On the Associations between Physical Activity and Quality of Life: Findings from an Australian Nationally Representative Panel Survey

Quality of Life (QoL) is an umbrella term which encompasses both (a) individuals' conscious cognitive assessments of their lives as a whole (life satisfaction), and (b) more traditional measures of health status or Health-Related Quality of Life (HRQoL) capturing their perceptions of their physical, emotional and social functioning [1]. QoL is a key concept in health promotion and enhancing it is a recognised public health goal [2]. Unbiased and comprehensive analysis of QoL contributes to monitoring progress in achieving national health and wellbeing objectives and can help devising preventive and palliative interventions [2-4]. Consequently, research on QoL – and particularly on HRQoL – is of uttermost importance for the emergence of evidence-based policy and for the efficient and effective allocation of public resources [2].

We already know much about the factors that are associated with QoL. The academic literature suggests that participation in regular Moderate to Vigorous Physical Activity (MVPA) is one such factor, with several theoretical models been developed and tested [5-8]. Both the quantity and the frequency of physical activity are argued to have important benefits for individuals' QoL regardless of the approach used to define the concept [1,9]. Mechanisms through which MVPA enhances QoL include social interactions resulting from group participation, time spent outdoors, enhanced self-esteem and increased endorphin levels [1,8,10]. Existing models also highlight the role of HRQoL as an intervening variable in the association between MVPA and global life satisfaction assessments [6-8].

However, the existing evidence is lacking. Most research has been conducted on small, rather specific groups, such as individuals with diabetes, cancer and cardiovascular diseases or the elderly population [11-16]. The few studies which target a broader segment of the population are usually not nationally representative and restricted to a single observation of a cross-section [17], whereas prospective (i.e. longitudinal) studies which track individuals over time are scarce [18-20]. Besides, existing studies usually offer only a partial picture of the benefits of MVPA for QoL by taking exclusively one of the two approaches to the concept described above or focusing on a single outcome (or a small number of these). This study adds to the existing body of knowledge by considering the relationships between MVPA and QoL (a) using longitudinal data and fixed effects panel regression methods, (b) on a large, representative sample of the Australian population and (c) for indicators of both life satisfaction and HRQoL (including measures derived from the SF-36).

Methods

Design and sample

We used data from waves 1 to 11 of the Household, Income and Labour Dynamics in Australia (HILDA) Survey. This is a large-scale multipurpose panel survey in which respondents are interviewed annually, with data currently available for the period between 2001 (wave 1) and 2011 (wave 11). The original HILDA Survey sample is representative of the Australian population in 2001 and attrition rates have remained remarkably low for international standards [21]. This survey is well-suited to explore the associations between the frequency of MVPA undertaken by individuals and their QoL for three reasons. First, the sample is very large (an average of around 13,000 respondents per year) and nationally representative. Second, the data stretches over a

long period of time, which allows for precise estimation of the relationships of interest and evaluation of within individual changes over time. Third, the survey contains rich information on QoL and health-related outcomes, physical activity and relevant contextual factors.

Measures

The key independent variable in the analyses was the weekly frequency of MVPA undertaken by respondents. Individuals in the HILDA Survey are asked to fill in and mail back a self-complete questionnaire which includes the following question: *"In general, how often do you participate in moderate or intensive physical activity for at least 30 minutes? Moderate level physical activity will cause a slight increase in breathing and heart rate, such as brisk walking"*. Respondents must choose one of the following answers: 'Not at all', 'Less than once a week', '1 or 2 times a week', 'Three times a week', 'More than 3 times a week (but not every day)' and 'Everyday'. We used this information to create two variables capturing the frequency of MVPA. In our main models, we grouped the different categories in the original question into two, to construct a new variable which approximates current public health recommendations about the optimal frequency of this type of physical activity for the general population [22]. The categories 'More than 3 times a week (but not every day)' and 'Everyday' take the value 1 ('Respondent undertakes the recommended level of physical activity') and the categories 'Not at all', 'Less than once a week', '1 or 2 times a week' and 'Three times a week' take the value 0 ('Respondent undertakes less than the recommended level of physical activity'). The results of equivalent analyses using the full set of categories in the original physical activity variable as explanatory variables are also reported.

QoL is a complex multidimensional concept. Its meaning its subject to discrepancy and its operational definition varies substantively across studies [1]. Here, we provide a more encompassing coverage of the concept than is usual in the literature by considering several outcomes that tap on its different dimensions. These include (i) measures that consider QoL as a psychological construct, such as self-reported life satisfaction, and (ii) clinical measures capturing health status or HRQoL, such as the SF-36 [1,5-8]. In a first set of models, we operationalized QoL as HRQoL using respondents' summary scores in the well-established SF-36 battery of health-related questions [23,24]. These include the SF-6D utility index (ranging from 0 to 1), the mental component summary (MCS, ranging from -1.21 to 76.19) and the physical component summary (PCS, ranging from 4.54 to 76.09). In a second set of models, we used the eight dimensions of the SF-36 (i.e. 'Bodily Pain', 'General Health', 'Mental Health', 'Physical Functioning', 'Role-Emotional', 'Role-Physical', 'Social Functioning' and 'Vitality') as dependent variables [24]. These dimensions are transformed to range from 0 to 100. In a final set of models, we used alternative outcome variables which capture other aspects of health and life satisfaction. These capture respondents' self-evaluations of their general health ('Very good', 'Good', 'Fair' or 'Poor'), self-reported satisfaction with their health (0-10), and self-reported satisfaction with life overall (0-10).

Based on a review of the literature, our multivariate analyses controlled also for a number of known confounders of the relationship between the frequency of MVPA and QoL. These included the respondents' age (in years), gender ('Male'/'Female'), ethnicity ('Indigenous'/'Not indigenous'), highest educational qualification ('University qualification', 'Professional qualification', 'Year 12' and 'Lower than year 12'), gross yearly personal income (in tens of thousands), perceptions of being stressed or rushed ('Often or almost always', 'Sometimes', 'Rarely or never'), weekly work hours (the sum

of weekly hours spent in paid work and unpaid domestic work), as well as information on whether they live alone ('Yes'/'No'), currently smoke ('Yes'/'No') or have a long-term health condition, impairment or disability that restricts their everyday activities ('Yes'/'No'). Table A1 in the Appendix provides descriptive statistics on all variables.

Statistical analysis

To explore the relationships between the frequency of MVPA and QoL we first estimated ordinary least squares (OLS) models, pooling the observations from respondents over the whole survey period. These take the form:

$$Q_{it} = P_{it}\beta + X_{it}\gamma + e_{it} \quad (1)$$

Where subscripts i and t refer to individuals and time periods; Q is an outcome variable capturing a given dimension of respondents' QoL; P is the key explanatory variable capturing the weekly frequency of MVPA undertaken by the respondents; X is a vector of control variables; β and γ are vectors of coefficients to be estimated; and e is a stochastic error term.

Subsequent, more complex analyses exploit the longitudinal design of the HILDA Survey dataset for enhanced estimation of the relationships of interest through the use of within group fixed effects (FE) panel regression models. FE models use the repeated observations from the same individuals over time contained in panel data to estimate how deviations from individuals' usual behaviour/characteristics associate with deviations from their usual outcomes (captured by the individual mean scores in these over time). More formally, the FE panel regression model we fitted can be expressed as:

$$Q_{it} - \overline{Q}_i = (P_{it} - \overline{P}_i)\beta + (X_{it} - \overline{X}_i)\gamma + (e_{it} - \overline{e}_i) \quad (2)$$

Our aim is to provide a better picture of the associations between MVPA and QoL than possible in cross-sectional regression models. These FE panel regression models enable us to do so by implicitly accounting for any unobserved person-specific (time-invariant) factors which might confound the associations, thus minimizing any omitted variable bias that may arise due to these [25,26].

As we will discuss later, there are other modelling approaches for panel data that stand as valid alternatives to FE models. Here, we settle for the latter because estimates from these models are the least likely to be biased (i.e. they are the most 'conservative'). This is because, despite having other desirable properties and advantages, other techniques such as hierarchical linear models assume strict orthogonality between the observable and unobservable factors influencing the outcome [25,26]. One drawback of FE models is that the impact of time-constant explanatory variables on the outcome variable (e.g. gender or ethnicity) cannot be directly estimated, though these factors are implicitly controlled for.

Results

Table 1 shows the distribution of the key explanatory variable of interest: the weekly frequency of MVPA undertaken by individuals. Of all respondents, 65.97% performed less physical activity in a normal week than recommendable, of which 11.05% reported not doing any MVPA at all, 15.56% reported doing it less than once a week, 23.68% reported doing it once or twice a week, and 15.68% reported doing it 3 times a week. The remaining 34.03% of respondents met the recommended criteria and undertook MVPA more than 3 times a week (21.21% of respondents) or everyday (12.82%).

Figure 1 offers a visual representation of the relationships between the reported frequency of MVPA and the observed levels of HRQoL, captured by the 3 summary

measures of the SF-36. For all 3 measures, more frequent MVPA was related to higher levels of HRQoL. Figure 2 depicts the relationships between the frequency of MVPA and the observed levels in the 8 dimensions of the SF-36. Evidence is again unambiguous: mean scores on each SF-36 dimension increase with the frequency of MVPA. For most indicators there is a sharp difference between the categories 'Not at all' and 'Less than once a week' and a less acute difference sustained across the categories denoting more frequent MVPA. Finally, Figure 3 shows the raw relationships between the frequency of MVPA and measures of self-assessed general health, satisfaction with one's health and satisfaction with life overall. Again, there was a marked gradient for these indicators, whereby individuals who reported more frequent MVPA tended to report higher scores in these outcomes too.

These results established that there were important bivariate associations between the variable capturing the frequency of MVPA and variables capturing QoL. The next step was to explore these relationships in a multivariate framework to test whether the observed associations faded away in the presence of statistical controls for factors known to affect QoL. We first estimated models using OLS (Tables 2-4). In these tables, each column is a separate regression model for a different indicator of QoL. The estimated coefficients on the explanatory variables give the predicted difference in the outcome variable for a one-unit difference in that explanatory variable holding all other variables in the model constant. Of key interest to this research is the first row of the tables, which contains the estimated association between frequency of MVPA and different QoL variables. Discussing these OLS estimates is helpful in (i) describing the cross-sectional associations in the data, and (ii) determining whether and how accounting for person-specific differentials in subsequent FE models changes the estimated relationships.

Table 2 presents the results of models for the 3 summary measures of the SF-36. In column 1, the estimated coefficient on the physical activity variable is 0.03. This indicates that individuals who undertook MVPA more than 3 times per week scored 3 percentage points higher in the SF-6D scale than individuals who undertook MVPA 3 times per week or less. Similar statistically significant relationships emerged between undertaking MVPA to the recommended standard and the PCS (b=1.95) and MCS (b=2.43) indicators (columns 2 and 3). In Table 3, the estimated coefficients on the MVPA variable give its association with each of the eight transformed dimensions of the SF-36. Undertaking the recommended level of MVPA was always associated with substantial and statistically significant gains in HRQoL. The associated effects ranged from 3.15 units (Bodily Pain) to 7.49 units (General Health), with those for the Mental Health (3.76), Social Functioning (4.88 units), Role-Emotional (5.00 units), Physical Functioning (5.56 units), Role-Physical (5.63 units) and Vitality (7.32 units) dimensions lying in-between. Table 4 contains the results of additional models where the outcome variables are measures of self-assessed general health, satisfaction with one's health and satisfaction with life overall. The coefficients on the MVPA variable, located across the first row of the table, were again positive and statistically significant across the board. These indicate that undertaking the recommended level of MVPA was associated with evident gains in self-assessed general health (0.32 units in a 1 to 5 scale), satisfaction with one's health (0.56 units in a 0-10 scale) and satisfaction with life overall (0.25 units in a 0-10 scale).

Given that the associations between the frequency of MVPA undertaken and QoL outcomes remain in the presence of statistical controls for observable factors, we proceeded to estimate more conservative FE panel regression models that also control for time-invariant unobserved factors. Results from these models are displayed in

Tables 5 to 7. The estimated regression coefficients give the change in the outcome variable associated with a *within person* change in the explanatory variables. Concerning our key explanatory variable, model coefficients give the average difference in QoL at observation points when the same individual undertakes the recommended levels of physical activity and at observation points when he/she does not. In Table 5, the estimated coefficients indicate that following public health recommendations was associated with a gain of 2 percentage points in the SF-6D indicator, 0.93 units in the PCS and 1.36 units in the MCS. Results in Table 6 show that the MVPA variable was also positively associated with all dimensions of the SF-36. The associated coefficients ranged from 1.89 units (Bodily Pain) to 3.67 units (Vitality). The same pattern emerged for the alternative outcome variables in Table 7. Undertaking the recommended levels of physical activity was associated with gains of 0.15 units in self-assessed general health, 0.25 units in satisfaction with one's health and 0.09 units in satisfaction with life overall, all of which were statistically different from zero at conventional levels.

To further explore the relationships of interest, we also fitted OLS and FE regression models using the full set of categories for the variable capturing the frequency of MVPA (i.e. 'Not at all', 'Less than once a week', '1 or 2 times a week', 'Three times a week', 'More than 3 times a week (but not every day)' and 'Everyday'). Results for the coefficients on these variables are presented in Table 8, with undertaking no MVPA at all serving as the reference category. The evidence in this table clearly demonstrates that there is a gradient in the impact of MVPA on QoL. Without exception, coefficients on the MVPA variables were positive, highly statistically significant and large. Additionally, across all the estimated models, any category of frequency of physical activity had always a more positive effect on QoL than any of the preceding categories denoting lower frequencies. In Tables 2 and 5 undertaking the recommended levels of MVPA

relative to not doing so was more strongly associated with the MCS than the PCS, which was counterintuitive. Results in Table 8 show that, by looking into more detailed MVPA frequency categories, stronger associations emerge with the PCS, as reported by previous literature [7].

Finally, in Table 9 we explored whether as proposed by others [6-8], HRQoL mediates the impact of MVPA on the global measure of life satisfaction. This would occur if coefficients on MVPA variables reported in Tables 7 and 8 decrease in magnitude and/or statistical significance when measures of HRQoL (operationalized using the PCS and MCS components of the SF-36) are added to the model. Results indicate that physical (b=0.01) and particularly mental health (b=0.04) have an impact on life satisfaction, and that most of the associations between MVPA and life satisfaction run through HRQoL. Interestingly, MVPA still retains a small independent effect on life satisfaction, regardless of how the variable is specified.

Discussion

In this paper we have investigated the relationships between the frequency of MVPA and several measures of QoL, including the SF-36 and overall life satisfaction. In doing so, we made two important contributions to existing literature. First, this is one of the first longitudinal nationally representative studies analyzing the relationships between MVPA and different QoL measures. This enables extrapolation of our findings to the Australian population as a whole. Second, the panel regression methods we employed allowed controlling for unmeasured time-constant factors which in typical cross-sectional analyses may have confounded the estimates of the associations between MVPA and QoL.

Key findings indicate that amongst the Australian population MVPA is positively and strongly associated with QoL. Evidence is unambiguous: greater levels of MVPA are related to higher levels of QoL for each of the measures analyzed, with the strongest associations occurring with the physical dimensions of the SF-36. These results are consistent with those from other cross-sectional and longitudinal population-based studies focusing on healthy individuals and with other research on special populations such as cancer survivors or diabetics [6-8,18,20,27-29].

We estimated our results using two alternative regression techniques. First, we estimated OLS models similar to those typically fitted in studies of the impact of MVPA on QoL [30]. These allowed us to obtain base estimates that were comparable to those from previous studies. However, the associations unveiled by OLS regression models could have been partially or totally spurious and driven by unobserved omitted variables. We therefore estimated the same models using a FE regression approach which exploited the longitudinal structure of the HILDA Survey data to account for person-specific time-constant unobserved heterogeneity. In these specifications, comparisons were made of the same individuals over time, rather than between individuals. As expected, the estimated impacts of the frequency of MVPA on QoL and the other used outcomes in FE models were lower than those estimated in OLS models. This demonstrates that unobserved factors correlated with both frequency of MVPA and QoL unaccounted for in the OLS model were successfully captured in our FE specifications. That is, variables that we did not explicitly control for in our models were important confounders of the relationships between the frequency of MVPA and QoL. This is something which a traditional cross-sectional research design would have ignored.

Nevertheless, the impacts of MVPA on QoL remained substantial and statistically significant in the preferred FE models, which strongly suggests a true relationship exists. Particularly noteworthy were the positive associations with the dimensions of the SF-36 that relate to physical aspects of health and vitality. The observed differences in QoL between individuals undertaking different degrees of MVPA are not only highly statistically significant, but also clinically meaningful, as denoted by effects sizes which revolve around 0.03 in the SF-6D [31]. Recently, Heesch et al. [18] found comparable, though somewhat stronger, results amongst Australian adult women. There are two main possible reasons for the divergences observed across studies. First, their study focused solely on women whereas ours considers the whole population. Second, their estimation strategy (random coefficients longitudinal regression models) is less successful in accounting for person-specific differentials than our FE models [25,26].

Our results provided additional interesting findings. First, the nature of the dose-response relationship between physical activity and health appears to be curvilinear: there are larger QoL differences between undertaking infrequent rather than no MVPA than between undertaking frequent rather than infrequent MVPA. This is consistent with results from other longitudinal studies focusing on specific population subgroups [18,20,32], but was for the first time unveiled using a nationally representative sample. Second, a positive association also emerged between the frequency of MVPA and other QoL indicators such as self-assessed general health and self-reported satisfaction with one's health. An association between the frequency of MVPA undertaken and overall life satisfaction was also apparent though less pronounced. This association ran primarily through improvements in HRQoL brought about by increased MVPA, but there was also evidence of a small independent effect of MVPA on overall wellbeing. The latter suggests that the benefits of MVPA on global assessments of wellbeing go beyond any health

improvements derived from participation in physical activity, for example via mechanisms such as perceived self-efficacy, physical self-esteem or affect [1,6,8].

Despite our contributions to the literature, two limitations need to be acknowledged when interpreting our results. First, the measure of the frequency of MVPA included in the HILDA Survey does not capture the precise number of minutes individuals spend undertaking this type of activity. Therefore, it is not possible to calculate the metabolic equivalents within each category or the exact dose-response pattern for the analyzed outcomes. Additionally, despite versions of this question have been used in other studies, to our knowledge, the psychometric properties of this measure are yet to be validated. Thus, this variable may contain a degree of error and consequently care must be exercised when interpreting the results. Second, our models lacked a measure of Body Mass Index (BMI), which is an important factor influencing QoL, is correlated with physical activity and thus is a potential source of omitted variable bias in our models [30,18]. Information on BMI is only available in waves 6-11 of the HILDA Survey and its inclusion in the models limits the sample size from circa 125,000 observations to circa 65,000 observations. As a sensitivity check we estimated models for the observations for which information on BMI is available, using this as a control variable. Changes to the coefficients on the MVPA variables, which are not shown but available upon request, were negligible.

Our findings suggest several avenues for future research. From a methodological standpoint, we argue that much can be learnt about the relationships between MVPA and QoL through the use of longitudinal survey data in general and the HILDA Survey in particular. In this article, intended as a foundational contribution, the focus has been on how accounting for person-specific time-constant unobserved heterogeneity matters

and to show that the estimates from cross-sectional models are subject to person-specific unobserved heterogeneity bias. Yet, it is still not possible to take the observed impacts of MVPA on QoL as evidence of causal relationships. For instance, it is still conceivable that the direction of the relationship between the frequency of MVPA and QoL runs to some extent in the reverse direction: enjoying high QoL levels may enable or incentivize individuals to undertake more MVPA. The richness of the panel data allows for future contributions which further exploit its features. Fruitful avenues for future research are the application within the field of MVPA of time-varying effects models, a flexible modelling approach that allows the effects of covariates to vary over time [33], structural equation models which further examine the paths between the latent variables [6] and pseudo-experimental modelling specifications that aim at establishing the direction of effects, such as instrumental variable models [34]. We hope that this study helps stir future research in these directions. Second, the relationships between MVPA and QoL we find are likely to vary across population groups with different characteristics, for instance, between male and female, young and old, or disabled and non-disabled individuals. Forthcoming research should explore whether the optimal dose of physical activity that maximizes health outcomes differs across these socio-demographic groups, so that more targeted and effective advice can be devised. Given its coverage and large sample size, the HILDA Survey might also prove an optimal source of data for this endeavor. Third, studies which test the validity of the MVPA question used in this large-scale nationally representative survey, for example by assessing its correlation with fitness outcomes or objectively measured physical activity obtained via accelerometry, would be enlightening.

In conclusion, we provide strong evidence that MVPA is related to QoL and add to the growing body of scientific literature demonstrating the benefits of becoming physically

active. Consequently, our research underscores the importance of developing and sustaining social and health policies and official recommendations that foment this.

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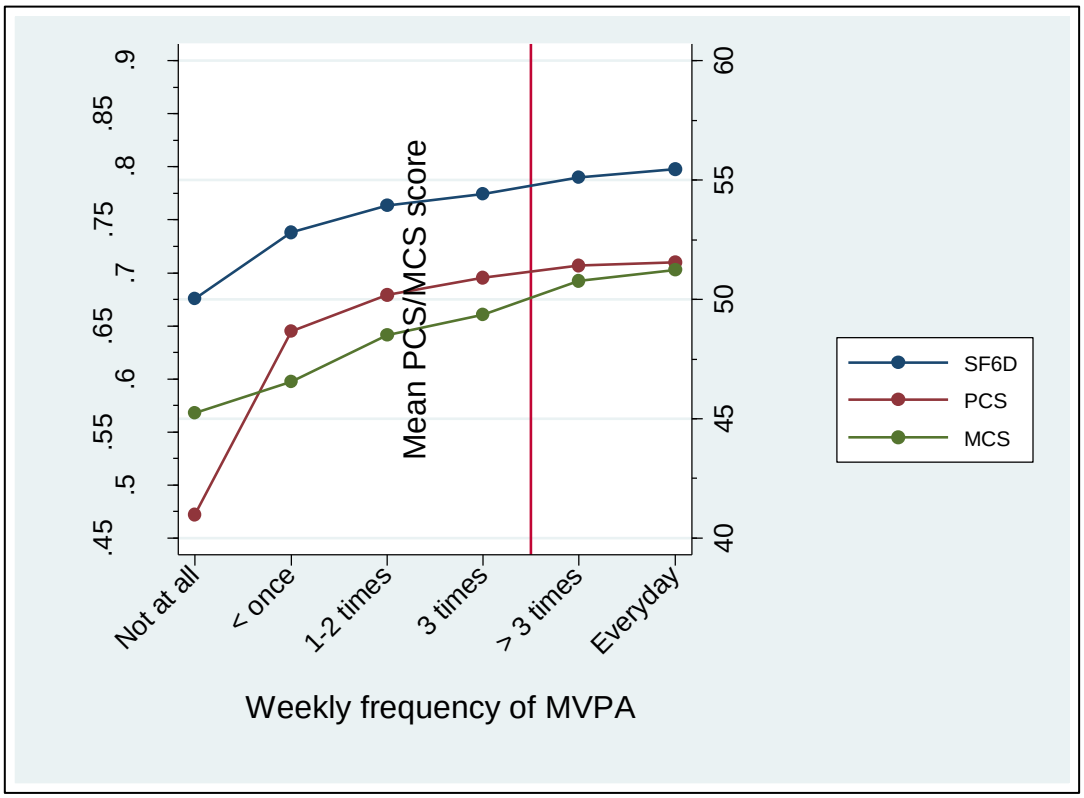
Tables and figures

Table 1. Frequency distribution of variables capturing the frequency of MVPA

	n	**%**
Original variable		
Not at all	14,603	11.05
Less than once a week	20,567	15.56
1 or 2 times a week	31,295	23.68
3 times a week	20,729	15.68
More than 3 times a week (but not every day)	28,028	21.21
Everyday	16,950	12.82
Transformed variable		
Below the recommended level (3 times a week or less)	87,194	65.97
Recommended level (more than 3 times a week)	44,978	34.03
N (person-year observations)	132,186	100

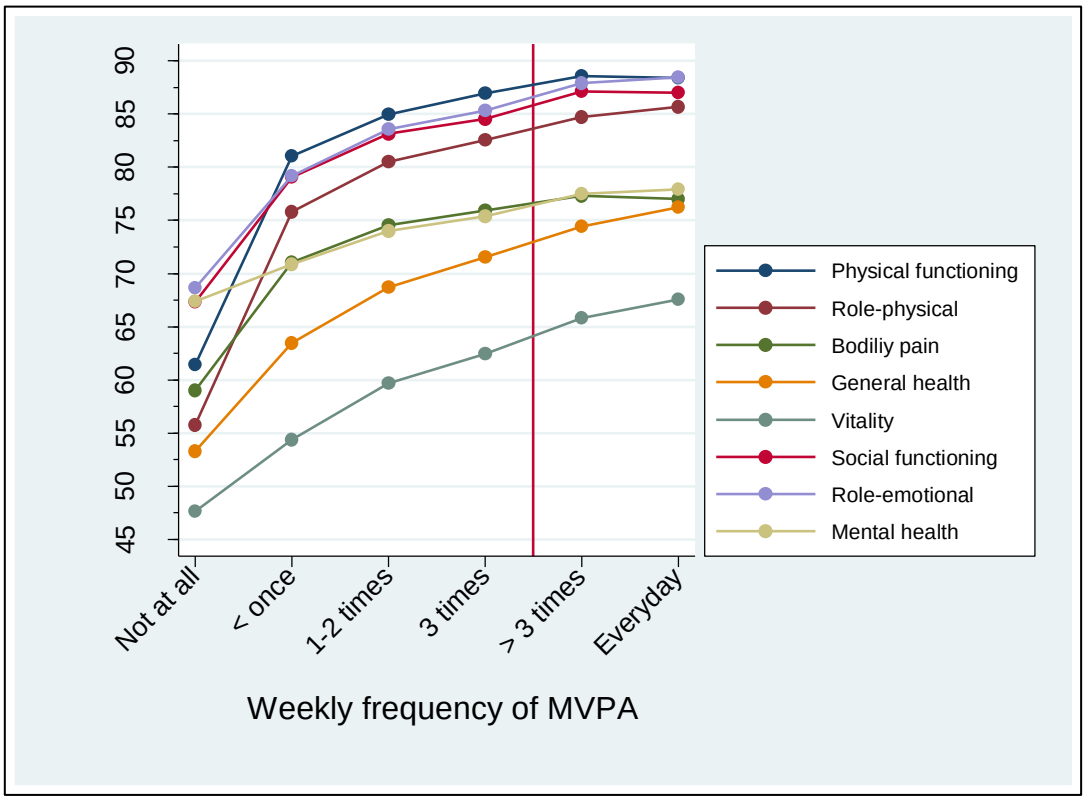
Notes: HILDA Survey data (2001-2011).

Figure 1. Mean scores in summary measures of the SF-36 by frequency of MVPA



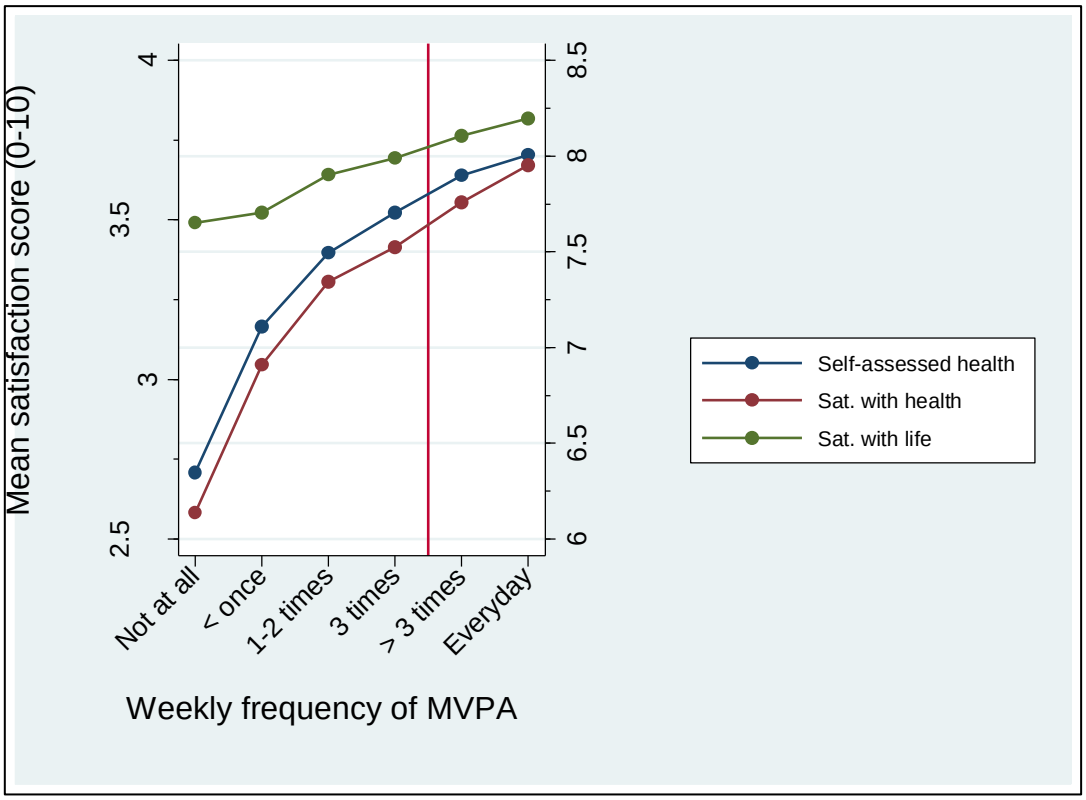
Notes: HILDA Survey data (2001-2011). The vertical red line marks the threshold denoting following vs. not following the recommended frequency of MVPA.

Figure 2. Mean scores in dimensions of the SF-36 by frequency of MVPA



Notes: HILDA Survey data (2001-2011). The vertical red line marks the threshold denoting following vs. not following the recommended frequency of MVPA.

Figure 3. Mean scores in self-assessed general health, satisfaction with one's health and satisfaction with life overall, by frequency of MVPA



Notes: HILDA Survey data (2001-2011). The vertical red line marks the threshold denoting following vs. not following the recommended frequency of MVPA.

Table 2. OLS models of the impact of the frequency of MVPA on summary measures of the SF-36

	1 **6D**	**2** **PCS**	**3** **MCS**
Recommended level of physical activity	0.03***	1.95***	2.43***
Female	-0.01***	-0.30***	-0.57***
Age	-0.00***	-0.17***	0.08***
Indigenous background	-0.02***	-0.65*	-1.17**
Education			
Lower than year 12 *(reference)*			
University qualification	0.01***	1.70***	0.25(*)
Professional qualification	0.00**	0.63***	0.12
Year 12	0.01***	0.91***	0.19
Income (in 10,000s)	0.00***	0.08***	0.11***
Long-term condition or disability	-0.10***	-9.68***	-4.73***
Current smoker	-0.02***	-0.50***	-2.46***
Lives alone	-0.01***	0.22	-1.20***
Total weekly work hours	0.00***	0.04***	0.05***
Feeling rushed or stressed			
Often or always *(reference)*			
Sometimes	0.04***	0.27***	4.86***
Rarely or never	0.07***	0.56***	7.95***
Intercept	0.75***	56.17***	40.29***
N (person-year observations)	122,061	122,061	122,061
N (individuals)	23,466	23,466	23,466
F	1073.88	1095.89	622.79
p	0.00	0.00	0.00
R^2	0.29	0.40	0.18

Notes: HILDA Survey data (2001-2011). 6D = SF-6D scale; PCS = Physical component summary; MCS = Mental component summary. The standard errors on the estimated coefficients are clustered to account for the fact that the data encompasses multiple observations from the same individuals. Significance levels: (*) $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 3. OLS models of the impact of the frequency of MVPA on dimensions of the SF-36

	1 PF	2 RP	3 BP	4 GH	5 V	6 SF	7 RE	8 MH
Recommended level of physical activity	5.56***	5.63***	3.15***	7.49***	7.32***	4.88***	5.00***	3.76***
Female	-1.44***	-1.60***	-1.35***	1.41***	-2.21***	-1.55***	-1.33***	-0.97***
Age	-0.37***	-0.37***	-0.22***	-0.11***	0.00	-0.02**	-0.04***	0.10***
Indigenous background	-2.98***	-2.01*	-0.96	-2.46**	-0.44	-3.96***	-3.99***	-2.06**
Education								
Lower than year 12 *(reference)*								
University qualification	5.26***	1.53***	4.11***	2.41***	1.16***	1.66***	1.82***	1.56***
Professional qualification	2.83***	0.69(*)	0.75*	1.04***	0.29	0.30	1.00*	0.93***
Year 12	2.94***	0.77(*)	2.13***	1.57***	0.56(*)	1.05***	0.89*	0.98***
Income (in 10,000s)	0.21***	0.33***	0.22***	0.18***	0.20***	0.29***	0.32***	0.19***
Long-term condition or disability	-17.94***	-31.68***	-21.84***	-19.25***	-13.62***	-17.70***	-17.80***	-8.59***
Current smoker	-1.75***	-2.20***	-2.52***	-5.39***	-3.03***	-4.78***	-5.69***	-3.90***
Lives alone	-0.75*	-1.90***	0.86**	-0.08	-0.40	-2.58***	-4.52***	-1.44***
Total weekly work hours	0.13***	0.19***	0.07***	0.09***	0.06***	0.13***	0.19***	0.08***
Feeling rushed or stressed								
Often or always *(reference)*								
Sometimes	1.75***	5.56***	4.34***	4.81***	9.82***	6.89***	9.58***	7.39***
Rarely or never	2.24***	9.03***	8.67***	8.83***	15.25***	10.75***	15.00***	12.93***
Intercept	94.19***	89.36***	79.76***	67.07***	51.88***	76.07***	73.75***	61.56***
N (person-year observations)	125,812	125,625	126,632	126,089	127,334	127,626	125,503	127,309
F	880.74	938.04	851.84	831.78	955.27	626.54	393.61	571.13
p	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R^2	0.37	0.29	0.27	0.29	0.24	0.21	0.14	0.18

Notes: HILDA Survey data (2001-2011). PF = Physical Functioning dimension; RP = Role-Physical dimension; BP = Bodily Pain dimension; GH = General Health Dimension; V = Vitality dimension; SF = Social Functioning dimension; RE = Role-Emotional dimension; MH = Mental Health dimension. The standard errors on the estimated coefficients are clustered to account for the fact that the data encompasses multiple observations from the same individuals. Significance levels: (*) $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 4. OLS models of the impact of the frequency of MVPA on self-assessed general health, satisfaction with one's health and satisfaction with life overall

	1 **SAH**	**2** **SwH**	**3** **SwL**
Recommended level of physical activity	0.32***	0.56***	0.25***
Female	0.02*	0.01	0.12***
Age	-0.01***	-0.01***	0.01***
Indigenous background	-0.13***	-0.09	0.11(*)
Education	0.22***	-0.07*	-0.21***
Lower than year 12 *(reference)*			
University qualification			
Professional qualification	0.05***	-0.10***	-0.14***
Year 12	0.11***	0.00	-0.13***
Income (in 10,000s)	0.01***	0.01***	0.02***
Long-term condition or disability	-0.78***	-1.88***	-0.52***
Current smoker	-0.27***	-0.49***	-0.34***
Lives alone	0.03(*)	-0.06*	-0.33***
Total weekly work hours	0.00***	0.00***	-0.00***
Feeling rushed or stressed			
Often or always *(reference)*			
Sometimes	0.13***	0.36***	0.39***
Rarely or never	0.26***	0.64***	0.71***
Intercept	3.65***	7.53***	7.43***
N (person-year observations)	125,800	127,628	127,598
F	1025.11	693.73	303.77
p	0.00	0.00	0.00
R^2	0.30	0.25	0.10

Notes: HILDA Survey data (2001-2011). SAH = Self-assessed general health; SwH = Satisfaction with one's health; SwL = Satisfaction with life overall. The standard errors on the estimated coefficients are clustered to account for the fact that the data encompasses multiple observations from the same individuals. Significance levels: (*) $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 5. FE models of the impact of the frequency of MVPA on summary measures of the SF-36

	1 **6D**	**2** **PCS**	**3** **MCS**
Recommended level of physical activity	0.02***	0.93***	1.36***
Age	-0.00***	-0.22***	0.03**
Education			
Lower than year 12 *(reference)*			
University qualification	0.01**	0.25	0.30
Professional qualification	0.01*	0.52**	-0.15
Year 12	-0.00	0.13	-0.27
Income (in 10,000s)	0.00***	0.02**	0.02**
Long-term condition or disability	-0.04***	-3.80***	-1.48***
Current smoker	-0.00(*)	0.38***	-0.68***
Lives alone	-0.01***	0.71***	-1.08***
Total weekly work hours	0.00***	0.02***	0.02***
Feeling rushed or stressed			
Often or always *(reference)*			
Sometimes	0.02***	-0.14*	2.51***
Rarely or never	0.03***	-0.19*	3.93***
Intercept	0.77***	58.62***	45.24***
N (person-year observations)	122,047	122,047	122,047
N (individuals)	23,466	23,466	23,466
R^2 Within	0.04	0.06	0.04

Notes: HILDA Survey data (2001-2011). 6D = SF-6D scale; PCS = Physical component summary; MCS = Mental component summary. The standard errors on the estimated coefficients are clustered to account for the fact that the data encompasses multiple observations from the same individuals. Significance levels: (*) $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 6. FE models of the impact of the frequency of MVPA on dimensions of the SF-36

	1 PF	2 RP	3 BP	4 GH	5 V	6 SF	7 RE	8 MH
Recommended level of physical activity	2.39***	3.54***	1.89***	3.37***	3.67***	3.08***	2.90***	2.01***
Age	-0.35***	-0.47***	-0.41***	-0.40***	-0.21***	-0.06**	-0.10**	0.03(*)
Education								
Lower than year 12 *(reference)*								
University qualification	2.01***	-0.32	0.81	0.08	0.51	0.39	2.94**	0.39
Professional qualification	2.17***	0.63	0.49	0.08	-0.05	0.43	0.97	0.07
Year 12	1.12**	-0.41	0.33	-1.19***	-0.75*	-0.32	0.84	-0.41
Income (in 10,000s)	0.06***	0.05*	0.04**	0.06***	0.04**	0.05***	0.07**	0.03**
Long-term condition or disability	-6.45***	-13.80***	-7.95***	-6.47***	-4.71***	-6.49***	-6.38***	-2.77***
Current smoker	0.37	1.06*	0.52(*)	-1.63***	-0.33	-0.20	-1.88***	-0.90***
Lives alone	0.26	0.68	0.99***	0.33	0.24	-1.89***	-3.55***	-1.44***
Total weekly work hours	0.05***	0.09***	0.03***	0.03***	-0.00	0.07***	0.10***	0.03***
Feeling rushed or stressed								
Often or always *(reference)*								
Sometimes	0.62***	1.60***	1.72***	2.17***	5.29***	3.11***	4.40***	3.79***
Rarely or never	0.94***	2.09***	3.14***	3.83***	7.84***	4.76***	6.92***	6.17***
Intercept	95.79***	97.13***	89.75***	84.28***	65.69***	81.19***	81.08***	69.26***
N (person-year observations)	125,798	125,611	126,618	126,075	127,320	127,612	125,489	127,295
N (individuals)	23,760	23,754	23,869	23,788	23,868	23,897	23,752	23,861
R^2 Within	0.04	0.04	0.04	0.07	0.06	0.03	0.02	0.04

Notes: HILDA Survey data (2001-2011). PF = Physical Functioning dimension; RP = Role-Physical dimension; BP = Bodily Pain dimension; GH = General Health Dimension; V = Vitality dimension; SF = Social Functioning dimension; RE = Role-Emotional dimension; MH = Mental Health dimension. The standard errors on the estimated coefficients are clustered to account for the fact that the data encompasses multiple observations from the same individuals. Significance levels: (*) $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 7. FE models of the impact of the frequency of MVPA on self-assessed general health, satisfaction with one's health and satisfaction with life overall

	1 **SAH**	**2** **SwH**	**3** **SwL**
Recommended level of physical activity	0.15***	0.25***	0.09***
Age	-0.02***	-0.04***	-0.01***
Education			
Lower than year 12 *(reference)*			
University qualification	0.01	-0.25***	-0.15***
Professional qualification	-0.02	-0.23***	-0.11**
Year 12	-0.08***	-0.35***	-0.19***
Income (in 10,000s)	0.00***	0.00*	0.01***
Long-term condition or disability	-0.28***	-0.79***	-0.18***
Current smoker	-0.05***	-0.10***	-0.06***
Lives alone	0.03**	0.01	-0.22***
Total weekly work hours	0.00***	0.00***	0.00(*)
Feeling rushed or stressed			
Often or always *(reference)*			
Sometimes	0.06***	0.13***	0.18***
Rarely or never	0.10***	0.19***	0.27***
Intercept	4.31***	9.18***	8.47***
N (person-year observations)	125,786	127,614	127,584
N (individuals)	23,812	23,895	23,891
R^2 Within	0.05	0.06	0.02

Notes: HILDA Survey data (2001-2011). SAH = Self-assessed health; SwH = Satisfaction with one's health; SwL = Satisfaction with life overall. The standard errors on the estimated coefficients are clustered to account for the fact that the data encompasses multiple observations from the same individuals. Significance levels: (*) $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 8. Coefficients on the full set of MVPA categories across all models

	Frequency of MVPA *(reference: Not at all)*				
	< Once	1-2 times	3 times	>3 times	Everyday
OLS models					
SF-6D	0.03***	0.05***	0.06***	0.07***	0.08***
PCS	3.48***	4.54***	5.05***	5.64***	5.77***
MCS	1.21***	2.75***	3.28***	4.29***	4.97***
Physical Functioning	10.46***	13.50***	14.97***	16.65***	16.68***
Role-Physical	8.27***	11.40***	12.66***	14.54***	15.48***
Bodily Pain	4.87***	7.06***	7.62***	8.81***	8.67***
General Health	4.74***	8.89***	10.99***	13.67***	16.13***
Vitality	4.67***	8.97***	11.08***	13.75***	15.60***
Social Functioning	6.85***	9.82***	10.53***	12.58***	12.85***
Role-Emotional	4.82***	8.00***	9.05***	10.92***	11.97***
Mental Health	2.62***	5.01***	5.87***	7.36***	8.19***
Self-assessed general health	0.17***	0.34***	0.44***	0.56***	0.65***
Sat. with one's health	0.37***	0.70***	0.82***	1.02***	1.24***
Sat. with life overall	0.09***	0.25***	0.30***	0.39***	0.51***
FE models					
SF-6D	0.02***	0.02***	0.03***	0.04***	0.05***
PCS	1.45***	2.11***	2.44***	2.80***	2.99***
MCS	0.71***	1.45***	1.97***	2.58***	3.18***
Physical Functioning	3.96***	5.69***	6.60***	7.45***	7.89***
Role-Physical	4.14***	6.37***	7.59***	9.05***	10.25***
Bodily Pain	2.49***	3.68***	4.33***	5.15***	5.49***
General Health	1.94***	3.88***	5.20***	6.63***	8.14***
Vitality	2.54***	4.71***	6.27***	7.81***	9.00***
Social Functioning	3.32***	5.02***	5.93***	7.35***	8.46***
Role-Emotional	2.27***	4.00***	4.95***	6.22***	7.53***
Mental Health	1.22***	2.40***	3.16***	4.02***	4.89***
Self-assessed general health	0.08***	0.15***	0.21***	0.28***	0.34***
Sat. with one's health	0.19***	0.33***	0.41***	0.52***	0.65***
Sat. with life overall	0.08***	0.13***	0.17***	0.21***	0.24***

Notes: HILDA Survey data (2001-2011). Controls: Gender, age, ethnicity, education, income, long-term conditions or disabilities, smoking behavior, living alone, total work hours, feeling rushed or stressed. The standard errors on the estimated coefficients are clustered to account for the fact that the data encompasses multiple observations from the same individuals. Significance levels: (*) $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 9. FE models of the impact of the frequency of MVPA on satisfaction with life overall, controlling for summary measures of physical and mental health

	1	**2**
HRQoL		
MCS	0.04***	0.04***
PCS	0.01***	0.01***
Recommended level of physical activity	0.02*	
Frequency of MVPA		
Not at all *(reference)*		
< Once		0.03(*)
1-2 times		0.04*
3 times		0.05**
>3 times		0.06**
Everyday		0.06**
N (person-year observations)	121,994	12,1994
N (individuals)	23,458	23,458
R^2 Within	0.09	0.09

Notes: HILDA Survey data (2001-2011). Controls: Gender, age, ethnicity, education, income, long-term conditions or disabilities, smoking behavior, living alone, total work hours, feeling rushed or stressed. The standard errors on the estimated coefficients are clustered to account for the fact that the data encompasses multiple observations from the same individuals. Significance levels: (*) $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Appendix

Table A1. Descriptive statistics on model variables

	Mean	SD
Frequency of moderate or intensive physical activity		
Not at all	0.10	
Less than once a week	0.16	
1 or 2 times a week	0.24	
3 times a week	0.16	
More than 3 times a week (but not every day)	0.21	
Everyday	0.13	
SF 6D	0.76	0.12
PCS	49.63	10.26
MCS	48.87	10.24
SF-36 dimensions		
Physical Functioning	84.06	22.50
Role-Physical	79.64	35.50
Bodily Pain	73.88	24.05
General Health	69.21	20.91
Vitality	60.47	19.59
Social Functioning	82.94	23.04
Role-Emotional	83.59	32.28
Mental Health	74.51	16.91
Self-assessed general health	3.42	0.96
Satisfaction with one's health	7.36	1.94
Satisfaction with life overall	7.93	1.46
Female	0.53	
Age	43.63	17.82
Indigenous background	0.02	
Education		
University qualification	0.22	
Professional qualification	0.30	
Year 12	0.15	
Lower than year 12	0.33	
Income (in 10,000s)	7.91	5.79
Long-term condition or disability	0.25	
Current smoker	0.21	
Lives alone	0.15	
Total weekly work hours	35.21	21.47
Feeling rushed or stressed		
Often or always	0.37	
Sometimes	0.42	
Rarely or never	0.20	
N (person-year observations)	122,061	
N (individuals)	23,466	

Notes: HILDA Survey data (2001-2011). Statistics using the sample for the OLS model where SF-6D is the dependent variable. These may vary slightly across models.