34 (2.25)	0.138	-7.76, 1.07
Diabetes status X Self-realisation	-2.12 (2.70)	0.428	-7.41, 3.17
Diabetes status X Pleasure	7.69 (4.92)	0.115	-1.95, 17.34

Note. Unadjusted for covariates: $n = 3859$. Adjusted for covariates: $n = 2817$. Models were adjusted for biological sex, age, ethnicity, level of education, smoking status, and body mass index.

Sensitivity Analysis. Cycling data were removed for a sensitivity analysis. Regression results are presented in table 12. In the unadjusted model ($n = 3377$), control, $\beta = 1.74$, $p = .001$, self-realisation, $\beta = 1.58$, $p < .001$, and pleasure were positively associated with physical activity, $\beta = -2.64$, $p < .001$; however, autonomy was not associated with physical activity; $\beta = .51$, $p = .206$. Diabetes status was inversely associated with physical activity, $\beta = -28.48$, $p < .001$; those with diabetes reported less physical activity than those without diabetes. Further, diabetes status did not moderate the association between physical activity and control, $\beta = 1.59$, $p = .535$; autonomy, $\beta = -3.23$, $p = .105$; self-realisation, $\beta = -1.59$, $p = .483$; or pleasure, $\beta = 4.91$, $p = .101$. In the adjusted model ($n = 2466$), control, $\beta = .92$, $p = .121$, autonomy, $\beta = .001$, $p = .998$, and pleasure were not associated with physical activity, $\beta = -.33$, $p = .656$; however, self-realisation was positively associated with physical activity, $\beta = 1.14$, $p = .018$. Diabetes status was inversely associated with physical activity, $\beta = -14.92$, $p = .006$; those with diabetes reported less physical activity than those without diabetes. Further, diabetes status did not moderate the association between physical activity and control, $\beta = 2.75$, $p = .338$; autonomy, $\beta = -3.09$, $p = .162$; self-realisation, $\beta = -1.99$, $p = .447$; pleasure, $\beta = 8.16$, $p = .087$.

Discussion

To my knowledge, this is the first study to test associations between PPWB, psychological distress, and physical activity during a five-year follow-up among people with diabetes. Contrary to the hypothesis, PPWB was not associated with physical activity above and beyond psychological distress among people with diabetes. The results of sensitivity analyses were consistent with the main findings.

PPWB and Physical Activity Among People With Diabetes

PPWB was not associated with physical activity above and beyond psychological distress among people with diabetes. Perhaps the analyses in the present study with the sample of people with diabetes (n = 112) were underpowered to detect associations between PPWB and physical activity in this population. A post-hoc power analysis on the sample size of the present study suggested that the analyses were powered at 80% to detect an effect size (f^2)of 0.14. Given that no association was found between PPWB and physical activity among people with diabetes, perhaps the true effect of this association is in fact smaller. Another reason why associations between PPWB and physical activity were not found among people with diabetes could be because PPWB was measured at an earlier timepoint than physical activity. Given that physical activity was measured five years after PPWB was measured, PPWB could have changed in the level of intensity between the baseline measurement and the outcome measurement of physical activity. Individuals with high PPWB scores at baseline could have experienced low PPWB at the outcome time point. It is possible that hypotheses from the present study were not supported because the co-occurrence of PPWB and physical activity should be examined to identify associations between PPWB and physical activity. Notably, the domains of the CASP-19 have been shown to change over time (Springer et al., 2011). Individuals within the sample may have experienced grief, loss of employment, divorce, financial difficulties, among other various life challenges that may have altered their well-being from the baseline measurement to the measure of the outcome.

Additionally, perhaps associations between PPWB and physical activity among people with diabetes were not found in the current study because there are factors related to having diabetes that influences the association between PPWB and physical activity differently than people without diabetes. For instance, the severity of diabetes complications is associated with PPWB, such that the worsening of diabetes caused by diabetes complications (e.g., retinopathy, cardiovascular disease; World Health Organization, 2013) has been found to affect PPWB (Nicolucci et al., 2016). Additionally, many individuals with progressing diabetes complications are severely hindered in mobility and thus impaired in their ability to engage in regular physical activity (Waden et al., 2008; Johnson et al., 2019). Thus, it is possible that associations between PPWB and physical activity among people with diabetes could have been identified if the severity of diabetes complications were taken into account in the present study.

Another factor specific to diabetes that may explain why PPWB was not associated with physical activity among people with diabetes is diabetes distress, which has been found to be linked with PPWB (Beverly et al., 2021; Chan et al., 2020; Liu et al., 2020) and physical activity (Fisher et al., 2010; Fisher et al., 2014). Although the present study controlled for psychological distress, it did not account for diabetes distress, which differs in that the experienced emotional distress is specific to the burden of living with and managing diabetes, in addition to the interpersonal distress related to living with diabetes (Jones et al., 2015). Research has found that diabetes distress is moderately correlated with psychological distress (e.g., $r - .44$, $r = .34$;

Westley et al., 2021), suggesting that these constructs of distress differ despite sharing some variance. Previous studies have consistently found that social support, a facet of PPWB, is associated with less diabetes distress (Baek et al., 2014; Chen et al., 2020); additionally, higher diabetes distress is consistently linked with lower physical activity (Fisher et al., 2010; Fisher et al., 2014). Despite controlling for psychological distress in the current study, diabetes distress likely captured other aspects of psychological well-being related to PPWB and physical activity among people with diabetes.

Another possible reason why PPWB was not associated with physical activity among people with diabetes in the present study relates to the CASP-19 measure. Because a few items from the measure were reverse scored to calculate the final score, perhaps the CASP-19 did not capture PPWB as existing on two separate continuums of well-being as suggested by Keyes' Two-Continua Model of Mental Health. Given that the concept of well-being existing on two separate continuums was a key theoretical inference that framed the design of the present study, it is unclear whether associations between PPWB and physical activity would have been identified if PPWB was measured using a scale that was able to capture two continuums of well-being.

Finally, it is possible that PPWB, as measured by the CASP-19, is more precise at capturing PPWB among sub-clinical diabetes population. For instance, a recent study that measured PPWB using the CASP-19 found that PPWB was inversely linked with HbA1c eight years later among a group of people that did not have diabetes at baseline (Poole et al., 2020). Similarly, another recent study in which participants did not have diabetes at baseline, found that PPWB, as measured by the CASP-19, was protective against the development of diabetes over a period of 12 years (Panagi et al., 2021). Perhaps PPWB has an impact on the biological processes implicated in the development of diabetes, such as HbA1c levels or inflammation.

PPWB and Physical Activity Among Older Adults Without Diabetes

Although this study did not find associations between PPWB and physical activity among people with diabetes, previous studies using the CASP-19 found PPWB to be associated with physical activity among older adults (e.g., Giltay et al., 2007; Strine et al., 2008; Stubbe et al., 2007). For instance, higher PPWB was identified as a significant correlate of physical activity among older adults with a probable generalized anxiety disorder (McDowell et al., 2019). Given that anxiety symptoms were not measured in the present study, it is not possible to determine the influence of anxiety symptoms on PPWB and physical activity. However, because people with diabetes are more likely to experience symptoms of anxiety and lower PPWB than the general population (Grigsby et al., 2002; Lipscombe et al., 2014; Peyrot et al., 2019), it is possible that the combination of having diabetes and experiencing anxiety, in addition to lower PPWB, may have influenced the lack of a link between PPWB and physical activity in the present study.

The CASP-19 measure could have influence the lack of association between PPWB and physical activity in the present study. Kim and colleagues (2017) found that higher baseline PPWB was associated with increased physical activity over time among a large sample of older adults. However, in contrast to the present study, two items were removed from the CASP-19 scale because the authors suggested that they conceptually overlapped with physical health. It is possible that the included items may have confounded findings between PPWB and physical activity in the present study. Additionally, Kim et al. (2017) adjusted for the presence of eight medical conditions (i.e., excluding diabetes), whereas dataset limitations did not allow for the control of these factors in the present study. Given that some medical conditions (e.g., arthritis, chronic lung disease) can affect one's ability to engage in physical activity (Metsios & Kitas, 2018; Vancampfort et al., 2017) and that many diseases (e.g., cancer, stroke) are known to be associated with PPWB (Panzeri et al., 2019; Zimmermann et al., 2018), the lack of control of acute or chronic conditions could have influenced both the predictor and outcome variables of the current study.

Although hypotheses from the current study were not supported, CASP-19 scores were consistent with other extensive studies examining older people. For instance, average CASP-19 scores from the present study from people without diabetes were consistent with CASP- 19 average scores (M = 42.7) from the Irish Longitudinal Study on Ageing, a large-scale, nationally representative study of over 8000 people aged 50 and over in Ireland (Barrett et al., 2011). Average CASP-19 scores from the present study were also similar to CASP-19 average scores (M = 42.5) from the TILDA study, another population-based nationally representative study of over 11000 older individuals in England (Netuveli et al., 2006). Therefore, similar average scores of the CASP-19 from the present study and other nationally representative studies may indicate that findings of the association between PPWB and physical activity among people with diabetes were not due to CASP-19 scores from the present study.

PPWB, Diabetes Status, and Physical activity

The current study found that people with diabetes engaged in less physical activity then people without diabetes. This finding is consistent with previous research that has demonstrated that those without diabetes report increased physical activity than people with diabetes (e.g., Sibai et al., 2013; Zhao et al., 2008; Morrato et al., 2007). However, diabetes status (i.e., diabetes/no diabetes) did not moderate the association between PPWB and physical activity, suggesting that the link between PPWB and physical activity did not differ between groups. However, there was a main effect of PPWB being positively associated with physical activity among people with and without diabetes. Despite there being no association between PPWB and physical activity among people with diabetes, the moderation analyses could have been sufficiently powered to detect a main effect of PPWB with physical activity with approximately 4000 people in the sample of people with and without diabetes. However, a possible explanation for diabetes status not moderating the link between PPWB and physical activity could be that there was only 112 people with diabetes in comparison to approximately 3800 people that did not have diabetes. Therefore, considering there was only 112 people with diabetes, the precision of the slope in the moderation analyses would have resulted in a large confidence band; there could have been a lack of statistical power that did not provide the analysis the precision necessary to differentiate between the diabetes conditions when examining associations between PPWB and physical activity.

In models unadjusted for covariates, there was a main effect of PPWB associated with physical activity among people with diagnosed diabetes and undiagnosed diabetes. However, after controlling for sociodemographic and health-related factors, the association between PPWB and physical activity did not hold, suggesting that sociodemographic and health variables explained more variance in physical activity than PPWB. Consistent with previous studies, having undiagnosed diabetes was positively associated with physical activity (Dankner et al., 2016).

Association Between PPWB and Physical Activity Explained by Theoretical Models

Positive psychological well-being was inversely and moderately associated with psychological distress. This finding is consistent with Keyes's Two-Continua model (2002) that suggests PPWB and psychological distress exist on separate continuums of well-being. The inverse and moderate correlation found between PPWB and psychological distress suggest that although for many, scores of PPWB increased as scores of psychological distress decreased, there were also many increasing scores of PPWB that varied with increasing psychological distress scores or decreasing scores of PPWB that varied with decreasing scores of psychological distress. Therefore, changes in PPWB or psychological distress were not fully explained by one another.

Other theories of well-being can be contrasted with the needs satisfaction model (Hyde et al., 2003), which the CASP-19 is derived from, to provide possible explanations as to why PPWB was not associated with physical activity among people with diabetes in the present study. For instance, part of the Self-Determination Theory (SDT; Ryan & Deci, 2002) posits that eudaimonic well-being facilitates health behaviour performance by increasing positive experiences that lead to the intrinsic pursuit of life goals (Ryan et al., 2008). Thus, if life goals become increasingly intrinsic, then it can be expected that an individual will feel autonomous motivation to perform health behaviours such as physical activity (Ryan et al., 2008; Patrick & Williams, 2012; Koponen, Simonsen, & Suominen, 2018). Given that health behaviour performance is linked with autonomous motivation, it is possible that autonomous motivation is a key driving factor in physical activity engagement. Therefore, autonomous motivation, rather than PPWB constructs measured by the CASP-19 could be associated with physical activity. Autonomous motivation may be especially key in the context of diabetes given that the responsibility of diabetes management, including engaging in regular physical activity, rests largely upon the individual with diabetes. That is, for optimal health outcomes, individuals with diabetes need to engage a variety of management strategies autonomously in various domain, including physical activity (Zhuo, Zhang, & Hoerger, 2013).

In contrast, the CASP-19 is derived from a needs satisfaction model that posits that all human beings pursue to satisfy a set of higher needs (i.e., control, autonomy, self-realization, pleasure). Although the model includes a facet of autonomy, the construct does not parallel autonomous motivation as outlined by the SDT, and as such, may not capture the feature of autonomy that is key for physical activity. Additionally, rather than explaining how PPWB may be linked to health behaviours, the needs satisfaction model suggests that satisfying higher needs is essential for achieving a good quality of life. Thus, it is expected that people will engage in activities and interests to satisfy these higher needs. Perhaps activities that are less focused on health behaviours are more strongly associated with the CASP-19 among people with diabetes.

The upward spiral theory of lifestyle change (Fredrickson, 2013; Van Cappellen et al., 2018) is another theory of well-being that could explain why PPWB was not associated with physical activity in the present study. The upward spiral theory of lifestyle change seeks to explain how hedonic processes, such as positive affect, can facilitate long-term adherence to positive health behaviours (Fredrickson, 2013; Van Cappellen et al., 2018). The theory posits that if people associate enjoyment with the thought of participating in physical activity, then they are more likely to engage in physical activity over time. The link between PPWB and physical activity was not identified in the present study perhaps because the hedonic process assessed differed from those proposed to be linked to physical activity from the upward spiral theory of lifestyle. For instance, the hedonic processes meant to be captured by the CASP-19 focus on participating in any pleasurable activity that would contribute to a better quality of life. In contrast, the upward spiral theory of lifestyle change argues that positive judgements of physical activity must be present to sustain engagement long term, in addition to positive affect and enjoyment that must be experienced during physical activity rather than after physical activity. Therefore, it is plausible that the context in which physical activity is experienced and judged as positive would be more appealing to people with diabetes rather than physical activity that is not perceived as pleasurable; especially given that people with diabetes are less likely to exercise than the general population (Chen et al., 2015; Colberg et al., 2010; Colberg et al., 2016; Plotnokoff et al., 2010; Sigal et al., 2013; Sigal et al., 2018; Vanden Bosch, Robbins, & Anderson, 2015), the positive experience and judgements could serve as added motivation to facilitate engagement in physical activity. As such, it could be that hedonic processes must occur in the context of physical activity to drive physical activity engagement, rather than participating in any general activity that is meant to contribute to a better quality of life could lead to the experience of hedonic processes.

CASP-19, PPWB, and Physical Activity

Much of the research assessing the association between PPWB and physical activity in the general population examined other facets of PPWB than control, autonomy, self-realization, and pleasure. For instance, one study examined links between optimism (i.e., facet of PPWB described as an attitude, disposition, or general expectation that the future will be favourable) and accelerometer assessed physical activity among acute coronary syndrome patients (Huffman et al., 2016). After controlling for baseline self-reported physical activity and psychological distress, optimism was positively associated with physical activity six months later. Another study examined longitudinal associations between optimism and self-reported vigorous physical activity outcomes among older adults. Over and above depressive symptoms and previous physical activity, individuals who were most optimistic were 15% more likely than less optimistic people to engage in vigorous physical activity 3 and 6 years later (Progovac et al., 2017). It is possible that findings from these studies differ from the present study because optimism was examined in relation to physical activity.

In contrast to the CASP-19, optimism is a future-oriented facet of PPWB that involves positive expectations about one's ability to achieve health goals (Carver et al., 2009). Expectancy-values theories suggest that optimists tend to persevere if facing a challenging goal due to confidence in one's efforts (Carver & Scheier, 1998). Therefore, if engaging in physical activity is the goal, then an optimistic person may have an easier time achieving this goal because of the general expectation that one's efforts will lead to a positive outcome (Carver et al., 2009; Scheier et al., 1985). Additionally, according to the theory of positive orientation, people with a positive perception of future experiences also tend to be high in self-efficacy (Caprara, 2009). Self-efficacy (i.e., belief in one's capabilities to execute actions required to attain a goal) is linked with being more likely to engage in and sustain attempts at maintaining physical activity among older adults (French et al., 2014). Although the present study did not test associations between these facets of PPWB and physical activity given the use of the CASP-19, it is possible that the co-occurrence of optimism and high self-efficacy provides a context in which physical activity is more likely to occur.

The present study did not measure purpose in life, another facet of PPWB associated with physical activity (e.g., Hooker & Masters, 2016; Sutin et al., 2021). Purpose in life conceptually differs from the CASP-19 facets in that purpose in life, for instance, is proposed as being part of one's identity and helps individuals select long-term goals consistent with health promotion (McKnight & Kasdan, 2009). Further, purpose in life can be described as a psychological resource that motivates individuals to attain long-term goals (Musich et al., 2018; Ryff, 1989). One study examined links between purpose in life and self-reported physical activity over an 18-to-20-year period among older adults (Rector et al., 2019). After adjusting for depressive symptoms, higher scores on purpose in life were associated with greater odds of being in the increasing physical activity trajectory than the decreasing physical activity trajectory. Similarly, a recent study assessed links between purpose in life and self-reported physical activity using two nationally representative samples of older adults in the US (Yemiscigil & Vlaev, 2021). The first analysis revealed that purpose in life was linked with greater levels of leisure-time physical activity four years later; the second analysis paralleled these findings with a nine-year follow-up. Further, purpose in life was linked with accelerometer-assessed moderate to vigorous physical activity after controlling for depressive symptoms (Hooker & Masters, 2016).

It is possible that the integration of purpose in life into one's identity creates stronger links with physical activity over time compared to control, autonomy, self-realization and pleasure. Additionally, purpose in life is associated with perceiving fewer barriers to being active (Sutin et al., 2021). As such, given that individuals often encounter barriers when trying to maintain physical activity long-term, perhaps individuals high in purpose in life have the necessary psychological resources to work through these barriers over time to be successful in achieving their health goals. In contrast, there is currently no available evidence to suggest that the CASP-19 is linked with fewer perceived barriers to engaging in physical active. Finally, theories suggest that an important predictor of physical activity is intentions, the conscious decisions and motivations to enact a behaviour (Brandstadter and Lerner, 1999; Holahan et al., 2011). Whereas the domains of the CASP-19 are not linked with intentions, results from the present study could be explained by people with greater levels of sense of purpose in life may be more likely to have intentions to take care of their lives, which can include intentions to be physically active.

CASP-19 Domains and Physical Activity

Diabetes status did not moderate associations between any of the domains of the CASP-19 (i.e., control, autonomy, self-realization, and pleasure) and physical activity. However, people without diabetes engaged in more physical activity than people with diabetes; this finding is consistent with previous studies suggesting that people from the general population report more physical activity than people with diabetes (e.g., Morrato et al., 2007; Zhao et al., 2008; Zhao et al., 2011). However, a significant main effect of each of the CASP-19 domains on physical activity suggested that the link between these domains and physical activity may not be dependent on whether or not one has diabetes.

Control

Consistent with prior research (Drewelies et al., 2018; Sargent-Cox et al., 2015; Qin & Guo, 2020), control was associated with physical activity among older adults. However, the association did not hold among people with diabetes; additionally, diabetes status did not moderate the association between control and physical activity. Although this analysis was exploratory, prior studies suggest that control is associated with physical activity among people with diabetes (e.g., Qin & Guo, 2020) and without diabetes (e.g., Drewelies et al., 2018; Sargent-Cox et al., 2015). For instance, Qin and Guo (2020) found that a stronger sense of control was associated with more frequent physical activity among people with diabetes. However, this study also used Pearlin and Schooler's Mastery Scale (1978) and only sampled people from an African American ethnic background with diabetes. The authors suggested that Black individuals with diabetes face unique stressors that impact levels of mastery and engagement in physical activity (Qin & Guo, 2020). For instance, Black individuals with diabetes have worse diabetes health outcomes and are least likely to participate in any level of physical activity compared to other ethnic groups (Zhao et al., 2011; Qin & Guo, 2020). However, according to Pearlin's stress process model (Pearlin et al., 1981), a strong sense of control over life's circumstances can buffer between stressful events (e.g., worse health outcomes as an African American with diabetes) and health outcomes. Additionally, this study found that control moderated the association between having diabetes and light-intensity physical activity only and not moderate and vigorous physical activity. Similarly, Buman et al. (2010) found that the majority of older adults more frequently engage in light activity compared to moderate or vigorous activity. Therefore, given that light physical activity can be achieved with fewer barriers (e.g., walking, chores around the home), perhaps people with diabetes are engaging in physical activity mainly of a milder intensity. As the present study did not consider intensity levels of physical activity, associations between control and mild physical activity could not be identified.

Further, in Drewelies et al. (2018) and Sargent-Cox et al. (2015), control was positively associated with physical activity among older adults without diabetes. In this study, control was measured using Pearlin and Schooler's Mastery Scale (1978) that asks individuals about their perceived ability to influence life circumstances. Although mastery and control are conceptually alike (Ryff, 1989; Hyde, 2003), and some items between the two measures are similar, some items differ. For instance, the control domain of the CASP-19 includes an item about age preventing one from doing things; in contrast, Pearlin and Schooler's Mastery Scale (1978) includes an item asking about one's ability to problem-solve. Problem-solving skills are linked with increased physical activity among people with diabetes (King et al., 2010) and without diabetes (Brennan & Elkins, 2012); therefore, the link between control and physical activity may be more likely to be captured if one has good problem-solving skills. Given that engaging in regular physical activity poses various challenges to many people, it is plausible that being able to apply problem skills toward the challenges of engaging in physical activity in conjunction with perceiving oneself as capable of controlling their life's circumstances helps maintain physical activity over time.

Autonomy

Autonomy was associated with physical activity among older adults. However, the association did not hold among people with diabetes; additionally, diabetes status did not moderate the association between autonomy and physical activity. This finding is inconsistent with prior studies, given that autonomy has been linked with physical activity among people with and without diabetes. For instance, one study found that autonomy was linked to increased physical activity among people with coronary artery disease three years later (Williams et al., 2005). Autonomy was conceptualized as autonomous motivation and measured with items that assessed one's belief in whether lifestyle changes would improve health. Perhaps the inclusion of health in the measurement of autonomy explains the link found with physical activity, given that SDT in the context of health promotion suggests that the presence of autonomous motivation is associated with long-term persistence of behaviour change, including engagement in physical activity (Deci & Ryan, 1985). In contrast, the measurement of autonomy in the present study did not link with health. Rather, autonomy from the CASP-19 was conceptualized as the right of an individual to be free from unwanted interference; items included were not specific to health and instead reflected the extent to which external factors interfere with the capacity to achieve desired goals.

Autonomy, in the present study, did not specify any level of intrinsic or extrinsic processes. However, specifying the level of autonomy could also play a role in distinguishing physical activity outcomes over time. For instance, a systematic review examining associations between self-determination theory constructs and physical activity found that perceived intrinsic autonomy (i.e., strongly internally motivated) was associated with long-term physical activity adherence. In contrast, identified motivation (i.e., somewhat internally motivated) was associated with short-term physical activity adherence (Teixeira et al., 2012). Different levels of autonomy are determinants for varying aspects of engaging in physical activity (e.g., access to facilities, weather, social influences); therefore, autonomy levels and context should be considered when attempting to ascertain long-term physical activity adherence (Williams et al., 2010). Similarly, among people with diabetes, high scores on increasingly autonomous forms of motivation are linked with physical activity (Castonguay & Miquelon, 2018; Gourlan et al., 2016).

Autonomy has also been found to be associated with physical activity among people with diabetes. Koponen and colleagues (2017) found that compared to various other psychological factors (e.g., perceived autonomy support, self-care competence) autonomous motivation was most strongly associated with engagement in physical activity ($r = .71$) among people with diabetes. Autonomous motivation is linked with more intrinsic processes than extrinsic processes (Deci & Ryan, 2000); autonomy as measured in the present study did not consider these processes and instead focused on the extent to which an individual can engage in activities without interference from external factors. Results from Koponen et al. (2017) are consistent with prior studies that emphasize that autonomy linked with motivation as a key psychological resource linked with physical activity. Given that regular physical activity is considered challenging for many people with diabetes (Chen et al., 2015; Colberg et al., 2010; Colberg et al., 2016; Plotnokoff et al., 2010; Sigal et al., 2013; Sigal et al., 2018; Vanden Bosch, Robbins, & Anderson, 2015), and diabetes management requires autonomous implementation of changes in exercise behaviours as part of treatment, perhaps the presence of autonomy with motivation is necessary to identify links with physical activity in the context of diabetes.

A possible explanation for diabetes status not moderating the association between autonomy and physical activity could involve how autonomy is conceptualized on the CASP-19. One study assessing the use of the CASP-19 among older adults found that the autonomy domain lacked face validity; as such, some respondents may have conceptualized autonomy differently than how it was operationalized within the scale (Sim et al., 2011). Another study examining the psychometric properties of the CASP-19 among an older Irish cohort found that the items from the autonomy domain were not sufficiently distinct from the control domain (Sexton et al., 2013). It was noted that although the concepts are theoretically distinct, the generic way that the items were worded does not reflect conceptual differences between these domains. Given that the present study only included older adults, the items of the autonomy domain may have been differently perceived than was intended.

Self-Realization

Self-realization was associated with physical activity among older adults. However, the association did not hold among people with diabetes; additionally, diabetes status did not moderate the association between self-realization and physical activity. Only one prior study linking self-realization with physical activity could be located. This study found that personal growth was positively associated with moderate physical activity and vigorous physical activity among women in early midlife (Holahan et al., 2011). Self-realization was measured via the personal growth subscale of Ryff's Scales of Psychological Well-Being (1989). Although some items from the self-realization domain of the CASP-19 and Ryff's measure are worded similarly, overall, the factors are conceptualized differently. For instance, the CASP-19 conceptualizes self-realization as a focus on fulfilling human potential and constructing a self that is necessary to do well in society (Hyde et al., 2003; Sexton et al., 2013); in contrast, Ryff's measure describes personal growth as a process of being challenged, continuing to develop and recognizing improvement in behaviour over time. Given that regular physical activity can be challenging, perhaps individuals who excel when being challenged and are focused on self-improvement can persevere when faced with barriers to engaging in physical activity.

Pleasure

The final domain of the CASP-19, pleasure, was also associated with physical activity among older adults. However, the association did not hold among people with diabetes; additionally, diabetes status did not moderate the association between pleasure and physical activity. No previous work on associations between pleasure and physical activity among people with diabetes could be located; much of the work to date linking pleasure and physical activity has been examined qualitatively among the general population. For example, one study identified emerging themes suggesting that there are various types of pleasure (e.g., pleasure of habitual action, pleasure of immersion) that older adults experience when engaging in physical activity (Phoenix & Orr, 2014) and that it is the pleasurable experience of physical activity that should be highlighted to encourage regular engagement. The present study tapped into facets of pleasure that focus on being in the company of others and perceiving one's life as happy; as such, a lack in specifying pleasure in the context of physical activity could explain why pleasure was not linked with physical activity among people without diabetes in the present study.

Similar results were found in a quantitative study that assessed whether physical activity was linked with pleasure. Gellert et al. (2012) found that emphasizing pleasurable feelings that occur after engaging in physical activity rather than highlighting health-related benefits is more beneficial for increasing physical activity. Another study found that individuals in the higher enjoyment group were more likely to be physically active than people in the low enjoyment group (Steptoe & Wardle, 2012). Therefore, specifying the type of pleasure that may be experienced during physical activity and encouraging people in older age to engage in physical activity because of the related pleasurable experience may aid in physical activity engagement. Further, a study found that having participants change their perceptions about physical activity from an obligation to an activity that felt good was associated with a 65% increase in physical activity (Segar et al., 2002), suggesting that assessing perceptions of affective processes related to physical activity may help to identify links between pleasure and physical activity.

Most studies examining links between pleasure and physical activity among the general population use other measures of hedonic well-being, such as positive affect. Positive affect can be described as pleasurable feelings that include happiness, interest, joy, excitement, among others (Clark et al., 1989). Associations between positive affect and physical activity are supported by the Broaden-and-Build Theory of positive emotion (Fredrickson, 1998), which explains that experiencing positive emotions lead to improved physical well-being through engaging in behaviours that are good for health. One study found that higher positive affect scores were associated with higher levels of habitual physical activity among older adults (Pasco et al., 2011). It is possible that pleasure was not linked with physical activity in the present study because different types of pleasurable experiences were not captured, given that the CASP-19 measures a broader conceptualization of pleasure (e.g., looking forward to each day; feeling like life has meaning; perceiving life with happiness) compared to positive affect.

Association Between PPWB and Measurement of Physical Activity

It is possible that the link between PPWB, as measured by the CASP-19, and physical activity is non-linear. For instance, it could be that when PPWB is low physical activity is decreased, and when PPWB is high, then physical activity in also decreased; optimal engagement in physical activity could be when PPWB is at moderate levels. Additionally, the way in which physical activity was measured in the present study could have influenced the lack of association with PPWB. Although the use of a direct measure of physical activity was a strength of this study because accelerometers are more reliable than self-report measures of physical activity, fewer studies have identified associations between PPWB and physical activity when using accelerometers in comparison to self-report measures. The Common Method Bias (Podsakoff et al., 2003) suggests that bias can be introduced into analyses from the measurement tool used to measure a given construct. Research has found that accelerometers are less precise in capturing levels of mild physical activity, in comparison to moderate and vigorous physical activity (Helmerhorst et al., 2012; Shiroma et al., 2015). Therefore, given that studies examining physical activity engagement among older adults often find that the physical activity is usual of a milder intensity (e.g., Buman et al., 2010), perhaps the use of accelerometers did not fully capture levels of physical activity in older adults in the present study.

Additionally, physical activity has been demonstrated to have a dose-response association with mental health among older adults (e.g., Bernard et al., 2018; Mummery et al., 2004). For instance, it has been found that less frequent physical activity is linked to moderate reductions in psychological distress, in addition to improved mental health when with at least 20 minutes per week of any type of physical activity among older adults (Hamer et al., 2009). Less is known about potential dose-response associations between PPWB and multiple levels of physical activity with regard to type (e.g., aerobic, weightlifting), purpose (e.g., leisure, occupation), intensity (e.g., low, moderate, and vigorous), duration, and frequency (Gebel et al., 2015; Kim et al., 2008; Shephard, 2001; Zheng et al., 2009). The current study examined physical activity as a continuous outcome without considering how much physical activity can vary in the previously mentioned respects. For instance, perhaps PPWB is differentially linked with mild aerobic physical activity than vigorous aerobic physical activity among people with diabetes. That is, aerobic physical activity at milder intensities may be more relevant and frequent among people with diabetes when PPWB is low vs high compared to more vigorous physical activity. Therefore, it could be helpful to identify groups of individuals with low versus high levels of PPWB and test associations with varying levels of physical activity intensity (Boehm et al., 2018). Vigorous physical activity is generally more difficult to engage in given the effort required to sustain the level of intensity compared to mild intensity physical activity, such as taking a walk. Given that many individuals with diabetes are challenged with engaging in physical activity, it is plausible that most people with diabetes may be engaging in milder intensity physical activity. Further, duration of physical activity bouts was not considered in the present study. Because it has been found that short bouts of physical activity are differentially linked to physical activity compared to longer bout of physical activity (Netz et al., 2005), duration is an important factor to consider in the link between PPWB and physical activity. Although accelerometers can indeed capture intensity and duration of physical activity, these factors were not assessed in the present study.

Strengths, Limitations, and Future Directions

The first strength of this study includes the use of a direct measure of physical activity. Given that self-reported physical activity is highly subjective, has been found to be problematic for interpreting findings, and often overestimated among people with diabetes (Warren et al., 2010; Oosterom et al., 2018), the use of a direct measure of physical activity is an important strength of this study. Other strengths include data from the Whitehall 2 study, a large, population-based study, theory-driven hypotheses, the inclusion of a biological measure of diabetes status, and a valid and reliable measure of PPWB. Further, this is the first study to examine associations between PPWB and physical activity in the context of diabetes. Given that most studies examining PPWB do so with PPWB as the outcome variable of interest, another strength of the current study is that PPWB was considered as a predictor. However, this study also has several limitations that can be addressed in future research. First, this study did not account for the variance associated with baseline levels of physical activity. Because baseline levels of physical activity were not accounted for, it was not possible to determine whether greater physical activity engagement at follow-up could have been due to physical activity levels at baseline. That is, low vs high levels of baseline physical activity could have influenced physical activity levels at follow-up. Additionally, this study did not assess physical activity at multiple time points to consider how PPWB and physical activity may have varied over time. Future studies should consider controlling for baseline levels of physical activity given that individuals physical activity at baseline could confound results measured at the outcome. Further, future studies could use survival curve analysis to account for any variations associated with time aspects of the association between PPWB and physical activity.

Second, this study did not account for the type of physical activity. Studies have found that well-being is differentially linked with different types of physical activity (e.g., Peluso & Andrade, 2005). For instance, a meta-analysis found that aerobic physical activity was more beneficial to well-being among older adults compared to resistance training (Netz et al., 2005). Future studies should consider the comparison between aerobic physical activity and strength training physical activity as factors that may be influenced by PPWB in the context of diabetes. Additionally, the present study did not measure physical activity duration nor intensity level. Therefore, besides examining the effect of PPWB on overall physical activity, future studies should also consider dose of physical activity, including duration of each physical activity session, number of physical activity session per week, as well as physical activity intensity.

Third, information about exercise self-efficacy, number and severity of diabetes-related complications, and prescribed medications was not available in the Whitehall 2 study. It is difficult to determine whether PPWB would be linked to physical activity if the present study would have controlled for these factors. Although the present study controlled for insulin use, it did not account for other medications that people with diabetes often take on a regular basis to regulate blood glucose levels among other symptoms (Yaribeygi et al., 2020). For instance, one study identified a link with well-being, such that approximately 1 in 5 people with diabetes perceived that taking non-insulin diabetes medication interfered with their ability to live a normal life (Jones et al., 2016). Further, some medications for the treatment of diabetes accelerate bone loss and increase the risk for fractures (Choi et al., 2015; Gilbert & Pratley, 2015); therefore, it is plausible that the increased risk for fractures could impair the ability of individuals with diabetes to engage in regular physical activity. Additionally, multiple comorbidities (e.g., cancer, cardiovascular disease, chronic pain diseases, arthritis) are known to influence physical activity levels (Alreshidi et al., 2020; Hoogeboom et al., 2013; Suarez-Villar et al., 2020; Vardar-Yagli et al., 2015). Future studies should consider controlling for these factors given that they are linked with people with diabetes who often suffer from comorbidities (Loprinzi 2014).

A fourth limitation concerned the measurement of PPWB at an earlier timepoint than physical activity. Given that physical activity was measured five years after PPWB was measured, PPWB could have changed in the level of intensity between the baseline measurement and the outcome measurement of physical activity. Individuals with high PPWB scores at baseline could have experienced low PPWB at the outcome time point. It is possible that hypotheses from the present study were not supported because the co-occurrence of PPWB and physical activity should be examined to identify associations between PPWB and physical activity. Notably, the domains of the CASP-19 have been shown to change over time (Springer et al., 2011). Individuals within the sample may have experienced grief, loss of employment, divorce, financial difficulties, among other various life challenges that may have altered their well-being from the baseline measurement to the measure of the outcome. To account for this possibility, future studies should consider evaluating the link between PPWB and physical activity simultaneously over multiple time points.

A fifth limitation involves cut-off scores for HbA1c that were used in the current study to identify individuals with undiagnosed diabetes (n = 198). Although the use of HbA1c cut-off scores as an indicator of diabetes status is common in research (e.g., Sherwani et al., 2016), there are mixed findings as to whether HbA1c is sufficient for diagnosing diabetes (Bergman et al., 2020; Bennett et al., 2007); therefore, it is possible that the group of individuals in the present study observed as having undiagnosed diabetes did not in fact have undiagnosed diabetes.

Clinical guidelines suggest that the diagnosis of diabetes should not be made in an asymptomatic person based on an abnormal HbA1c value (World Health Organization, 2011) and that at least one additional HbA1c test should be repeated to confirm the diagnosis (International Expert Committee, 2009). For diabetes diagnosis in the UK, the WHO recommends using HbA1c only if there are no other conditions present that hinder its accurate measurement (e.g., alcoholism; John, 2012; World Health Organization, 2011). One study found that HbA1c cut-off scores showed limited sensitivity to diabetes diagnosis and would be improved with the addition of glucose-based measurements (Cavagnolli et al., 2011). Therefore, it is difficult to determine whether individuals identified as having undiagnosed diabetes in the present study had the condition. Due to dataset limitations, additional assessments to determine diabetes status was not employed in the present study. Furthermore, HbA1c can be affected by a variety of genetic, hematologic and illness-related factors (Gallagher et al., 2009); as such, alternative justifications for meeting the cut-off threshold used in this study should be considered. Although less common than diabetes, raised scores of HbA1c could be due to alcoholism, anemias and disorders associated with red cell turnover, such as malaria (Acquah et al., 2014; Broz et al., 2017; Chen et al., 2020; Silva et al., 2016; World Health Organization, 2011).

A sixth limitation relates to sample size. Because the sample of people with diabetes was limited, the present study may not have had the necessary power to detect significant associations between PPWB and physical activity above and beyond psychological distress. Another limitation related to the sample, is that findings from the present study may not be generalizable to the entire population of individuals from the UK. This could be because the Whitehall 2 sample from the present study mostly consisted of government workers, and the demographic of government workers differs from the general population (e.g., socioeconomic status). Seventh, the GHQ-30, used as the measure of psychological distress used in this study, was not a diagnostic interview and did not assess clinical levels of depression. Therefore, it is unclear whether clinical levels of depression would have different implications for this study. Additionally, it has been found that the depression subscale of the GHQ-30 has low sensitivity when compared to structured psychiatric interviews for depression (Head et al., 2013). Therefore, although there is a possibility that the measured was confounded by unmeasured psychological distress, this is unlikely given that the GHQ-30 has been found to be a valid measure of mental health disorders.

Finally, the Whitehall 2 study provided limited data on ethnicity (i.e., white, non-white) that did not allow consideration of how ethnically diverse individuals may have been implicated in the analyses. Future studies should include ethnically diverse groups of people to be able to generalize to these populations.

Conclusion

This study was the first to examine associations between PPWB, psychological distress, and physical activity among people with diabetes. It was found that PPWB was not associated with physical activity above and beyond psychological distress among people with diabetes. Additionally, diabetes status did not moderate the association between PPWB and physical activity. However, control, autonomy, self-realization, and pleasure were linked to physical activity among older adults, adding to current knowledge of associations between PPWB as measured by the CASP-19 and physical activity. Notably, these associations did not hold among people with diabetes, suggesting that factors related to having diabetes may influence the link between PPWB and physical activity. Finally, consistent with previous studies examining individuals from the general population, people with diabetes engaged in less physical activity than people without diabetes. Overall, future studies should identify which PPWB factors are linked with physical activity among people with diabetes given that various PPWB factors are modifiable and that regular physical activity is essential for diabetes management.

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Appendix A

Demographics

Please answer all the questions.

1.a) What is your date of birth?	Day/Month/Year	
b) Sex	Male	1
	Female	2

5.b) Now thinking just of your full-time education: what type of school or college did you last attend full-time?

Elementary	1
University/Polytechnic	2
Nursing School/Teaching Hospital	3
Some other type of college	4
Other (please specify)	5

Appendix B

Health-related Demographics

39.a) Do you smoke cigarettes now? (i.e., not cigars/pipes)	Yes	1
	No	2

Appendix C

Control, Autonomy, Self-realisation, Pleasure

Here is a list of statements that people use to describe their lives or how they feel. We would like to know how often, if at all, you think they apply to you.

	Please tick one box on each line			
	Often	Sometimes	Not often	Never
	1	2	3	4
a) My age prevents me from doing the things I would like to do				
b) I feel that what happens to me is out of my control				
c) I feel free to plan for the future				
d) I feel left out of things				
e) I can do the things that I want to do				
f) Family responsibilities prevent me from doing what I want to do				
g) I feel that I can please myself in what I do				
h) My health stops me from doing what I want to do				
i) Shortage of money stops me from doing things I want to do				
j) I look forward to each day				
k) I feel that my life has no meaning				
l) I enjoy the things I do				
m) I enjoy being in the company of others				
n) On balance, I look back on my life with a sense of happiness				
o) I feel full of energy these days				
p) I choose to do things that I have never done before				
q) I feel satisfied with the way my life has turned out				
r) I feel that life is full of opportunities				
s) I feel that the future looks good for me				

Appendix D

General Health Questionnaire

Please read this carefully. We should like to know if you have had any medical complaints, and how your health has been in general **over the past few weeks.** Please answer ALL questions on the following pages simply by indicating the answer which you think most nearly applies to you. Remember that we want to know about your **present** and **recent** complaints, not those you had in the past. It is important that you try to answer ALL the questions.

Have you recently… Please tick one box for each question

	1	2	3	4
1) Been able to concentrate on whatever you're doing?	Better than usual	Same as usual	Rather less than usual	Much less than usual
2) Lost much sleep over worry?	Not at all	No more than usual	Rather more than usual	Much more than usual
3) Been having restless, disturbed nights?	Not at all	Same as usual	Rather less than usual	Much less than usual
4) Been managing to keep yourself busy and occupied?	More so than usual	Same as usual	Rather less than usual	Much less than usual
5) Been getting out of the house as much as usual?	More so than usual	About the same as usual	Less than usual	Much less than usual
6) Been managing as well as most people would in your shoes?	Better than most	About the same	Rather less well	Much less well

7) Felt on the whole you were doing things well?

Better than usual	About the same	Less well than usual	Much less well

8) Been satisfied with the way you've carries out your task(s)?

More satisfied than usual	About the same as usual	Less satisfied than usual	Much less satisfied

9) Been able to feel warmth and affection for those near to you?

Better than usual	About the same as usual	Less well than usual	Much less well

10) Been finding it easy to get on with other people?

Better than usual	About the same as usual	Less well than usual	Much less well

11) Spent much time chatting with people?

More time than usual	About the same as usual	Less time than usual	Much less than usual

12) Felt that you are playing a useful part in things?

More so than usual	Same as usual	Less useful than usual	Much less useful

13) Felt capable of making decisions about things?

More so than usual	Same as usual	Less so than usual	Much less capable

14) Felt constantly under strain?

Not at all	No more than usual	Rather more than usual	Much more than usual

15) Felt you couldn't overcome your difficulties?

Not at all	No more than usual	Rather more than usual	Much more than usual

16) Been finding life a struggle all the time?

Not at all	No more than usual	Rather more than usual	Much more than usual

17) Been able to enjoy your normal day-to-day activities?

More so than usual	Same as usual	Less so than usual	Much less than usual

18) Been taking things hard?

Not at all	No more than usual	Rather more than usual	Much more than usual

19) Been getting scared or panicky for no good reason?

Not at all	No more than usual	Rather more than usual	Much more than usual

20) Been able to face up to your problems?

More so than usual	Same as usual	Less able than usual	Much less able

21) Found everything getting on top of you?

Not at all	No more than usual	Rather more than usual	Much more than usual

22) Been feeling unhappy and depressed?

Not at all	No more than usual	Rather more than usual	Much more than usual

23) Been losing confidence in yourself?

Not at all	No more than usual	Rather more than usual	Much more than usual

24) Been thinking of yourself as a worthless person?

Not at all	No more than usual	Rather more than usual	Much more than usual

25) Felt that life is entirely hopeless?

Not at all	No more than usual	Rather more than usual	Much more than usual

26) Been feeling hopeful about your own future?

More so than usual	About the same as usual	Less so than usual	Much less hopeful

27) Been feeling reasonably happy, all things considered?

More so than usual	About the same as usual	Less so than usual	Much less than usual

28) Been feeling nervous and strung-up all the time?

Not at all	No more than usual	Rather more than usual	Much more than usual

29) Felt that life isn't worth living?

Not at all	No more than usual	Rather more than usual	Much more than usual

30) Found at times you couldn't do anything because your nerves were too bad?

Not at all	No more than usual	Rather more than usual	Much more than usual

Appendix E

Diabetes Status

Since January 2006 have you been told by a doctor that you have, or have had, any of the following?

	Please tick one answer per row	
	Yes	No
e) Diabetes	1	2