Physical activity and body mass shape quality of life trajectories in mid-age women

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Abstract

Objective: To determine the combined longitudinal effect of body mass index (BMI) and physical activity (PA) on health-related quality of life (HrQoL), using the SF-6D (SF-36) utility measure.

Methods: Five waves of self-reported data from the 1946–51 cohort (n=5,200; data collection, 2001–2013) of the Australian Longitudinal Study on Women's Health were used. Mixed effect models were employed to address the objective.

Results: Women with *high* PA experienced higher HrQoL regardless of BMI group, however, for those healthy or overweight, there was a very small decline in HrQoL over time. Women reporting *no* PA levels experienced the lowest baseline mean SF-6D score within each BMI group, with decreasing trajectories over the follow-up period. The rate of decline was greatest in women with obesity. Within each BMI group, there was a large, increasing gap in HrQoL between those who reported *no* and *low* PA over time. Women with obesity and *high* PA experienced similar HrQoL trajectories to women with normal weight or overweight with *low* PA levels. Overweight women with *moderate* PA experienced similar HrQoL to those with *low* PA but normal weight.

Conclusions: PA may mitigate the adverse effect of overweight and obesity on HrQoL at mid-life, at higher activity levels.

Implications for public health: PA benefits HrQoL regardless of body mass, with larger gains for those currently not physically active. Moderate to high PA may mitigate the effect of overweight and obesity.

Key words: SF-6D, health-related quality of life, physical activity, Body Mass Index, longitudinal, women

Overweight and obesity, and physical inactivity, are major contributors to poor quality of life, mortality and morbidity.[1] In Australia, high body mass (being overweight or obese) is the second-highest contributor to burden of disease (5.5%), while physical inactivity is the fourth-highest (5%), and both are modifiable risk factors.[1] One-third of adults globally are estimated to be overweight or obese,[2] while almost-two thirds of Australian adults are overweight or obese, with prevalence increasing by 10% since 1995.[3] The prevalence of obesity in Australian women is expected to rise from 27% in 2015 to 40% in 2035, with associated healthcare costs estimated to double over the next 20 years.[4] Given the increased health and economic consequences for the public health system that are expected, long-term health policies and strategies to prevent or manage the obesity epidemic and its health consequences at the population level are needed.

Physical activity (PA) confers health benefits across the lifespan including improved physical and mental health-related quality of life (HrQoL),[5] reduced risk of all-cause and cardiovascular disease (CVD), specific mortality, and risk of chronic conditions such as obesity and other CVD-related conditions, diabetes, cancer and depression.[6] In mid-age women, PA is also associated with reduced risk of fractures, falls and osteoporosis, particularly in post-menopausal women.[6] Recent studies have demonstrated that the beneficial effect of PA on CVD risk may outweigh the negative impact of overweight and obesity in mid-age and older women;[7,8] however, body mass had a greater influence on diabetes risk than PA.[9,10]

While overweight and obesity are negatively associated with HrQoL, PA has been found to be positively associated with HrQoL. Thus, it is important to determine whether PA can mitigate the negative effects of overweight and obesity on HrQoL. Existing cross-sectional research using single-item measures of HrQoL suggest that those who are physically inactive report poorer HrQoL than those physically active, regardless of body mass index (BMI) level.[11-13] Longitudinal evidence is sparse. A study on Canadian adults examined the joint association of BMI and leisure time physical activity (LTPA) on HrQoL.[14] They found that those physically inactive or sedentary had steeper declines in HrQoL with age, compared to those active in leisure time. However, to date, the change in HrQoL patterns over time, based on different combinations of BMI and total PA – particularly at the lower and upper end of the PA continuum – remains unknown.

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This research aims to address this gap by quantifying the combined effect of BMI and total PA over time with the SF-6D, a preference-based measure of HrQoL, using data from a large population-based cohort of mid-age Australian women.

Methods

Australian Longitudinal Study on Women's Health (ALSWH) survey

ALSWH is a national longitudinal study investigating the health and wellbeing of Australian women since 1996. The study randomly recruited 13,715 women aged 45–50 years at baseline ('mid-age' cohort, born 1946–51, response rate=53–56%) from the Australian Medicare database, which covers all Australian citizens and permanent residents. Women from rural and remote regions were oversampled to capture the heterogeneity of health and wellbeing of women living outside urban areas. Women were surveyed every three years (after 1998), using online or mailed questionnaires. Written informed consent was obtained prior to participation. Full details of study methodology, sample recruitment and retention are available elsewhere.[15] This research was approved by the University of Newcastle and The University of Queensland human ethics committees.

Survey items on PA at Survey 1 and Survey 2 were not comparable to subsequent surveys, thus these surveys were excluded from analysis. Five waves of data (Survey 3 to Survey 7) from the 1946–51 cohort were used, with a follow-up period of 12 years. Data were collected between 2001 and 2013 (Table 1) and were analysed in 2017. A total of 5,200 women who had SF-6D, BMI (BMI 18.5 or more kg/m^2) and PA information in all five surveys were included in the analysis (Table 1).

Measures

At each survey, BMI was calculated using self-reported health and weight using the formula: BMI= [(weight in kilograms)/(height in meters)^2]. Participants were categorised as either 'normal weight' (BMI 18.5–<25 kg/m^2); 'overweight' (BMI 25–<30); or 'obese' (BMI 30 or more).[16] Due to small numbers, those underweight at any survey (n=132) were excluded from the main analysis.

Physical activity (PA) was measured using validated self-reported version of the Active Australia survey.[17] It includes items on frequency and duration of walking (for recreation or transport) and moderate to vigorous intensity activity in the last week. Participants were categorised as *No* [0–<33.3 total metabolic equivalent (MET) minutes per week (min/wk)]; *Low* (33.3–<500 MET min/wk); *Moderate* (500–< 1000 MET min/wk); or *High* (≥1000 MET min/wk) PA, based on revised activity guidelines.[18,19]

Participants were then classified to one of twelve BMI–PA combinations based on their PA and BMI level: BMI 18.5–<25 & No PA; BMI 18.5–<25 & Low PA; BMI 18.5–<25 & Moderate PA; BMI 18.5–<25 & High PA; BMI 25–<30 & No PA; BMI 25–<30 & Low PA; BMI 25–<30 & Moderate PA; BMI 25–<30 & High PA; BMI 30+ & No PA; BMI 30+ & Low PA; BMI 30+ & Moderate PA; BMI 30+ & High PA).

SF-36v1 metrics and deriving SF-6D

The ALSWH collected women's HrQoL at all surveys using the generic SF-36v1 instrument.[20] To give a single overall measure of HrQoL, the SF-36v1 responses were converted to a utility score, using the Australian preference-based SF-6D algorithm.[21]

The SF-6D utility score is a preference-based measure that quantifies HrQoL based on the perceived importance of six different health dimensions (physical functioning, mental health, role limitation, social functioning, bodily pain, vitality) to overall health, in a single preference-based scale.[22,23] An SF-6D utility score of 0 represents a health state equivalent to being dead and 1 represents full health.[21,22] Higher scores represent better overall health. Eleven items from six dimensions of the SF-36v1 are used to calculate SF-6D scores using a scoring algorithm based on the preferences of the general public.[20-22] Participants are assigned to a health state level for each dimension. A health state Level 1 for each dimension represents having no limitations/problems in that particular dimension. A utility score is then assigned to each participant's health state based on a set of preference weights. The original weights were developed based on the preferences of the general public in the UK.[22] However, weights based on preferences of the Australian public have subsequently been developed and are used in this study.[21,22] Using the Australian preference weights, the SF-6D scores range from -0.363 to 1, where negative health utility scores represent health states deemed worse than being dead.[21]

Mean differences in SF-6D scores were categorised based on the minimally important difference (MID) as: 'small', less than 0.03; 'modest', 0.03 to <0.05; 'moderate', 0.05 to <0.10; and 'large', 0.10 and above.[25] A MID has not been published for the SF-6D based on the Australian preference weights. Therefore, the MID of at least 0.03 based on the UK weights was adopted for this study.[24]

Reponses to the SF-1 (SF-36v1) global health item "In general, would you say your health is . . ." with response options 'excellent', 'very good', 'good', 'fair' or 'poor' used to provide meaningful interpretation of SF-6D scores based on women's perception of their own health. Summary statistics for SF-6D scores by SF-1 categories were quantified (Supplementary Table S1). SF-6D scores of 0.55 and above and less than 0.55 were used to capture 'good' and 'fair/poor' perceived health respectively, based on the mean of SF-6D scores across surveys.

Demographic and other lifestyle factors

Demographic factors included area of residence (major cities; regional; remote), education status (no formal qualification; Year 10/Year 12; trade/diploma; university degree or higher), marital status (in a relationship; separated/divorced; widowed; never married), employment status (employed, paid; employed, not paid; unemployed), and ability to manage on income (impossible/difficult always; difficult sometimes; not too bad; easy).

Lifestyle factors included alcohol use (non-drinker; rarely drinks; low risk drinker; risky drinker; high risk drinker),[26] smoking status (never smoked; ex-smoker; smokes <10 cigarettes per day; 10–19 cigarettes per day; ≥20 cigarettes per day),[27] menopause status (surgical menopause; hormone use; pre-menopausal; peri-menopausal; post-menopausal) and mean stress (a continuous measure, ranged from 0, representing 'Not stressed' to 4, representing 'Extremely stressed').[28]

Statistical analysis

Data were analysed using SAS 9.4. Descriptive statistic for the SF-6D score (mean, SD) at each survey were tabulated. Ceiling and floor effects for the SF-6D score were quantified using the proportion of participants at each survey who reported "full health" (SF-6D score of 1) and "pits" (SF-6D = -0.363) respectively.

The proportion of participants reporting no problems in each SF-6D dimension were calculated**.**

Linear mixed-effects model with random intercept and unstructured variance-covariance matrix were used in all regression analyses. These models also handle item non-response using maximum likelihood methods (assuming missing at random) by implicitly imputing a value for missing responses based on the values of other responses and modelled correlation structure.[29,30] In all models, age at baseline was mean centred for meaningful interpretation of the model intercept. The time variable, 'time from baseline', measured in three-yearly intervals, was fitted as a linear variable in all regression analyses.

The joint association between BMI and PA on the SF-6D scores was investigated (Model 1), then an interaction effect between BMI-PA combinations and time since baseline on the SF-6D score was tested (Model 2). SF-6D score Least Square (LS) means were calculated from Model 1 and Model 2 and plotted in Figures 1 and 2, respectively. For Model 2, SF-6D trajectories (stable, estimated slope = 0.001; increasing, estimated slope >0.001; or decreasing, estimated slope <-0.001) for each BMI–PA combination were quantified. T-tests were used to test for differences in SF-6D LS means between BMI-PA combination, at each time point. Multiple comparison adjustments using simulation methods (SIMULATE algorithm in SAS) were used to control the family-wise error rate in the *p*-value estimations.[31] Post-hoc analyses were conducted using likelihood ratio tests (LRT) to determine the presence of an interaction effect between BMI and PA on the SF-6D (Model 3).

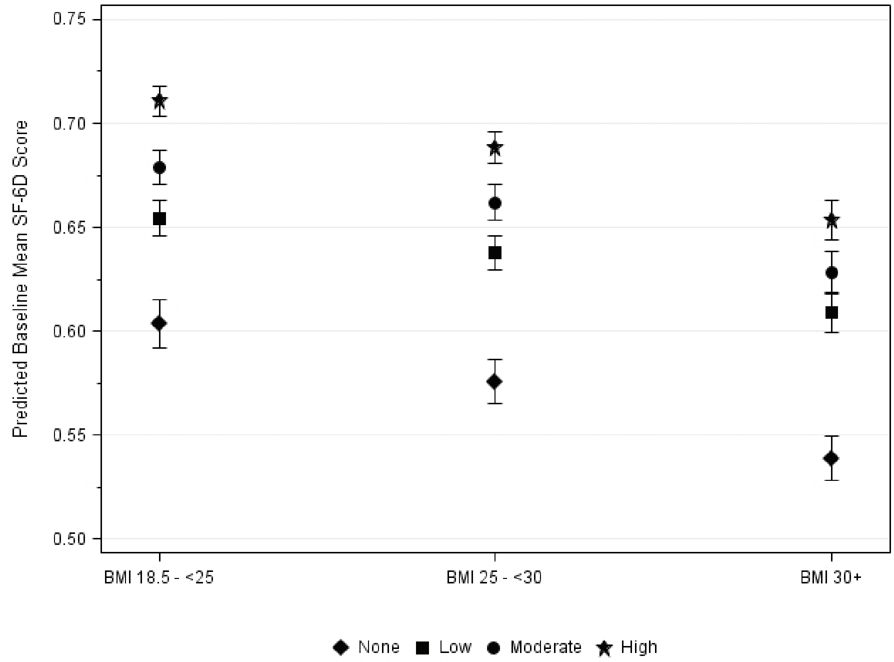
All basic models presented were adjusted for age at baseline (Survey 3, year 2001) and 'time from baseline'. The fully adjusted models also included variables measured at baseline (area of residence and education status), and the time dependent variables (marital status, employment status, ability to manage on income, alcohol use, smoking status, menopause status and mean stress). Potential confounders were selected based on identified existing relationships with SF-6D in the literature.[32]

Sensitivity analysis

The main analysis was limited to those with complete SF-6D, BMI (BMI 18.5+) and PA information in all five surveys. To assess for any bias in results from the main analysis due to its sample selection criteria, Models 1 to 3 were repeated using data from all women who responded to surveys 3 to 7.

A second sensitivity analysis was conducted by repeating Models 1 to 3 on data including those underweight at any time point to assess any possible bias of excluding underweights from the main analysis. Due to small sample

Figure 1: Baseline predicted mean SF-6D scores and 95% CI by BMI-PA combinations in mid-age women.

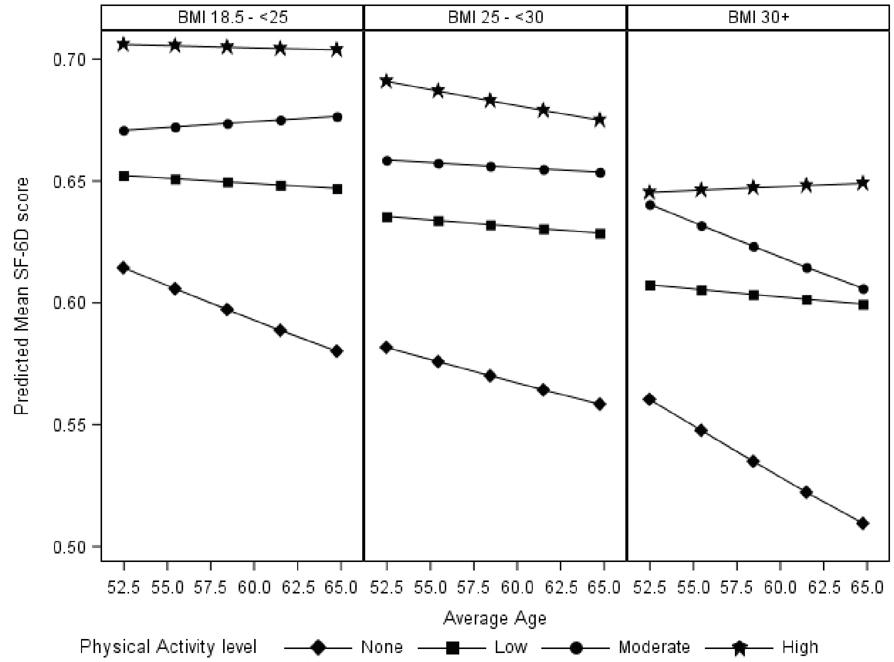


Note:

BMI, Body Mass Index; PA, Physical Activity

Baseline age was mean centred at 52.5 years. Model 1 was adjusted for fixed effects age at baseline, area of residence at baseline and education at baseline, and time dependant factors, 'time from baseline', marital status, employment status, ability to manage on income, alcohol use, smoking status, menopause status and mean stress.

Figure 2: SF-6D trajectories by BMI-PA combinations, in mid-age women.



Note:

BMI, Body Mass Index; PA, Physical Activity

Baseline age was mean centred at 52.5 years. Model 2 was adjusted for fixed effects age at baseline, area of residence at baseline and education at baseline, and time dependant factors, 'time from baseline', marital status, employment status, ability to manage on income, alcohol use, smoking status, menopause status and mean stress.

sizes, those underweight were grouped with those in normal weight range.

Results

Mean SF-6D scores were consistent at 0.65, over a 12-year period, and scores range from -0.273 to 1.00 (Table 1). There were no substantial ceiling or floor effects in SF-6D scoring. The majority of mid-age women experienced no problems with social functioning and role limitations. Women experienced increasing problems with physical functioning as they aged but, for mental health, problems reduced with age.

Obesity prevalence increased by 6.3% over a 12-year period, a 28% increase in obesity prevalence from baseline. The percentage of women reporting *no* PA increased by 1.6% while those reporting *high* PA increased by 13% over the same period, a 10% and 45% increase in *no* and *high* PA respectively from baseline. At baseline, women with obesity and *no* PA were more likely to live in remote areas, have no formal education qualifications, be unemployed, find it difficult to manage on income, rarely drink and experience higher stress on average (Supplementary Table S2).

Table 1: BMI, Physical activity and SF-6D descriptive statistics at each survey (N= 5200).

Cohort	1946-51 cohort				
Survey	3	4	5	6	7
Cohort age range, years	50 - 55	53-58	56-61	59-64	62-67
Year surveyed	2001	2004	2007	2010	2013
Years from baseline	0	3	6	9	12
Mean Age	52.5	55.4	58.4	61.5	64.7
SF-6D Score					
Mean	0.648	0.648	0.655	0.643	0.637
SD	0.227	0.227	0.227	0.228	0.228
Median	0.692	0.693	0.702	0.692	0.692
Minimum	-0.209	-0.273	-0.223	-0.273	-0.273
Maximum	1.000	1.000	1.000	1.000	1.000
Ceiling effect, %	0.7	0.7	0.8	0.7	0.9
Floor effect, %	0.0	0.0	0.0	0.0	0.0
Percentage with no problems in each SF-6D dimension					
Physical Functioning, %	20.0	16.5	16.6	13.8	12.2
Mental Health, %	23.4	25.6	27.8	29.0	31.1
Role limitation, %	66.3	65.0	67.2	66.0	65.1
Social functioning, %	61.6	62.2	64.4	64.1	62.8
Pain, %	19.3	17.7	17.8	14.9	13.6
Vitality, %	2.6	3.0	3.3	3.0	3.7
Body Mass Index, n (%)					
Normal Weight, 18.5−<25	2,278 (43.8)	2,072 (39.8)	2,012 (38.7)	1,898 (36.5)	1,854 (35.7)
Overweight, 25−<30	1,744 (33.5)	1,850 (35.6)	1,863 (35.8)	1,849 (35.6)	1,837 (35.3)
Obese, 30+	1,178 (22.7)	1,278 (24.6)	1,325 (25.5)	1,453 (27.9)	1,509 (29)
Physical Activity, n (%)					
None	756 (14.5)	750 (14.4)	693 (13.3)	803 (15.4)	835 (16.1)
Low	1,720 (33.1)	1,294 (24.9)	1,149 (22.1)	1,163 (22.4)	1,050 (20.2)
Moderate	1,201 (23.1)	1,268 (24.4)	1,234 (23.7)	1,157 (22.3)	1,114 (21.4)
High	1,523 (29.3)	1,888 (36.3)	2,124 (40.8)	2,077 (39.9)	2,201 (42.3)
BMI-PA combination, n (%)					
BMI 18.5 -<25 & None PA	242 (4.7)	199 (3.8)	170 (3.3)	186 (3.6)	196 (3.8)
BMI 18.5 -<25 & Low PA	703 (13.5)	467 (9)	390 (7.5)	350 (6.7)	304 (5.8)
BMI 18.5 -<25 & Moderate PA	549 (10.6)	527 (10.1)	482 (9.3)	447 (8.6)	407 (7.8)
BMI 18.5 -<25 & High PA	784 (15.1)	879 (16.9)	970 (18.7)	915 (17.6)	947 (18.2)
BMI 25-<30 & None PA	244 (4.7)	263 (5.1)	255 (4.9)	266 (5.1)	282 (5.4)
BMI 25-<30 & Low PA	582 (11.2)	462 (8.9)	431 (8.3)	438 (8.4)	363 (7)
BMI 25-<30 & Moderate PA	424 (8.2)	465 (8.9)	447 (8.6)	404 (7.8)	418 (8)
BMI 25-<30 & High PA	494 (9.5)	660 (12.7)	730 (14)	741 (14.3)	774 (14.9)
BMI 30+ & None PA	270 (5.2)	288 (5.5)	268 (5.2)	351 (6.8)	357 (6.9)
BMI 30+ & Low PA	435 (8.4)	365 (7)	328 (6.3)	375 (7.2)	383 (7.4)
BMI 30+ & Moderate PA	228 (4.4)	276 (5.3)	305 (5.9)	306 (5.9)	289 (5.6)
BMI 30+ & High PA	245 (4.7)	349 (6.7)	424 (8.2)	421 (8.1)	480 (9.2)

Note:

BMI, Body Mass Index; PA, Physical Activity

BMI-PA combinations and the SF-6D

Women reporting *no* PA levels experienced the lowest baseline mean SF-6D score within each BMI group, with mean SF-6D score within each BMI group increasing in a dose–response manner with increasing PA level (Figure 1, Supplementary Table S3). Within each BMI group, the largest mean difference in SF-6D scores between consecutive PA levels were between *no* and *low* PA levels, considered 'moderate' size difference based on the MID (*No* vs *Low* PA Mean difference: BMI 18.5–<25 -0.05; BMI 25–<30 -0.06; BMI 30+ -0.07). Post-hoc analysis suggests an interaction effect between BMI and PA on SF-6D scores suggesting PA modifies the association between BMI and HrQoL (Model 3, LRT χ^2 =41.9, df=6, P<0.001).

SF-6D trends by BMI-PA combinations

Mean SF-6D baseline scores were highest for those with normal weight and *high* PA, and their trajectory remained stable over the follow up period (Figure 2, Supplementary Table S4). Within each BMI group, the largest mean difference in SF-6D scores between consecutive PA levels were between *no* and *low* PA levels, considered 'small' size difference based on the MID (*No* vs *Low* PA Mean difference: BMI 18.5–<25 -0.04; BMI 25–<30 -0.05; BMI 30+ -0.05). Baseline SF-6D scores for most combinations were statistically different to those with BMI 18.5–<25 *Moderate* PA, with 'moderate to large' size difference observed based on MID when compared with *No* PA for each BMI group, and BMI 30+ *Low* PA.

Mean SF-6D patterns varied by BMI-PA combinations (Figure 2, Supplementary Table S4). Some combinations were stable (BMI 18.5–<25 & *Low*, *Moderate* and *High* PA; BMI 25–<30 & *Moderate* PA; BMI 30+ & *High* PA); others, decreasing (BMI 18.5–<25 & *No* PA; BMI 25–<30 & *No*, *Low,* and *High* PA; BMI 30+ & *No*, *Low,* and *Moderate* PA); however, only slopes for three decreasing trajectories were significantly different from zero (BMI 18.5–<25 & *No* PA; BMI 30+ & *No* and *Moderate* PA). Across BMI groups, those with *no* PA experienced a steep decline in mean SF-6D scores over time, with women with obesity experiencing the greatest average decline in SF-6D score of -0.013 units every three years compared to the two other BMI groups (BMI 18.5–<25 -0.009, BMI 25–<30 -0.006). The declines in SF-6D scores were significantly larger in magnitude for BMI 18.5–<25 & *No* PA, and BMI 30+ & *No* and *Moderate* PA, when compared to those with BMI 18.5–<25 & *Moderate* PA.

Taking baseline and slope changes together, within each BMI group, the largest mean difference in SF-6D scores between consecutive PA levels were between *no* and *low* PA levels, which widened over time, with the greatest difference in gap at end of follow-up observed for those with obesity (Figure 2). Over the follow-up period, women with overweight and *high* PA reported small increases in mean SF-6D scores over time (statistically significant and met the MID threshold of 0.03) compared to those with normal weight but with *low* PA (Supplementary Table S5). Women with obesity and *high* PA experienced similar SF-6D scores to those with normal weight or overweight with *low* PA. However, these women experienced modest to moderate increases in mean SF-6D scores over time when compared with those with normal weight or overweight with *no* PA. From age 53–58 years onwards, overweight women with *low* PA had small to modest increases in average SF-6D scores over time compared to women with normal weight and *no* PA of similar age.

Results from the sensitivity analysis using data from all women (N=10,591 at baseline) or including underweight women (N=5,332) were similar to those from the main analysis (data not shown).

Discussion

To the best of our knowledge, this is the first study to have identified different types of longitudinal trajectories of HrQoL (measured using the SF-6D utility score) based on BMI-PA combinations in a large longitudinal cohort of mid-age women. We found that those who were at minimum *low* PA had better overall health (measured using the SF-6D utility score) compared to those in the *no PA* regardless of BMI, over a 12-year period. Within each BMI group, those with *no* PA experienced a steep decline in HrQoL over time, where the rate of decline was greatest in women with obesity. Women with *high* PA experienced higher HrQoL regardless of BMI group, however for those healthy or overweight, there was a very small (but not statistically significant) decline in HrQoL over time. Within each BMI group, there was a large and increasing gap in SF-6D scores between *no* and *low* PA levels over the follow-up period.

Women at mid-life face many age-related health changes, in some cases accelerated by the experience of menopause.[33] PA has been shown to moderate these changes, and may be beneficial to functional and cognitive health in later years.[33] Previous studies have examined the association between BMI and PA separately, and with HrQol, including using preference weighted HrQoL measures. Current evidence suggests that BMI[32,34,35] and PA[32,36] are each important lifestyle factors associated with HrQoL. We found those physically active or with normal weight reported higher overall health, supported by current evidence.[14,32]

There have been recent debates on the effectiveness of PA in weight loss.[37-39] In mid-life, weight gain may be due to existing health changes resulting from menopause transition.[40] While the evidence on the role of PA and weight loss remains unclear, our results with regards to HrQoL suggest that PA is beneficial to overall health, regardless of body weight. We found PA level, when assessed in combination with BMI level, had a larger effect on the SF-6D score; this is consistent with longitudinal findings using the Health Utilities Index Mark 3 (HUI3)[14] and from cross-sectional HrQoL research.[11-13]

Cohort increased prevalence in obesity and PA over time: comparison to the Australian population

We found a 28% increase in obesity prevalence from baseline and 10% and 45% increase in *no* and *high* PA, respectively, from baseline. The large increase seen for high PA in this cohort may reflect women's transition from employment at baseline, to retirement at the end of follow-up, resulting in more time available to be physically active at retirement.[5] The increase seen for obesity in this cohort may be due to changes in health as a result of increased sedentary lifestyle at retirement, menopause or from ill health, limiting physical activity participation.[5]

When compared to women aged 55–64 years from the 2007 and 2014 Australian Health Survey (AHS), a national survey on the health of the Australian general population,[41,42] our cohort reported lower prevalence of obesity in 2007 (AHS vs ALSWH, %: 33.2 vs 25.5) and 2014 (AHS vs ALSWH, %: 34.9 vs 29), but greater increase in obesity prevalence over the period (increase in obesity prevalence from 2007: AHS 5% increase; ALSWH 14% increase). For physical activity, compared to the AHS, our cohort reported lower prevalence of *no* PA and higher prevalence of *high* PA in 2007 (AHS vs ALSWH, %: *No* PA, 37.8 vs 13.3; *High* PA, 2.9 vs 40.8) and 2014 (AHS vs ALSWH, %: *No* PA, 36.7 vs 16.1; *High* PA, 5.7 vs 42.3). The AHS found a 3% decrease in *no* PA in 2014 from 2007, and almost a double increase in *high* PA, while for ALSWH, there was a 21% increase in *no* PA and 3.6% increase for *high* PA. The differences in prevalence seen in ALSWH compared to the AHS may reflect the different and narrowed age group for ALSWH women (AHS 2007 and 2014, 55–64 years; ALSWH 2007, age 56–61; ALSWH 2013, age 62–67). The lower obesity prevalence and higher PA participation in ALSWH may be due to the higher education attainment, socioeconomic advantage and a healthier ALSWH cohort compared to the general population of similar age, but may also reflect differences in PA measurement between AHS and ALSWH.

Different patterns of HrQoL change – age effect or something more?

Our new finding of different patterns of SF-6D scores (stable or decreasing) over mid-life period based on BMI-PA combinations highlights the importance of PA in shaping HrQoL trajectories. Previous research has shown that average HrQoL patterns measured using the SF-6D are generally consistent in young and mid-age women as they age, but steadily decline in older women,[32] which may be due to an age effect in physical functioning.[43] Our finding that women with high PA still experience very small decline in HrQoL over time may be due to underlying changes in physical functioning and ageing.

The baseline average HrQoL of those with *no* PA, regardless of BMI level, were within the average SF-6D threshold for 'good' perceived health level (based on the SF-1). However, the average HrQoL for overweight or obese women with *no* PA was equivalent to the HrQoL score of the average ALSWH woman aged 72.5 years, suggesting a mean HrQoL score of a woman who was 20 years older.[32] For those with normal weight but *no* PA, baseline scores were lower compared to the average ALSWH mid-age woman aged 65 years.[32]

There was a marked decline in HrQoL scores over time for those with *no* PA, most prominently in women with obesity. While small in magnitude, at the end of the follow-up period (average age 65 years), the decline seen in women with obesity and no PA resulted in mean HrQoL in the 'fair or poor' health range, with a HrQoL score equivalent to an ALSWH woman age 81 years.[32] For those overweight with *no* PA, at the end of follow-up, the mean HrQoL was close to average for the 'fair or poor' health range, with a HrQoL score comparable to an ALSWH woman age between 75–78 years.[32] Those with normal weight but *no* PA remained in 'good' perceived health ranges at the end of follow-up, however, had an average HrQoL score comparable to an ALSWH woman aged 72.5 years.[32]

While we observed poorer HrQoL for those with higher BMI and lower PA, we cannot rule out reverse causation. The poorer HrQoL observed for *no* PA at later mid-life may result from ill health, which may limit PA, and is likely amplified for those with obesity due to its strong association with multimorbidity.[44] Nevertheless, the finding that the increasing gap in SF-6D scores over time between those with *no* vs *low* PA across BMI groups suggests that while being physically active has benefits early in mid-life, it may have greater health benefits later in life (Figure 2).

Can PA mitigate the effect of overweight and obesity?

All things being equal, the finding that women with obesity and *high* PA had similar HrQoL to those with normal weight or overweight with *low* PA levels suggests high PA may be needed to mitigate the effect of obesity on HrQoL. For those overweight, at minimum, moderate levels of PA are needed to obtain similar HrQoL to those with *low* PA but normal weight. These findings may assist in goal setting for targeted, graduated PA interventions to maximise the quality of life in otherwise healthy mid-age women.

Implications

These findings have several important implications. Given the benefits of PA across BMI levels, public health campaigns should emphasise the benefit of PA to overall health, regardless of body weight, to promote healthy ageing.[5,6] Based on women's health circumstances, improving PA levels in those currently not active at all, to at minimum low level, regardless of body weight may result in large gains in HrQoL in the long term, supporting recommendations from current Australian guidelines.[19]

Understanding factors associated with PA at mid-life including life events such as retirement and spousal death[5] are important for tailoring public health campaigns to mid-age women. From a health policy perspective, our use of a preference-based measure of quality of life means that our findings could be used as a reference case in economic evaluations of health interventions. These findings can help guide the choice of interventions to recommend based on individuals' BMI and PA levels as well as be able to evaluate the net economic benefit of these interventions.

Strengths and limitations

This research used longitudinal data from a large cohort of Australian women in mid-life, followed over 12 years. These women were generally representative of the Australian population (compared to the 2011 Australian Census), but at Survey 6 were more likely to be highly educated and less likely to be immigrants.[15] Retention rates for the 1946–51 cohort was 83% at Survey 6, and non-response mainly due to being unable to contact participants. In our study, a higher proportion of women were sufficiently active (at least 500 MET mins/week), compared to the general population of a similar age.[45]

We have used self-reported height and weight to calculate BMI. Previous ALSWH research has demonstrated acceptable agreement (Kappa=0.81) between BMI categories derived from self-report and measured data.[46] While PA measures were self-reported, they were validated to be suitable to be used in a self-report setting.[17]

The Australian SF-6D scoring algorithm[21] was used to derive utilities from women's responses to the SF-36v1, which is a standard, validated measure of quality of life.[20] The Australian valuation method of SF-6D used has low ceiling or floor effects compared to other valuation methods.[21] However, due to the methodology of the Australian valuation of the SF-6D, preference weights derived may not fully reflect the opinions of these those aged ≥60 years.[21] Despite this, previous research on SF-6D trends using ALSWH data[32] were consistent with SF-6D longitudinal findings elsewhere[47] for those aged 60 and older, suggesting this is unlikely to be a limitation. As the MID in the Australian context has not been established, we have used MID threshold of 0.03, derived from studies that use UK SF-6D algorithms. The differences in the valuation of Australian and 2002 UK SF-6D algorithms result in differences observed in the SF-6D utility score range, floor and ceiling effects between the two algorithms, limiting comparability.[21] To address these limitations, we have compared our findings to SF-6D cohort averages described in previous ALSWH research using the Australian SF-6D algorithm.[32] We have also quantified the average SF-6D score based on SF-1 levels, to assist in interpreting the results based on perception of health. Further work is required to determine the MID threshold for Australian general population and patient samples, using the Australian algorithm. Australian population norms for the SF-6D, updated using Australian preference weights are needed to facilitate direct comparisons with other Australian studies.

Conclusion

We have provided new longitudinal evidence for the varied trajectories of HrQoL based on the combined effects of BMI and PA. To mitigate the effect of overweight and obesity at mid-life, moderate to high activity levels may be needed. PA is associated with benefits in overall health regardless of body weight with potentially significant gains in HrQoL for women currently not physically active at all.

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Supporting Information

Additional supporting information may be found in the online version of this article:

Supplementary Table 1: SF-6D summary statistic by SF- 1 level in mid-age women.

Supplementary Table 2: SBaseline demographic and lifestyle characteristics by BMI and Physical activity combinations.

Supplementary Table 3: The baseline SF-6D predicted mean, and mean difference between SF-6D and BMI-PA combinations in mid-age women (Model 1).

Supplementary Table 4: The baseline SF-6D predicted mean (intercept), and Slope of each BMI-PA combinations in mid-age women (Model 2).

Supplementary Table 5: Model predicted mean difference between BMI-PA combinations across all time points, using T-test.