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How Subjective Well-Being and Physical Health Are Linked: Mediation Analysis

Prompong Shangkhum
Ph.D. Candidate
School of Economics
University of the Thai Chamber of Commerce
prompong.shangkhum@gmail.com

Dusanee Kesavayuth
Associate Professor
Faculty of Economics
Kasetsart University
dusanee.k@ku.th

ABSTRACT

In this paper, the authors study the direct and indirect effects of subjective well-being on physical health using mediation analysis. Subjective well-being is captured by two separate measures: one for overall life satisfaction and one for mental health. Using thirteen waves (2005-2017) of the data from the Household, Income and Labour Dynamics in Australia (HILDA) Survey, the authors consider physical activity, social interaction, smoking, drinking alcohol, outdoor tasks and volunteer or charity work as potential mediators. The authors find that the direct and indirect effects of past overall life satisfaction and past mental health are positively influenced present physical health. The indirect effects of this influence stand at 9.53% and 9.78% of the total effect of past overall life satisfaction and the total effect of past mental health, respectively, on physical health. Specifically, physical activity is a strong mediator in determining present physical health. As a result, for promoting better health, the design of health policies should consider both the direct and indirect effects of overall life satisfaction (or mental health) on physical health.

Keywords: physical health, well-being, mediation analysis, panel data, HILDA

JEL Classification: D01, I10

1. Introduction

Across the literature, there is strong evidence of the link between subjective well-being and health (see Diener et al., 2017 for a meta-analytic review; Diener, Lucas, & Oishi, 2002; Sin, 2016 for other reviews). However, the focus has been mostly on the direct link between subjective well-being and health, while little is known about the potential pathways through which subjective well-being affects an individual's physical health (i.e., the so-called "mediation effect"). Understanding such pathways and how heterogeneous they are between population groups could have important health policy implications. To fill this gap, this paper proposes a mediation framework and employs the multiple mediation analysis to examine factors that could potentially mediate the relationship between subjective well-being and physical health.

In order to shed some light on the mediators of this relationship, it is reasonable to consider the conceptual framework of how subjective well-being influences physical health. For example, Ong (2010) reviewed many studies on how well-being may influence an individual's health through several pathways, such as physiological systems (e.g., cardiovascular and immune systems), stress, and health behaviours (e.g., physical activity, diet, smoking). People with higher-level well-being are more likely to exercise more regularly, smoke less and consume a healthier diet (Boehm, Vie, & Kubzansky, 2012; Contoyannis & Jones, 2004). In light of these findings, this paper focuses on the mediation role of two forms of human capital investments, namely lifestyle choices (such as physical activity, smoking, drinking alcohol and outdoor tasks) and social capital (social interaction and volunteer or charity work).

To the best of our knowledge, the only study on health that employs mediation analysis is Ohrnberger et al. (2017),

who investigated the direct and indirect relationships between physical health and mental health. They analysed the direct and indirect effects of past mental health on physical health and vice versa. Focusing on a population of people aged 50 years and older, they used physical activity, social interaction and cigarette consumption as mediators in the indirect effect model. Using a random-effects model, they found that the effect of past mental health on current physical health is mediated by physical activity and social interaction. However, they ignored some important mediators proposed by previous studies (e.g., Mujcic & Oswald, 2016; Stampfer et al., 2005), such as dietary choices, drinking alcohol and other lifestyle choices.

Our paper expands this analysis by covering a wider age-range population and by including more mediators, such as frequency of alcohol consumption, spending time on outdoor tasks and participating in volunteer or charity work. Furthermore, in this study, the authors also improved the estimation by including the individual-specific means of time-varying variables as additional regressors in the estimation of the random effects to proxy the fixed-effect (Mundlak, 1978). Using data from the Household Income and Labour Dynamics of Australia (HILDA) survey, the findings reveal that the direct and indirect effects of past overall life satisfaction and past mental health are significantly related to present physical health. The indirect effect of past overall life satisfaction and past mental health on present physical health is strongly mediated by past physical activity. Furthermore, these findings are consistent when the heterogeneity by gender is taken into account. The findings are robust under alternative specifications and limitations of the data.

2. Conceptual and mediation framework

Grossman's model (Grossman, 1972) presents health as a part of human capital because healthy time provides individuals with production benefit as an input to the production of income. As a part of human capital, an individual's health can be increased through investments (i.e., people can adopt healthy behaviours such as socialising, taking part in physical activities, eating a healthy diet, and avoiding smoking and alcohol consumption to increase their stock of health capital).

The authors adopt this framework to identify several potential factors mediating the relationships between subjective well-being and physical health. The mediator variables are expected to affect physical health and be affected by subjective well-being. Therefore, the authors first identify the factors that determine physical health.

Many psychological, epidemiological, and economic studies consider socioeconomic factors, lifestyle choices, and individual characteristics as determinants of health (World Health Organization, 2017; Kelly, 2009). Socioeconomic factors, such as income and labour market status, are found to have positive correlations with health. For instance, individuals with higher incomes tend to be healthier than those with lower incomes (van Doorslaer and Koolman, 2004; Lenhart, 2017). Further, individuals with physically demanding occupations are likely to face health problems earlier in life than those in other occupations (Llena-Nozal et al., 2004).

With regard to lifestyle choices, there is a strand of research that investigates the impacts of health behaviours (such as physical activity, smoking, alcohol consumption, and dieting) and social interaction on physical and mental health. For example, Contoyannis and Jones (2004) found that

sufficient sleep, exercise, and not smoking positively contribute to people's health status. In addition, Durstine et al. (2013) reveal that physical health is positively correlated with physical activities: higher physical activity and exercise help reduce cardiovascular disease, type II diabetes, obesity, and cancer. Regarding social interaction, Steptoe et al. (2013) found that loneliness and social isolation significantly increase mortality risk while controlling for baseline mental health and physical health.

In light of these findings, it is clear that a study of the direct and indirect effects of subjective well-being on physical health is relevant, especially when using mediation analysis.

3. Data and variables

In this paper, the authors utilised data from the Household, Income, and Labour Dynamics of Australia (HILDA) Survey (2005-2017).[1] HILDA is an Australian national representative household-based longitudinal survey, which collects data on economic, labour market dynamics, subjective well-being, and family life. The survey started in 2001, and data are obtained from almost 14,000 individuals from 7,682 households who are at the age of 15 and above.

Based on the HILDA survey, the analytical sample for the present study consisted of respondents aged between 15 and 85 over the sample period.[2] After excluding observations with

[1] The authors are not able to utilise data from waves 1-4 as one of the explanatory variables on private health insurance is available only from wave 5 onwards.

[2] Understanding mortality selection at old age, for example, the individuals who are still alive at very old age could have low levels of physical health or mental health than their younger counterparts. The older people may also face higher mortality rate. To mitigate this concern, the authors deselected individuals aged 85 and higher in this analysis.

missing answers, the final sample was 14,055 individuals (6,304 males, 7,751 females) and 65,937 observations (28,288 males, 37,649 females).

3.1 Physical health measure

Physical health is obtained from the 36-item Short Form Survey (SF-36), which is based on the answers to 21 questions designed to capture four dimensions of an individual's physical health.[3] Table 1 shows the summary of physical health, including how physical health is defined in each dimension.

Table 1. SF-36: Physical Health

Summary	Scales	Meaning
Physical health	Physical Functioning (PF: 10 items)	Limitation of daily physical activities such as walking 100 meters.
	Role Physical (RP: 4 items)	Limitation of work caused by physical health such as difficulty performing the work
	Bodily Pain (BP: 2 items)	Pain and limitation of pain.
	General Health (GH: 5 items)	Health status.

In this paper, the authors also provided the test result of Cronbach's alpha for the four dimensions of physical health. The Cronbach's alpha test scale is slightly above 0.85, indicating that the different dimensions of physical health are sufficiently and closely related to one another. This enables us to construct a single index for physical health by computing the average of the four physical health dimensions for each

[3] Besides, one question covers a change in health status over the past year. This was not taken into account while scoring the four dimensions of physical health but was used to estimate the change in health from a cross-sectional administration of the SF-36.

observation (e.g., Hemingway et al., 1997; Zhu, 2016; Kesavayuth et al., 2020). Then, the authors obtained physical health measures ranging from 0 to 100, where the higher scores indicate better physical health and the lower scores indicate negative physical health. Finally, to aid the interpretation of the results, the authors divided the physical health scores by 10 so that the scale ranges from 0 to 10.

3.2 Subjective well-being variables

According to Diener (1984), subjective well-being (also called "self-reported wellbeing") refers to how people experience the quality of their lives and includes having good mental or physical health, a sense of meaning or purpose or fulfilment, and the ability to manage stress. For example, people who experience good feelings such as joy, hope, and positive thinking are more likely to enjoy a high quality of life (Skevington & Böhnke, 2018). Furthermore, other dimensions of one's well-being (such as life satisfaction, not just negative emotions such as stress and depression) can potentially influence healthier behaviors (Grant et al., 2009). Definitions of subjective well-being therefore focus on how people evaluate his/her own life, including emotions and moods (Diener, 2000). The findings of studies that focus on these variables can help policymakers in offering support for programs aimed at increasing societal welfare and contribute to a better quality of life for citizens and communities across the world (OECD Better Life, 2013; Stiglitz et al., 2010). However, our subjective well-being is captured by two separate measures: one for overall life satisfaction and one for mental health. Indeed, we believe that people who are highly satisfied with their life and have good mental health are deemed to have high levels of subjective well-being (i.e., they

are generally happy people), would be in better physical health simply.

Overall, life satisfaction is often measured as part of well-being. For example, the question on overall life satisfaction asks, "All things considered, how satisfied are you with your life?" The answers are reported on a scale ranging from 0 (totally dissatisfied) to 10 (totally satisfied). The overall life satisfaction measure has been widely used in the literature since it has been shown that there is little difference in estimating effects using a cardinal or ordinal model (Ferrer-i-Carbonell and Frijters, 2004). However, in this paper, the overall life satisfaction measure was treated as cardinal.

The second measure of well-being is mental health. Note that the authors measured mental health using the five-item Mental Health Inventory (MHI-5), which is a part of the SF-36. The MHI-5 has proven to be a good psychometric method, with a high Cronbach's alpha of 0.82 (Butterworth and Crosier, 2004). It has been extensively employed in the literature and has consistently shown to be as good as a proxy for a person's mental health. (e.g., Roy & Schurer, 2013; Berwick et al., 1991). For example, individuals were asked how often, over the past 4 weeks, they have felt (i) nervous person, (ii) calm and peaceful, (iii) down, (iv) happy, and (v) so down in the dumps that nothing could cheer you up. These five questions are then added together to create an index that is reported on a scale from 0 (all of the time) to 6 (none of the time). In the HILDA survey, a standardised self-reported measure of this mental health score ranged from 0 to 100 scales, where the higher scores indicate better mental health and the lower scores indicate worse mental health. Then to aid the interpretation of the results, the authors divided the mental health scores by 10 so that the scale ranges from 0 to 10.

3.3 Mediator variables

In this paper, multiple mediation analyses were performed to assess the relationship between overall life satisfaction (or mental health) and physical health through the mediator's lifestyle choices (such as frequency of physical activity, frequency of smoking, frequency of drinking alcohol and hours spent on outdoor tasks) and mediator's social capital (frequency of social interaction and hours spent on volunteer or charity work).

The authors considered six mediator variables as the main mediating factors for the following reasons. Firstly, these mediators are important predictors of mortality. For example, physical activity, smoking, and drinking alcohol are major risk factors for heart diseases, cancers and musculoskeletal disorders (Australia's Mental and Physical Health Tracker, 2018), which lead to higher risks of mortality. Social interaction is similarly important in increasing the risks of mortality: people who are socially isolated are often associated with higher mortality, especially in older men and women (Steptoe et al., 2013).

Secondly, mediator variables can be chosen by performing a literature review to determine conceptual theory (i.e., the relationship between mediator variables and dependent variable) and action theory (i.e., the relationship between the independent variables of interest and mediator variables) (Chen, 1990). Based on prior research, people with physical activity (i.e., those who exercise regularly) are likely to have improved physical health. That is, they are less likely to suffer from diseases such as cardiovascular disease, diabetes, obesity, and cancer (Durstine et al., 2013). Evidence from Durstine et al. (2013) indicates that physical health positively correlates with physical activity. Other potential mediators such as smoking and drinking alcohol are also

related to mental health; for example, people with mental health problems may be more likely to smoke or drink so as to regulate the symptoms or emotions associated with their condition (Cornah, 2006; Minichino et al., 2013). In addition, there is currently insufficient evidence showing that outdoor tasks and volunteer or charity work can explain high levels of physical health. Nevertheless, there is evidence that time spent on outdoor tasks and volunteer or charity work may also have effects on health (Kesavayuth et al., 2020). Finally, information on all mediators is available in the HILDA survey.

3.4 Control variables

A number of socioeconomic variables are included in the model, namely age, gender, household size, real household income in thousands of AUD,[4] the number of children living in the household, educational attainment, private health insurance, living as a couple, employment status, Australian states of residence and territories, and survey waves. The summary statistics of these variables are provided in Table 2, which also describes all these variables.

[4] The base year is 2012.

Table 2. Descriptive Statistics

Variables	Description	Mean	SD
Physical health (SF-36)	0-10 scale; with 0 = worst physical health and 10 = best physical health	7.49	2.20
Lagged overall life satisfaction	0-10 scale; with 0 = totally dissatisfied with life and 10 = totally satisfied with life	7.92	1.38
Lagged mental health (MHI-5)	0-10 scale; with 0 = worst mental health and 100 = best mental health and 10 = best mental health	7.53	1.67
Lagged frequency of physical activity	0-5 scale; with 0 = not at all and 5 = every day	2.57	1.51
Lagged frequency of social interaction	0-6 scale; with 0 = less often than once every 3 months and 6 = every day	3.46	1.43
Lagged frequency of smoking	0-3 scale; with 0 = non-smokers and 3 = smoke daily	0.47	1.06
Lagged frequency of drinking	0-6 scale; with 0 = no drinking and 6 = drink every day	2.51	1.83
Lagged outdoor tasks	Number of hours per week spent in outdoor tasks	4.31	6.01
Lagged volunteer or charity work	Number of hours per week spent in volunteer or charity work	1.18	3.35
Age	Age of the respondent	49.58	16.37
Male	1 if male, 0 if female	0.43	0.49
Household size	Number of persons living in the household	2.59	1.35
Real household income	Real household income in thousands of AUD (base year, 2012)	83.02	59.83
Number of children in the household	Number of children living in the household.	0.76	1.09
Private health insurance	1 if the respondent spent annual household expenditures on private health insurance, 0 otherwise	0.59	0.49
Living as a couple	1 if legally married and de facto, 0 otherwise	0.70	0.46
High education	1 if graduated at least from college, 0 otherwise	0.62	0.48
Employed	1 if employment, 0 otherwise	0.64	0.48
Unemployed	1 if unemployed, 0 otherwise	0.02	0.14
Not in the labour force	1 if not in the labour force, 0 otherwise	0.34	0.47

Notes: Number of observations 65,937.

4. Empirical approach

This study investigated the relationship between subjective well-being and physical health with mediation using Baron and Kenny (1986), which has been widely utilized

in psychological and economic studies. However, instead of looking at only one mediator, this study considered multiple mediators that cover human capital investment: social capital and lifestyle choice.

The authors started by using conventional panel methods (i.e., random effect and fixed-effect panel regression) to estimate the model. In the random effect model, the unobservable variables were assumed to be uncorrelated with the observed variable. On the other hand, unobserved variables were allowed to have correlations with the observed variables in the fixed-effect model. Then, the authors considered an alternative specification that directly controls for individual specifics. This was controlled for in the remaining correlation between individual specifics and the regressors. That alternative specification was proposed by Mundlak (1978), who argued that it is a more parsimonious and flexible method.[5] The authors estimated random effect by including the individual-specific means of the time-varying variable as additional control variables in order to proxy the fixed-effect outcome. This minimises the potential for time-invariant unobserved heterogeneity to bias the estimates. Hence, the estimation equation is given by:

$$PH_{it} = b_0 + b_1 SWB_{i,t-1} + b_2 PA_{i,t-1} + b_3 SI_{i,t-1} + b_4 S_{i,t-1} + b_5 D_{i,t-1} + b_6 OT_{i,t-1} + b_7 V_{i,t-1} + b_8 X_{it} + b_9 \overline{X}'_{it} + v_{it} \quad (1)$$

where PH_{it} is the physical health of individual i at time t, $SWB_{i,t-1}$ refers to subjective well-being (overall life

[5] Mundlak (1978) proposed that individual effects are a linear function of the means of all the time-varying variables across time. This method allowed us to obtain the equivalent of fixed effects.

satisfaction or mental health) at *t*-1, $PA_{i,t-1}$ is the frequency of physical activity at *t*-1, $SI_{i,t-1}$ is the frequency of social interaction at *t*-1, $S_{i,t-1}$ is the frequency of smoking at *t*-1, $D_{i,t-1}$ is the frequency of drinking alcohol at *t*-1, $OT_{i,t-1}$ is the number of hours spent on outdoor tasks at *t*-1, $V_{i,t-1}$ is hours spent on volunteer or charity work, X_{it} is a vector of predictor variables, and $\overline{X'}_{it}$ *i*s a vector of means of predictor variables that vary over time, including age, household size, real household income, the number of children living in the household, educational attainment, private health insurance, living as a couple, employment status, Australian state of residence and territories. Finally, v_{it} is a composite error term that consists of a person-specific error μ_i and an idiosyncratic error ε_{it}.

In equation (1), the direct effect of past subjective well-being (past overall life satisfaction or past mental health) on present physical health was measured by the coefficient b_1.[6] In order to estimate the indirect effect, the authors evaluated how past subjective well-being could influence the mediators. Hence, the authors considered six additional equations:

$$PA_{it-1} = a_{01} + a_{11}SWB_{i,t-1} + a_{21}X_{i,t-1} + a_{31}\overline{X'}_{i,t-1} + e_{i,t-1} \quad (2)$$

$$SI_{it-1} = a_{02} + a_{12}SWB_{i,t-1} + a_{22}X_{i,t-1} + a_{32}\overline{X'}_{i,t-1} + e_{i,t-1} \quad (3)$$

[6] The authors thus estimated equation (1) two times to obtain the coefficients of past overall life satisfaction and past mental health.

$$S_{it-} = a_{03} + a_{13}SWB_{i,t-1} + a_{23}X_{i,t-1} + a_{33}\overline{X'}_{i,t-1} + e_{i,t-1} \quad (4)$$

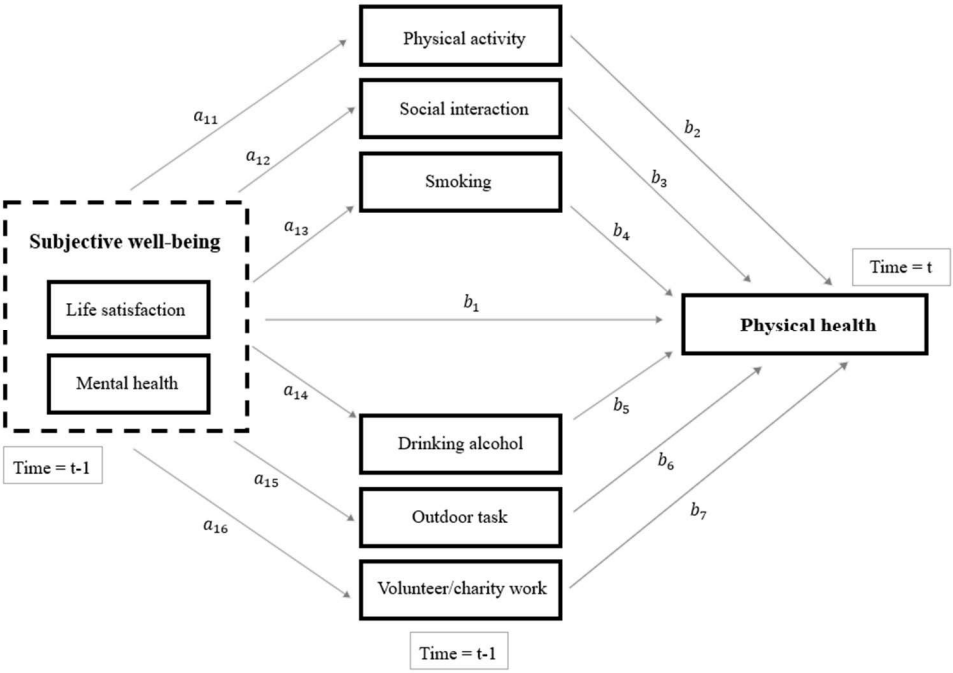
$$D_{it-1} = a_{04} + a_{14}SWB_{i,t-1} + a_{24}X_{i,t-1} + a_{34}\overline{X'}_{i,t-1} + e_{i,t-1} \quad (5)$$

$$OT_{it-1} = a_{05} + a_{15}SWB_{i,t-1} + a_{25}X_{i,t-1} + a_{35}\overline{X'}_{i,t-1} + e_{i,t-1} \quad (6)$$

$$V_{it-1} = a_{06} + a_{16}SWB_{i,t-1} + a_{26}X_{i,t-1} + a_{36}\overline{X'}_{i,t-1} + e_{i,t-1} \quad (7)$$

To calculate the indirect effect, it is defined as the multiplication of the path coefficient $a_{1j}b_k$ (j=1 to 6; k= 2 to 7). For example, the indirect effect of past overall life satisfaction (or past mental health) on present physical health by past physical activity is $a_{11}b_2$. Similarly, the total indirect effect of past overall life satisfaction (or past mental health) on present physical health by six mediators is the summation of all indirect effects: $a_{11}b_2 + a_{12}b_3 + a_{13}b_4 + a_{14}b_5 + a_{15}b_6 + a_{16}b_7$. The effect of past subjective well-being on each mediator variable is shown in Figure 1.

Figure 1. The direct and indirect effects of subjective well-being on physical health via multiple mediators.



4.1 Testing the indirect effect

According to MacKinnon et al. (2002), the mediation effect testing can be categorised into four types: the causal-steps test, product-of-coefficients test, difference-in-coefficients test, and the resampling method. In this paper, the product of the coefficients approach, which applies to models with multiple mediators (Baron and Kenny, 1986; Preacher and Hayes, 2008a), was applied.

The null hypothesis is to test if the indirect effect is significantly different from zero. The indirect effect is calculated from the product of (i) pathway a_{1j} (j=1 to 6),

which is the effects of past overall life satisfaction (or past mental health) on any mediator variables, and (ii) pathway b_k (k= 2 to 7), which is the effects of any mediator variables on physical health. To test the null hypothesis, the authors utilised the Sobel test (Sobel, 1982) for analysis.

The Sobel test considers the value of the standard error of pathway a_{1j} ($se_{a_{1j}}$) and pathway b_k (se_{b_k}). The indirect effect $a_{1j}b_k$ and its standard error $se_{a_{1j}b_k}$ were computed (Baron and Kenny, 1986; Goodman, 1960; MacKinnon, 2000; Preacher & Hayes, 2004; Sobel, 1982). Sobel's Z of indirect effect is given as:

$$Z_{a_{1j}b_k} = \frac{a_{1j}b_k}{\sqrt{{a_{1j}}^2 {se_{b_k}}^2 + {b_k}^2 {se_{a_{1j}}}^2}}; \quad j = 1, 2, \ldots, 6 \text{ and } k = 2, 3, \ldots, 7 \tag{8}$$

where $se_{a_{1j}}$ and se_{b_k} are the standard error of the coefficient a_{1j} and b_k respectively.

4.2 Testing the total indirect effect

The total indirect effect of past overall life satisfaction (or past mental health) on present physical health by six mediators is the summation of each indirect effect. The authors then used the Sobel test to test whether the total indirect effect is also statistically significant. Importantly, the standard error of the total indirect effect is corroborated by Preacher and Hayes (2008b). They show that the total indirect effect is the sum of each indirect effect: $f = a_{11}b_2 + a_{12}b_3 + a_{13}b_4 + a_{14}b_5 + a_{15}b_6 + a_{16}b_7$. Using methods from Bollen (1987), the asymptotic variance of a total indirect effect of past overall life satisfaction (or past mental health) is as follows

$$\text{Var}(f) = b_2^2 se_{a_{11}}^2 + a_{11}^2 se_{b_2}^2 + b_3^2 se_{a_{12}}^2 + a_{12}^2 se_{b_3}^2 + b_4^2 se_{a_{13}}^2 + a_{13}^2 se_{b_4}^2 + b_5^2 se_{a_{14}}^2 + a_{14}^2 se_{b_5}^2 + b_6^2 se_{a_{15}}^2 + a_{15}^2 se_{b_6}^2 + b_7^2 se_{a_{16}}^2 + a_{16}^2 se_{b_7}^2 + 2(a_{11}a_{12}se_{b_2,b_3} + a_{11}a_{13}se_{b_2,b_4} + a_{11}a_{14}se_{b_2,b_5} + a_{11}a_{15}se_{b_2,b_6} + a_{11}a_{16}se_{b_2,b_7} + a_{12}a_{13}se_{b_3,b_4} + a_{12}a_{14}se_{b_3,b_5} + a_{12}a_{15}se_{b_3,b_6} + a_{12}a_{16}se_{b_3,b_7} + a_{13}a_{14}se_{b_4,b_5} + a_{13}a_{15}se_{b_4,b_6} + a_{13}a_{16}se_{b_4,b_7} + a_{14}a_{15}se_{b_5,b_6} + a_{14}a_{16}se_{b_5,b_7} + a_{15}a_{16}se_{b_6,b_7} + b_2b_3se_{a_{11},a_{12}} + b_2b_4se_{a_{11},a_{13}} + b_2b_5se_{a_{11},a_{14}} + b_2b_6se_{a_{11},a_{15}} + b_2b_7se_{a_{11},a_{16}} + b_3b_4se_{a_{12},a_{13}} + b_3b_5se_{a_{12},a_{14}} + b_3b_6se_{a_{12},a_{15}} + b_3b_7se_{a_{12},a_{16}} + b_4b_5se_{a_{13},a_{14}} + b_4b_6se_{a_{13},a_{15}} + b_4b_7se_{a_{13},a_{16}} + b_5b_6se_{a_{14},a_{15}} + b_5b_7se_{a_{14},a_{16}} + b_6b_7se_{a_{15},a_{16}}) \quad (9)$$

Therefore, the Sobel test's Z of total indirect effect is given as:

$$Z_f = \frac{f}{\sqrt{\text{Var}(f)}} = \frac{\sum a_{1j}b_k}{\sqrt{\text{Var}(f)}}; \quad j = 1, 2, \ldots, 6 \text{ and } k = 2, 3, \ldots, 7 \quad (10)$$

5. Results

5.1 Model for mediators

The analysis started by examining whether subjective well-being at *t*-1 is significantly related to the mediators at *t*-1. The findings indicate that those who have higher levels of overall life satisfaction and mental health have significant effects on lifestyle choices and social capital (see Tables 3 and 4). Looking across columns 2 to 7 in Table 3, we can see that overall life satisfaction is significantly related to the possible mediators, with the exception of smoking and drinking

alcohol. Those who are highly satisfied with their lives tend to enjoy more physical activity and social interaction. Moreover, they are more likely to spend more time on outdoor tasks and participate more in volunteer or charity work.

Our second type of subjective well-being measure was mental health. Columns 2 to 7 in Table 4 show that better levels of mental health have significant effects on lifestyle choices and social capital, increasing enjoying physical activity and social interaction, and spending time in outdoor tasks while decreasing smoking frequently.

5.2 Direct and indirect effects: Mediation analysis

We now turn to examine whether the mediators at t -1 relate to our outcome variable of interest, physical health at t. Column 1 in Tables 3 and 4 shows that past physical activity and past volunteer or charity work are positively related to present physical health and statistically significant at least at the 5% level. This implies that people who often exercise and participate more in volunteer or charity work are often healthier.

Our results raise the possibility that physical activity, social interaction, smoking, drinking alcohol, outdoor tasks and volunteer or charity work may partly explain the relationship between past subjective well-being and present physical health (see Table 5 for a summary of the results). Regarding the indirect effects, which is the effect of subjective well-being at t-1 on physical health at t that goes indirectly through the mediators at t-1, it was estimated that the indirect effects for each mediator by multiplying the influence of subjective well-being on the mediator (pathway a_{1j} (j=1 to 6)) with the impact of the particular mediator on an individual's physical health (pathway b_k (k= 2 to 7).). For example, the indirect effect of past overall life satisfaction to present

physical health through the lagged frequency of physical activity is $0.079 \times 0.\ 0589 = 0.0047$ ($a_{11}b_2$). The significant level of this indirect effect is tested by the Sobel test.

As expected, it was found that subjective well-being also has a positive and statistically significant indirect effect on physical health. People who are highly satisfied with their life and their mental health tend to have better physical health through the various possible mediators. Table 5 presents the mediation effects on physical health. Column 1 in Table 5 suggests that the effect of past overall life satisfaction on physical health is significantly mediated by physical activity at p-values < 0.01, while also significant at p-values < 0.1 for volunteer or charity work.

The direct and total indirect effects of overall life satisfaction are positive and statistically significant at p-values < 0.01. The total indirect effect of all six mediators was 9.53% of the total effect. Physical activity is the main mediator, which provided 85.46% of the total indirect effect and 8.19% of the total effect. Unfortunately, volunteer or charity work only explained 3.6% of the total indirect effect.

Consistently, the direct and total indirect effects of mental health on physical health are still positive and statistically significant. Column 2 in Table 5 shows that the link between past mental health and present physical health is also explained by physical activity and volunteer or charity work. The total indirect effect of all six mediators was 10.79% of the total effect. Physical activity is still the main mediator, which provided 90.77% of the total indirect effect and 9.78% of the total effect in the mental health pathway. Volunteer or charity work explained 3.1% of the total indirect effect, although marginally significant at the 10% level.

We may conclude that the mediating effect of past subjective well-being on present physical health is best explained by physical activity. These results indicate that

happy people tend to participate more often in physical activity, which in turn positively influences their physical health.

Table 3. Random effects regression models with control means of time varying for physical health, physical activity, social interaction, smoking, drinking, outdoor tasks and volunteer or charity work (overall life satisfaction pathway).

	Physical health	Frequency of physical activity (t-1)	Frequency of social interaction (t-1)	Frequency of smoking (t-1)	Frequency of drinking (t-1)	Outdoor tasks (t-1)	Volunteer or charity work (t-1)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Frequency of physical activity (t-1)	0.0589***						
	(0.00558)						
Frequency of social interaction (t-1)	0.00498						
	(0.00575)						
Frequency of smoking (t-1)	-0.000208						
	(0.0132)						
Frequency of drinking (t-1)	0.00218						
	(0.00771)						
Outdoor tasks (t-1)	0.00261*						
	(0.00149)						
Volunteer or charity work (t-1)	0.00613**						
	(0.00262)						
Overall life satisfaction (t-1)	0.0519***	0.0790***	0.0646***	-0.00213	-0.00315	0.0966***	0.0406***
	(0.00658)	(0.00591)	(0.00558)	(0.00292)	(0.00482)	(0.0220)	(0.0128)
Age	-0.0576***	-0.0179***	-0.0104**	-0.00185	0.0276***	0.0890***	0.0325***
	(0.00612)	(0.00453)	(0.00410)	(0.00348)	(0.00528)	(0.0170)	(0.00945)
Male	0.0168	0.262***	-0.0992***	0.140***	0.664***	2.088***	-0.00941
	(0.0275)	(0.0215)	(0.0195)	(0.0174)	(0.0284)	(0.0832)	(0.0462)
Household size	-0.0227	-0.0457***	-0.0872***	-0.000198	0.00672	-0.0194	0.0365
	(0.0159)	(0.0152)	(0.0139)	(0.00799)	(0.0114)	(0.0523)	(0.0254)
Number of children in the household	0.0720***	-0.0147	-0.0425**	-0.00389	-0.00151	0.0735	0.0399
	(0.0188)	(0.0178)	(0.0167)	(0.00938)	(0.0136)	(0.0644)	(0.0328)
Real household income	0.000224	-0.00000299	-0.000222	0.0000568	0.000161	0.0000987	-0.00118***
	(0.000178)	(0.000162)	(0.000141)	(0.0000617)	(0.000128)	(0.000596)	(0.000418)
Private health insurance	-0.00265	0.00520	-0.0284	-0.00371	-0.0237	-0.0649	-0.0493
	(0.0251)	(0.0237)	(0.0222)	(0.0128)	(0.0180)	(0.0821)	(0.0512)
Living as couple	-0.0381	-0.0796***	-0.293***	-0.0755***	-0.0484*	0.259**	-0.146**
	(0.0330)	(0.0301)	(0.0301)	(0.0186)	(0.0264)	(0.104)	(0.0632)
High education	0.0527	0.0522	-0.0732	-0.0596**	0.0758**	0.0839	-0.0120
	(0.0486)	(0.0489)	(0.0446)	(0.0289)	(0.0354)	(0.131)	(0.104)
Unemployed	0.0354	0.101**	0.142***	0.0164	-0.0872***	1.585***	0.720***
	(0.0450)	(0.0408)	(0.0394)	(0.0228)	(0.0292)	(0.181)	(0.110)
Not in the labour force	-0.322***	0.0113	0.240***	-0.0150	-0.116***	1.395***	0.546***
	(0.0285)	(0.0233)	(0.0213)	(0.0104)	(0.0178)	(0.102)	(0.0656)
Observations	65,937	65,937	65,937	65,937	65,937	65,937	65,937

Note: *p < 0.1, **p< 0.05, ***p< 0.01. Robust standard errors are in parentheses. All models included Australian region of residence dummies and waves as control variable. For models (2)-(7) control variables take on lagged values (t-1) (e.g. Age (t-1), Male (t-1), Household size (t-1), Number of children in the household (t-1), Real household income (t-1), Private health insurance (t-1), Living as couple (t-1), High education (t-1), Unemployed (t-1), Not in the labour force (t-1)).

Table 4. Random effects regression models with control means of time varying for physical health, physical activity, social interaction, smoking, drinking, outdoor tasks and volunteer or charity work (mental health pathway).

	Physical health	Frequency of physical activity (t-1)	Frequency of social interaction (t-1)	Frequency of smoking (t-1)	Frequency of drinking (t-1)	Outdoor tasks (t-1)	Volunteer or charity work (t-1)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Frequency of physical activity (t-1)	0.0566***						
	(0.00555)						
Frequency of social interaction (t-1)	0.00330						
	(0.00573)						
Frequency of smoking (t-1)	-0.000325						
	(0.0132)						
Frequency of drinking (t-1)	0.00322						
	(0.00771)						
Outdoor tasks (t-1)	0.00271*						
	(0.00149)						
Volunteer or charity work (t-1)	0.00615**						
	(0.00262)						
Mental health (t-1)	0.0538***	0.105***	0.0782***	-0.00206	-0.0135***	0.0563***	0.0322***
	(0.00617)	(0.00538)	(0.00487)	(0.00252)	(0.00428)	(0.0187)	(0.0109)
Age	-0.0702***	-0.0221***	-0.0154***	0.0000415	0.0267***	0.0864***	0.0301***
	(0.00586)	(0.00449)	(0.00406)	(0.00347)	(0.00528)	(0.0170)	(0.00944)
Male	-0.0936***	0.219***	-0.149***	0.158***	0.656***	2.061***	-0.0338
	(0.0257)	(0.0213)	(0.0194)	(0.0174)	(0.0284)	(0.0828)	(0.0463)
Household size	-0.0234	-0.0456***	-0.0872***	-0.000196	0.00664	-0.0198	0.0364
	(0.0157)	(0.0152)	(0.0139)	(0.00799)	(0.0114)	(0.0523)	(0.0254)
Number of children in the household	0.0714***	-0.0143	-0.0426**	-0.00385	-0.00199	0.0705	0.0390
	(0.0186)	(0.0178)	(0.0167)	(0.00938)	(0.0136)	(0.0644)	(0.0327)
Real household income	0.000229	0.0000357	-0.000191	0.0000558	0.000158	0.000135	-0.00117***
	(0.000176)	(0.000163)	(0.000141)	(0.0000617)	(0.000128)	(0.000596)	(0.000417)
Private health insurance	-0.000610	0.00562	-0.0281	-0.00372	-0.0237	-0.0648	-0.0492
	(0.0250)	(0.0236)	(0.0221)	(0.0128)	(0.0180)	(0.0821)	(0.0512)
Living as couple	-0.0337	-0.0753**	-0.288***	-0.0758***	-0.0467*	0.279***	-0.139**
	(0.0328)	(0.0299)	(0.0300)	(0.0186)	(0.0264)	(0.104)	(0.0630)
High education	0.0553	0.0511	-0.0743*	-0.0596**	0.0756**	0.0804	-0.0132
	(0.0484)	(0.0482)	(0.0444)	(0.0289)	(0.0354)	(0.131)	(0.104)
Unemployed	0.0435	0.105***	0.143***	0.0164	-0.0891***	1.575***	0.718***
	(0.0449)	(0.0405)	(0.0392)	(0.0228)	(0.0292)	(0.182)	(0.110)
Not in the labour force	-0.320***	0.0179	0.245***	-0.0152	-0.117***	1.398***	0.548***
	(0.0284)	(0.0232)	(0.0212)	(0.0104)	(0.0178)	(0.102)	(0.0657)
Observations	65,937	65,937	65,937	65,937	65,937	65,937	65,937

Note: The same footnote as for Table 3 applies.

Table 5. Mediation effects on physical health

	Physical health mediation	
	Overall life satisfaction pathway	Mental health pathway
	(1)	(2)
(A) indirect physical activity	0.0047***	0.0059***
	(0.0006)	(0.0007)
(B) indirect social interaction	0.0003	0.0003
	(0.0004)	(0.0004)
(C) indirect smoking	0.0000004	0.000001
	(0.00003)	(0.00003)
(D) indirect drinking	-0.00001	-0.00004
	(0.00003)	(0.0001)
(E) indirect outdoor tasks	0.0003	0.0002
	(0.0002)	(0.0001)
(F) indirect volunteer or charity work	0.0002*	0.0002*
	(0.0001)	(0.0001)
(A + B + C + D + E + F) total indirect effect	0.0055***	0.0065***
	(0.0011)	(0.0012)
(G) direct effect	0.0519***	0.0538***
	(0.00658)	(0.00617)
(A) + (B) + (C) + (D) + (E) + (F) + (G) total effect	0.0574	0.0603
Total indirect / total effect	9.53%	10.79%
Observations	65,937	65,937

Note: The pathway in the model (1) is lagged overall life satisfaction with the outcome physical health. The pathway in the model (2) is lagged mental health with the outcome physical health. The Sobel test provides an approximate estimate for the indirect effect of the lagged overall life satisfaction and lagged mental health on the outcome physical health via the mediators; *p < 0.1, **p< 0.05, ***p< 0.01.

6. Robustness checks

This section checks in several ways whether the results found previously are robust in different circumstances; first, to test whether gender differences matter in this study. The study found that past overall life satisfaction and past mental health improve the present physical health of both males and females. Second, a potential concern is that individuals with relatively low levels of mental health or overall life satisfaction are more

likely to drop out of the panel survey over time, using a balanced panel of those respondents who participated in all 13 waves used in this study. The findings indicate that even in this smaller sample (of approximately 14.7% of the initial observations), the estimates are very similar to those using an unbalanced panel. Finally, the authors are particularly interested in the following questions for the older population: Are the results found in the 2017 Ohrnberger et al. study of older people similar to those found in this study? The present study focused on the older population aged 50 years and above and used three mediator variables in the model. The findings are consistent with Ohrnberger et al. (2017), who found that the direct and indirect effects of past overall life satisfaction and past mental health positively influence present physical health for older people and that past physical activity is a strongly important mediator in the model.

7. Conclusion

This paper has examined the direct and indirect effects of subjective well-being on physical health using mediation analysis. Subjective well-being is captured by two separate measures: one for overall life satisfaction and one for mental health. Importantly, the authors performed a mediation analysis to investigate whether six mediators mediate the causal effect of the relationship between subjective well-being on physical health. The six mediators are (i) frequency of physical activity, (ii) frequency of social interaction, (iii) frequency of smoking, (iv) frequency of drinking alcohol, (v) hours spent on outdoor tasks, and (vi) hours spent on volunteer or charity work. Besides, the authors used large-scale population data for Australia and a large number of waves to estimate random effect specification by including the individual-specific means of the time-varying variable as

additional control variables in order to proxy the fixed-effect (e.g., Mundlak, 1978). Analysis revealed that past subjective well-being has positive direct and indirect effects on present physical health. This indirect effect is best mediated by past physical activity. Those who are highly satisfied with their life and their mental health tend to enjoy more physical activity, which in turn positively influences their physical health.

In terms of overall life satisfaction, it was found that the total indirect effect provided 9.53% of the total effect on present physical health. Physical activity is the main mediator, which provided 85.46% of the total indirect effect and 8.19% of the total effect. For mental health, findings indicate that the total indirect effect accounts for about 10.79% of the total effect on present physical health. Similarly, physical activity explains the main share, accounting for approximately 90.77% of the total indirect effect and 9.78% of the total effect. This finding is consistent with Ohrnberger et al. (2017), who found that the total indirect effect accounts for 9.7% of the total effect of mental health on present physical health.

Most of the previous studies do not conduct a mediation analysis and the effect of individual well-being on physical health. Ohrnberger et al. (2017) found that the effect of past mental health on physical health is mediated by physical activity and social interaction. However, they focused on an older population aged 50 years and above and used three mediator variables (i.e., physical activity, cigarette consumption, and social interaction) while ignoring some important mediators, which may affect physical health. Importantly, they did also not consider overall life satisfaction. The findings in the present study add new information to existing literature and suggest that overall life satisfaction directly influences physical health and indirectly (via some mediators) influences physical health. The key mediators are different from the existing literature; the presented study

utilised more mediator variables. In sum, physical activity is the largest contributor to the total indirect effect.

This study is not without shortcomings. One limitation is that the mediation analysis accounted for only six possible pathways. Dietary choices and medical care, which are not considered here, may also be important. One implication of this is that we can capture an upper bound of the direct effects of subjective well-being and a lower bound of its indirect effects (e.g., Ohrnberger et al., 2017). Further studies are, therefore, needed in order to consider a broader set of mediators.

Good health results not only from medical care but also from any healthy public policy for all people. Therefore, this paper would provide support for encouraging certain behaviour and activity in daily life, and it could be useful particularly for policymakers in aiding the design of health policies that promote an individual's physical health. Building healthy public policy is the process of developing policies that support health by not only protecting the health of individuals and communities but also making it easier for people to make healthy choices. The policymakers should set out the ultimate well-being objectives in policies and how they plan to deliver them. Healthcare policies are not made just by health departments but by all levels and sectors of government and other organisations, even if only indirectly. For example, laws requiring people to wear their seatbelts and helmets, and implementing smoking restrictions and workplace health and safety regulations are examples of public healthcare policies. In this paper, the key pathway is physical activity that should be considered, as it matters not only as a direct effect but also an indirect effect between overall life satisfaction (or mental health) and physical health. To promote physical activity, the government should provide more green spaces and make it easier to walk and cycle, both of which have potential benefits

for public health. In particular, more green spaces should be provided in the areas of the city with small or no green spaces, adding more attractive activities, such as yoga, running race, and cycling race.

References

Australia's Mental and Physical Health Tracker. (n.d.) (2018). Available from: https://www.vu.edu.au/sites/default/files/australias-mental-and-physical-health-tracker-background-paper.pdf

Baron, R. M., & Kenny, D. A. (1986). The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. Journal of Personality and Social Psychology, 51(6), 1173-1182.

Berwick, D. M., Murphy, J. M., Goldman, P. A., Ware, J. E., Barsky, A. J., & Weinstein, M. C. (1991). Performance of a Five-Item Mental Health Screening Test. Medical Care, 29(2), 169–176.

Boehm, J. K., Vie, L. L., & Kubzansky, L. D. (2012). The promise of well-being interventions for improving health risk behaviors. Current Cardiovascular Risk Reports, 6, 511-519.

Bollen, K. A. (1987). Total, Direct, and Indirect Effects in Structural Equation Models. Sociological Methodology, 17, 37.

Butterworth, P., & Crosier, T., (2004). The validity of the sf-36 in an australian national household survey: demonstrating the applicability of the household income and labour dynamics in australia (HILDA) survey to examination of health inequalities. BMC 4, 44.

Chen, H.T. (1990). Theory-driven evaluations. Newbury Park, CA: Sage.

Contoyannis, P., & Jones, A. M. (2004). Socio-economic status, health and lifestyle. Journal of Health Economics, 23(5), 965–995.

Cornah, D. (2006). Cheers? Understanding the relationship between alcohol and mental health. Mental Health Foundation. Available from: https://www.drugsandalcohol.ie/15771/1/cheers_report%5B1%5D.pdf.

Diener, E. (1984). Subjective well-being. Psychological Bulletin, 95(3), 542–575. https://doi.org/10.1037/0033-2909.95.3.542

Diener, E. (2000). Subjective well-being: The science of happiness and a proposal for a national index. American psychologist, 55(1), 34.

Diener, E., Lucas, R. E., & Oishi, S. (2002). Subjective well-being: The science of happiness and life satisfaction. Handbook of positive psychology, 2, 63-73.

Diener, E., Pressman, S. D., Hunter, J., & Delgadillo-Chase, D. (2017). If, why, and when subjective well-being influences health, and future needed research. Applied Psychology: Health and Well-Being, 9(2), 133-167.

Doorslaer, E. V., & Koolman, X. (2004). Explaining the differences in income-related health inequalities across European countries. Health Economics, 13(7), 609–628.

Durstine, J. L., Gordon, B., Wang, Z., & Luo, X. (2013). Chronic disease and the link to physical activity. Journal of Sport and Health Science, 2(1), 3-11. doi: 10.1016/j.jshs.2012.07.009

Ferrer-i-Carbonell, A., & Frijters, P. (2004). How Important is Methodology for the Estimates of the Determinants of Happiness? The Economic Journal, 114(497), 641–659.

Goodman, L. A. (1960). On the Exact Variance of Products. Journal of the American Statistical Association, 55(292), 708–713.

Grant, N., Wardle, J., & Steptoe, A. (2009). The relationship between life satisfaction and health behavior: A cross-cultural analysis of young adults. International Journal of Behavioral Medicine, 16(3), 259-268.

Grossman, M. (1972). On the concept of health capital and the demand for health. Journal of Political Economy, 80(2), 223-255.

Hemingway, H., Stafford, M., Stansfeld, S., Shipley, M., & Marmot, M. (1997). Is the SF-36 a valid measure of change in population health? Results from the Whitehall II study. BMJ, 315(7118), 1273-1279.

Kelly, M., Stewart, E., Morgan, A., Killoran, A., Fischer, A., Threlfall, A., & Bonnefoy, J. (2009). A conceptual framework for public health: NICEs emerging approach. Public Health, 123(1).

Kesavayuth, D., Poyago-Theotoky, J., & Zikos, V. (2020). Locus of control, health and healthcare utilization. Economic Modelling, 86, 227-238.

Lenhart, O. (2017). The Effects of Income on Health: New Evidence from the Earned Income Tax Credit. SSRN Electronic Journal.

Llena-Nozal, A., Lindeboom, M., & Portrait, F. (2004). The effect of work on mental health: does occupation matter? Health Economics, 13(10), 1045–1062.

MacKinnon, D. P. (2000). Contrasts in multiple mediator models. Multivariate applications in substance use research: New methods for new questions, 141-160.

Mackinnon, D. P., Lockwood, C. M., Hoffman, J. M., West, S. G., & Sheets, V. (2002). A comparison of methods to test mediation and other intervening variable effects. Psychological Methods, 7(1), 83–104.

Minichino, A., Bersani, F., Calò, W., Spagnoli, F., Francesconi, M., Vicinanza, R., ... & Biondi, M. (2013). Smoking behaviour and mental health disorders—mutual influences and implications for therapy. International Journal of Environmental Research and Public Health, 10(10), 4790-4811.

Mujcic, R., & J. Oswald, A. (2016). Evolution of well-being and happiness after increases in consumption of fruit and vegetables. American Journal of Public Health, 106(8), 1504-1510.

Mundlak, Y. (1978). On the Pooling of Time Series and Cross Section Data. Econometrica, 46(1), 69.

OECD Better Life. (2013). In Search of Satisfaction. Retrieved from http://www.oecdbetterlifeindex.org/blog/in-search-of-satisfaction.htm

Ohrnberger, J., Fichera, E., & Sutton, M. (2017). The relationship between physical and mental health: A mediation analysis. Social Science & Medicine, 195, 42-49.

Ong, A. D. (2010). Pathways Linking Positive Emotion and Health in Later Life. Current Directions in Psychological Science, 19(6), 358–362.

Preacher, K. J., & Hayes, A. F. (2004). SPSS and SAS procedures for estimating indirect effects in simple mediation models. Behavior Research Methods, Instruments, & Computers, 36(4), 717–731.

Preacher, K. J., & Hayes, A. F. (2008a). Assessing mediation in communication research (pp. 13-54). London: The Sage sourcebook of advanced data analysis methods for communication research.

Preacher, K. J., & Hayes, A. F. (2008b). Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. Behavior Research Methods, 40(3), 879–891.

Roy, J., & Schurer, S. (2013). Getting Stuck In The Blues: Persistence Of Mental Health Problems In Australia. Health Economics, 22(9), 1139–1157.

Sin, N. L. (2016). The protective role of positive well-being in cardiovascular disease: review of current evidence, mechanisms, and clinical implications. Current Cardiology Reports, 18(11), 106.

Skevington, S. M., & Böhnke, J. R. (2018). How is subjective well-being related to quality of life? Do we need two concepts and both measures?. Social Science & Medicine, 206, 22-30.

Sobel, M. E. (1982). Asymptotic confidence intervals for indirect effects in structural equation models. Sociological Methodology, 13, 290-312.

Stampfer, M. J., Kang, J. H., Chen, J., Cherry, R., & Grodstein, F. (2005). Effects of moderate alcohol consumption on cognitive function in women. New England Journal of Medicine, 352(3), 245-253.

Steptoe, A., Shankar, A., Demakakos, P., & Wardle, J. (2013). Social isolation, loneliness, and all-cause mortality in older men and women. Proceedings of the National Academy of Sciences, 110(15), 5797-5801.

Stiglitz, J.E., Sen, A., & Fitoussi, J.P. (2010). "Report by the commission on the measurement of economic performance and social progress", Paris: Commission on the Measurement of Economic Performance and Social Progress.

World Health Organization (2017). Determinants of health. Available from: https://www.who.int/news-room/q-a-detail/determinants-of-health.

Zhu, R. (2016). Retirement and its consequences for women's health in Australia. Social Science & Medicine, 163, 117-125.