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Physical activity and quality of life in older women with a history of depressive symptoms

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ABSTRACT

Physical activity (PA) is positively associated with health-related quality of life (HRQL) in older adults. It is not evident whether this association applies to older adults with poor mental health. This study examined associations between PA and HRQL in older women with a history of depressive symptoms. Participants were 555 Australian women born in 1921-1926 who reported depressive symptoms in 1999 on a postal survey for the Australian Longitudinal Study on Women's Health. They completed additional surveys in 2002, 2005 and 2008 that assessed HRQL and weekly minutes walking, in moderate PA, and in vigorous PA. Random effects mixed models were used to examine concurrent and prospective associations between PA and each of 10 HRQL measures (eight SF-36 subscales; two composite scales). In concurrent models, higher levels of PA were associated with better HRQL ($p<0.001$). The strongest associations were found for the bodily pain, physical functioning, general health perceptions, social functioning and vitality measures. Associations were attenuated in prospective models, more so for mental HRQL-related scales than for physical HRQL-related scales. However, strong associations (>3 point differences) were evident for physical functioning, general health, vitality and social functioning. For women in their 70s-80s with a history of depressive symptoms, PA is positively associated with HRQL concurrently, and to a lesser extent prospectively. This study extends previous work by showing significant associations in older women with a history of depressive symptoms. Incorporating PA into depression management of older women may improve their HRQL.

Keywords Exercise, Depression, Quality of life, Women, Longitudinal studies, Cohort studies

1. Introduction

With global increases in life expectancy, the ageing population is expanding. The number of people aged 65+ years is projected to rise from 524 million in 2010 to almost 1.5 billion in 2025, representing 16% of the world's population (World Health Organization, 2015). A key priority for public health action is, therefore, to foster healthy ageing to maximize functional ability. Health-related quality of life (HRQL) is a key indicator of healthy ageing (Bize et al., 2007). This multidimensional construct reflects not only subjective perceptions of physical and psychological health, but also role and social functioning and general life status. This broad perspective is particularly important for older adults given the range of their age-related experiences, processes, and health conditions that can negatively affect HRQL. To inform policy makers and service providers, more research is required to identify ways to support healthy ageing and optimize HRQL in older adults.

Physical activity (PA) is an important determinant of HRQL in older adults. A systematic review of 42 articles (27 cross-sectional, four prospective cohort, and 11 intervention studies) concluded that there is a positive, consistent association between PA and general HRQL, functional capacity, mental health, vitality and psychological HRQL (Vagetti et al., 2014). A cross-sectional study using pedometers as an objective measure of PA found that participants (mean age=66 years) doing >7,000 steps/day had higher scores for mental, physical, and global health domains of HRQL than those doing less ($p \leq 0.001$) (Vallance et al., 2015). Those reporting >150 mins/week of moderate-vigorous PA also had better HRQL than those doing less, with the highest HRQL among people reporting 300+ mins/week. A 6-year longitudinal study reported significant and clinically meaningful associations between PA and physical functioning, physical role functioning, bodily pain, vitality, social functioning, emotional role functioning and mental health HRQL in community-dwelling older adults (Balboa-Castillo et al., 2011). Positive associations between PA and HRQL in older adults have been predominantly demonstrated for functional capacity, with strong support for mental health, vitality and psychological domains and moderate evidence for social relationships, pain and environmental domains (Vagetti et al., 2014). Some research has suggested stronger associations between PA and physical HRQL than psychological HRQL (Salguero et al., 2011; Stewart et al., 2003).

Most studies of PA and HRQL in older adults are with healthy people; those that are not tend to focus on physical conditions. Few studies have considered older adults with mental health concerns. Of the studies identified in the systematic review (Vagetti et al.,

2014), only one (Salguero et al., 2011) recruited people with a mental health condition (depression). Depression is projected to be the second-leading cause of burden of disease worldwide by 2030 and the leading cause in high-income countries (Mathers and Loncar, 2006). In the general population, depression can precipitate greater declines in HRQL than chronic medical conditions (Bonicatto et al., 2001; Hays et al., 1995). In older adults, depression is associated with deteriorations across all domains of HRQL, even in the absence of comorbid medical illness (Gallegos-Carrilloa et al., 2009).

Most evidence on PA and HRQL in older adults with depression comes from exercise training studies, and results are mixed (Tavares et al., 2014). One study showed no significant differences between PA and social visits for impact on physical or psychological HRQL (Kerse et al., 2010). Another demonstrated that resistance training improved physical function, role physical, vitality, social function, role emotional, and mental health (Singh et al., 2005). A third study demonstrated significantly greater improvements in bodily pain, vitality, social functioning and role emotional HRQL from PA (progressive resistance training) than from group health education (Singh et al., 1997). Little work has been done with observational studies using population-based cohorts.

This study's aim was to examine concurrent and 9-year prospective associations between PA and HRQL in ambulatory community-dwelling healthy women who reported depressive symptoms in 1999, when they were aged 73-78 years.

2. Methods

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

ALSWH is a prospective study of health and well-being of Australian women born in 1973-1978, 1946-1951 and 1921-1926. They were first surveyed in 1996 and have been surveyed on a rolling-basis every 3 years. Sampling and recruitment details have been reported elsewhere (Brown et al., 1998). The study was approved by the Ethics Committees of the University of Queensland and the University of Newcastle. Informed consent was received from all respondents. Further study details are available on the ALSHW website at http://www.alswh.org.au/.

2.1.1 Sample

The analysis sample included the women born in 1921-1926 who completed surveys in 1999, 2002, 2005 and 2008. The baseline 1996 survey was not included because the

presence of depressive symptoms was not measured then. At baseline 12,432 women born in 1921-1926 completed the ALSWH survey (Brown et al., 1998). They were broadly representative of the general population of Australian women aged 70-75 years, although married and university-educated women were over-represented (Brown et al., 1998).

In 1999, the baseline for this analysis, 10,030 women born in 1921-1926 completed the survey (Young et al., 2006). Of these women, 819 reported depressive symptoms (CESD10 score ≥10) (Andresen et al., 1994), and, therefore, were eligible for inclusion in the current analysis. Data from 176 were excluded because they did not complete any surveys after 1999. Data from another 81 were excluded because they reported on more than one survey that they were unable to walk 100 m, which suggested a long-term limited ability to engage with ambulatory PA. Excluding them decreased the possibility of reverse causation (e.g., that low HRQL resulted in women being unable to be physically active). After excluding data from another seven with missing HRQL data on all four surveys, data from 555 women were available for analysis. There were no significant differences in demographic characteristics ($p>0.05$) between included and excluded women (n=264). However, excluded women reported being treated or diagnosed with fewer chronic conditions, were more likely to report being diagnosed or receiving treatment for anxiety or other psychiatric conditions, were more likely to report being non-drinkers and less likely to be low-risk drinkers, and more likely to be overweight or obese ($p<0.05$; see Supplementary Table 1).

2.3 Measures

2.3.1 Health-related quality of life

The well-validated Medical Outcomes Study's Health Status Survey short form (SF-36) (Ware Jr, Kosinski, et al., 1998; Ware Jr. and Gandek, 1998) served as the measure of HRQL. Four subscales (21 items) measure mental HRQL: vitality, social functioning, mental health, and role limitations from emotional problems. The items in these subscales are summarized to create a general mental HRQL measure, called the Mental HRQL Component Summary scale (MCS). Four additional subscales (14 items) measure physical HRQL: bodily pain, physical functioning, general health perception, and role limitations from physical problems. The items in these subscales are summarized to create a physical HRQL measure, called the Physical Component Summary scale (PCS). The factor structures of the MCS and PCS were validated using the 1996 baseline ALSWH survey (Mishra and Schofield, 1998). HRQL scores were standardized to range from 0-100, with the population average set at 50

(Mishra and Schofield, 1998). MCS, PCS and each subscale were treated as separate outcome variables. Higher scores indicated better HRQL.

2.3.2 Physical activity

PA was measured with the validated Active Australia survey (Brown et al., 2004; Brown et al., 2008; Heesch et al., 2011). The survey measures minutes in the previous week (in ≥10-minute bouts) spent walking briskly ('for recreation or exercise or to get from place to place'), in moderate-intensity PA ('like golf, social tennis, moderate exercise classes, recreational swimming, line dancing'), and in vigorous-intensity PA ('that makes you breathe harder or puff and pant, like aerobics, competitive sport, vigorous cycling, running, swimming'). As done previously (Heesch et al., 2007; Heesch et al., 2012), to compute a PA MET.min/week score, minutes in each PA type were first multiplied by an assigned metabolic equivalent (MET): walking by 3.0 METs; moderate-intensity PA by 4.0 METs and vigorous-intensity PA by 7.5 METs (Brown and Bauman, 2000). The MET.mins per PA type were then summed. Because the distribution of scores was highly skewed, women were categorized based on total MET.min/week into: no PA (<40), insufficient (40-<600), and sufficient (600+). Participants in the sufficient category were considered to be meeting international PA guidelines (World Health Organization, 2016) because the lower cut-off for this category is equivalent to 150 minutes/week of moderate-intensity PA (150 minutes x 4 METS = 600 MET.min).

2.3.3 Confounders

Socio-demographic and health-related variables indicated by previous work to be confounders (Heesch et al., 2015) were examined as potential confounders. These included demographic variables: country of birth (proxy for ethnicity), area of residence (derived from postal codes), educational attainment, and ability to manage on one's income (proxy for income status). Social variables were marital status, the number of stressful life events in the past year (e.g., death of partner), caregiving duties to children or adults, and social support (measured with the Medical Outcomes Study Social Support Index [Sherbourne and Stewart, 1991]). Health-related variables were body mass index (BMI; kg/m^2 computed from self-reported height and weight), number of doctor-diagnosed chronic conditions in the previous 3 years (from a list that included diabetes, cancer, and heart disease), and medical diagnoses or treatment for anxiety or other psychiatric condition in the previous 3 years. Health behaviors were smoking status and alcohol consumption. All potential confounders were categorized to

be consistent with previous examinations of the association between PA and health outcomes (e.g., Heesch, et al., 2015). Table 1 and Supplementary Table 1 provide further details.

2.4 Data analysis

Associations between PA and HRQL scores were examined in Stata 13.0 (StataCorp, College Station, Texas, US), using random intercept multivariable mixed models. Separate models were computed for each HRQL variable. Logistic models (the XTLOGIT function) were used for the role limitations variables as these two variables exhibited bimodal distributions. For other HRQL outcomes, linear models (the XTREG function) were used. Individuals served as random effects. As done previously (Heesch et al., 2015), survey year served as a covariate to account for changes in the outcome as the women aged, and area of residence at baseline served as a covariate to account for intentional oversampling from rural and remote areas. All confounders were treated as categorical, and missing data for these variables were imputed using the Hot deck function in Stata created by Schonlau (2006). In this procedure, missing values are replaced by random values from the same variable. Hot deck preserves the distributional characteristics of the covariates and performs almost as well as more sophisticated imputation approaches (Roth, 1994). PA and HRQL data were not imputed.

To assess concurrent relationships between PA and each HRQL variable, PA and confounders measured in 1999, 2002, 2005 and 2008 served as predictors in models without a time lag, with HRQL at the same survey serving as outcome variables. These models account for repeated observations from each woman, and the overall estimates account for within-subject correlations. Therefore, these models have a longitudinal element. To create parsimonious and consistent models across outcomes, only variables that showed the potential to be confounders in univariate modeling ($p<0.20$) were included. This process eliminated two variables: caregiving duties and smoking status. To assess whether past PA is associated with future HRQL, PA and potential confounders measured in 1999, 2002, and 2005 served as predictors in time-lag models with HRQL in 2002, 2005, and 2008, respectively, serving as outcome variables. Bootstrap corrections were applied in all linear models due to violations of model assumptions for some models. Logistic models met model assumptions with the distribution of a success (failure) exceeding 30% for all time points: bootstrap or robust corrections were therefore not undertaken.

To test whether the imputation of missing data on the confounders biased estimates, concurrent models were re-run with confounders not imputed. Estimates were slightly lower than those from the initial models, but the conclusions drawn from un-imputed estimates

remained unchanged. This testing was not done for the prospective models because the sparsity of data in the un-imputed prospective models created unstable estimates.

3. Results

Socio-demographic and health-related characteristics of participants are presented in Table 1 and Supplementary Table 1. The percentage of women who reported sufficient PA decreased between 1999 and 2008 (see Table 2). All mean SF-36 scores decreased slightly over time except MCS and mental health scores, which slightly increased.

Table 1
Select characteristics of Australian women with depressive symptoms in 1999 (N=555, aged 73-78 years).[a]

Variables	***n***	**(%)**
Country of birth [b]		
Australia	429	(77.3)
Other English-speaking	62	(11.2)
Other non-English speaking	64	(11.5)
Area of residence [c]		
Urban	237	(42.7)
Large rural town	72	(13.0)
Small rural town/remote area	246	(44.3)
Education [b]		
Some high school or less	402	(72.4)
Completed high school	79	(14.2)
Trade/certificate/diploma	62	(11.2)
University degree	12	(2.2)
Income management		
Difficult/impossible	203	(36.6)
Not too bad	260	(46.8)
Easy	92	(16.6)
Marital status		
Married/partnered	259	(46.7)
Not married or partnered	296	(53.3)
Number of stressful life events in previous year		
0	118	(21.3)
1	156	(28.1)
2	128	(23.1)
3 or more	153	(27.6)
Social networks		
Low (below median score)	253	(45.6)
High (median or higher score)	302	(54.4)
Number of chronic conditions diagnosed or treated for in previous 3 years		
0	159	(28.6)
1	126	(22.7)
2	157	(28.3)
3 or more	113	(20.4)
Diagnosed or treated anxiety/other psychiatric condition in previous 3 years [d]		
No	419	(75.5)
Yes	136	(24.5)
Alcohol consumption		
Low risk drinker (1-14 drinks/week)	216	(38.9)
Non-drinker	149	(26.8)
Rarely drinks (<1 drink/week)	162	(29.5)
Risky drinker (≥15 drinks/week)	28	(5.0)
Body mass index (kg/m2) [e]		
Healthy weight (18.5-<25)	276	(49.7)
Underweight (<18.5)	25	(4.5)

Overweight (25-<30)	183	(33.0)
Obese (≥30)	71	(12.8)

[a] Data collected in 1999 unless indicated otherwise. Variables listed here were those that were included as confounders in multivariable modeling. The full list of variables that were examined as potential confounders is available in Supplementary Table 1.
[b] Assessed in 1996.
[c] Derived from postal code.
[d] Diagnosed or received treatment for anxiety or other psychiatric conditions in the previous 3 years.
[e] Based on self-reported weight and height (kg/m2).

Table 2

Physical activity and health-related quality of life scores [a] of Australian women with depressive symptoms in 1999 (N=555).

Variables	**1999 Aged 73-78 yrs**		**2002 Aged 76-81 yrs**		**2005 Aged 79-84 yrs**		**2008 Aged 82-87 yrs**	
	n	**% [b]**	***n***	**% [b]**	***n***	**% [b]**	***n***	**% [b]**
Physical activity (MET.min/week) [c]								
No PA (0 - <40)	209	38.1	239	46.9	192	48.5	166	52.2
Insufficient (40 - <600)	168	30.6	137	26.9	108	27.3	90	28.3
Sufficient (600+)	172	31.3	134	26.3	96	24.2	62	19.5
SF-36 subscales	**M**	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**
Physical components summary	48.0	8.6	46.0	8.3	45.1	8.5	44.0	7.8
Mental components summary	43.8	9.4	45.2	9.7	45.8	8.8	45.6	9.4
Bodily pain	52.4	25.0	50.4	24.8	49.1	24.3	49.1	23.9
Physical functioning	54.4	23.4	48.2	26.0	45.9	26.5	41.3	25.2
General health perception	54.6	20.5	54.6	20.4	54.3	19.6	52.7	20.6
Vitality	42.1	19.3	43.1	19.8	42.9	19.0	41.6	19.3
Social functioning	68.2	27.0	65.2	28.7	65.9	26.6	65.0	27.5
Mental health	64.5	17.0	66.8	17.3	69.0	16.6	68.5	16.3
	n	**% [b]**	***n***	**% [b]**	***n***	**% [b]**	***n***	**% [b]**
Role limitations from physical problems [d]								
≤ 50	253	45.8	235	46.6	209	51.4	158	50.6
> 50	300	54.3	269	53.4	198	48.7	154	49.4
Role limitations from emotional problems [d]								
≤ 50	227	41.6	196	39.4	162	40.9	131	43.0
> 50	319	58.4	302	60.6	234	59.1	174	57.1

SF-36 = Medical Outcomes Study's short form health survey

[a] Health-related quality of life was measured with SF-36 component scales and subscales. Each component summary score was standardized to range from 0 to 100, with the population average of each cohort set at 50. Higher scores indicate better health-related quality of life.

[b] Percentage may not add up to 100% due to rounding errors.

[c] Physical activity included minutes spent in walking, moderate-intensity physical activity, vigorous-intensity physical activity in the previous week. MET.min/week equals the sum of physical activity minutes in the previous week after weighting walking by 3.0, moderate-intensity physical activity mins by 4.0 and vigorous-intensity physical activity mins by 7.0.(Brown and Bauman 2000)

[d] The role limitations variables were dichotomized because of their bimodal distributions. Frequencies and percentages are presented.

In concurrent models all coefficients were significantly higher for the insufficient- and sufficient-PA levels than for the no-PA level, except for the insufficient-PA level in models of mental health and role limitations due to emotional problems (Tables 3 and 4). Across models, coefficients were higher with increasingly higher levels of PA, indicating better HRQL with more PA. The greatest point difference from the no-PA level was for the sufficient-PA level in the models for bodily pain (8 points higher), physical functioning (16 points higher), vitality (7 points higher), and social functioning (13 points higher).

In prospective, time-lagged models all relationships were attenuated, more so for the mental HRQL-related scales (Table 4) than for the physical HRQL-related scales (Table 3). However, associations were detected for three physical HRQL outcomes (physical functioning, general health, and role limitations-physical) and two mental HRQL outcomes (vitality and role limitations-social). The greatest point difference from the no-PA level was for the sufficient-PA level in the models for physical functioning (8 points higher), general health (5 points higher) and vitality (4 points higher).

Table 3

Associations between physical activity and physical health-related quality of life in Australian women with depressive symptoms aged 73-78 years in 1999, the baseline for this study.[a]

	PCS			Bodily pain			Physical functioning			General health perception			Role limitations-physical		
	β	95% CI	p	B	95% CI	p	β	95% CI	p	β	95% CI	p	OR	95% CI	p
Concurrent models: [b] PA MET.min/week [c]															
1	REF			REF			REF			REF			REF		
2	2.99	2.21-3.81	<0.001	6.02	3.74-8.59	<0.001	10.68	8.50-12.55	<0.001	4.87	3.11-6.84	<0.001	1.67	1.17-2.26	0.002
3	3.97	2.94-4.98	<0.001	8.11	5.26-10.52	<0.001	15.96	13.41-18.62	<0.001	6.30	4.10-8.52	<0.001	1.94	1.40-3.30	<0.001
		Trend	<0.001		Trend	<0.001		Trend	<0.001		Trend	<0.001		Trend	<0.001
Prospective models: [d] PA MET.min/week[c]															
1	REF			REF			REF			REF			REF		
2	1.44	-0.01-3.23	0.05	1.01	-2.45-5.95	0.47	5.66	1.18-10.43	0.010	1.51	-0.65-5.19	0.09	1.98	1.38-2.84	<0.001
3	1.17	-0.37-2.77	0.06	-0.27	-4.60-3.84	0.62	8.20	3.24-13.73	0.005	5.06	1.76-8.86	0.010	1.85	1.26-2.71	0.002
		Trend	0.05		Trend	0.59		Trend	0.004		Trend	0.009		Trend	<0.001

CI=confidence interval; PA = physical activity: PCS= Physical Component Summary scale; REF=referent group

[a] 1-No PA (0 to <40 MET.min/week), the referent category; 2-Insufficient (40 to <600 MET.min/week); 3-Sufficient (600+ MET.min/week). All models were adjusted for survey year, area of residence in 1996 to account for sampling process, country of birth, area of residence, educational attainment, income management, marital status, number of stressful life events, social support, body mass index, number of chronic conditions, diagnosis or treatment for anxiety or other psychiatric condition, and alcohol consumption. Point estimates and confidence interval estimates are bootstrapped and bias-corrected for linear models to address violations of model assumptions. Point estimates and confidence interval estimates are bootstrapped and bias-corrected for linear models. For logistic models, bootstrap or robust corrections were not undertaken because model assumptions were met for these models. Higher scores across physical activity categories (≥3-points) (Bize et al., 2007a) are considered clinically meaningful differences.

[b] PA was assessed at the same time as health-related quality of life (SF-36 scores) in 1999, 2002, 2005 and 2008.

[c] MET.min equals the sum of total physical activity minutes after weighting time walking by 3.0, moderate-intensity mins by 4.0 and vigorous-intensity mins by 7.5.

[d] Health-related quality of life (SF-36 scores) was assessed in 2002, 2005 and 2008. PA was assessed 3 years earlier than each of these time periods.

Table 4

Associations between physical activity and mental health-related quality of life in Australian women with depressive symptoms aged 73-78 years in 1999, the baseline for this study.[a]

	MCS			Vitality			Social functioning			Mental health			Role limitations-emotional		
	β	**95% CI**	**p**	**B**	**95% CI**	**p**	**β**	**95% CI**	**p**	**β**	**95% CI**	**p**	**OR**	**95% CI**	**p**
Concurrent models: [b] PA MET.min/week [c]															
1	REF			REF			REF			REF			REF		
2	1.06	0.20-1.95	0.03	4.28	2.41-6.08	<0.001	9.63	6.90-12.40	<0.001	1.59	-0.06-3.10	0.07	1.25	0.92-1.70	0.15
3	2.33	1.33-3.54	<0.001	7.24	5.19-9.50	<0.001	12.54	9.73-15.67	<0.001	3.96	2.11-5.73	<0.001	1.44	1.02-2.02	0.04
		Trend	<0.001		Trend	<0.001		Trend	<0.001		Trend	<0.001		Trend	0.15
Prospective models: [d] PA MET.min/week[c]															
1	REF			REF			REF			REF			REF		
2	0.07	-1.92-1.95	0.75	2.98	-0.82-6.90	0.18	3.77	-0.76-8.63	0.05	-0.39	-3.65-2.03	0.80	1.63	1.11-3.39	0.01
3	0.12	-1.66-2.02	0.94	4.31	0.83-8.00	0.03	-0.92	-3.03-4.49	0.42	-0.68	-3.53-2.64	0.67	1.22	0.81-1.83	0.33
		Trend	0.93		Trend	0.03		Trend	0.35		Trend	0.66		Trend	0.18

CI=confidence interval; MCS=Mental Component Summary scale; PA = physical activity; REF=referent group

[a] 1-No PA (0 to <40 MET.min/week), the referent category; 2-Insufficient (40 to <600 MET.min/week); 3-Sufficient (600+ MET.min/week). All models adjusted for survey year, area of residence in 1996 to account for sampling process, country of birth, area of residence, educational attainment, income management, marital status, number of stressful life events, social support, body mass index, number of chronic conditions, diagnosis or treatment for anxiety or other psychiatric condition, and alcohol consumption. Point estimates and confidence interval estimates are bootstrapped and bias-corrected for linear models to address violations of model assumptions. For logistic models, bootstrap or robust corrections were not undertaken because model assumptions were met for these models. Higher scores across physical activity categories (≥ 3-points) (Bize et al., 2007a) are considered clinically meaningful differences.

[b] PA was assessed at the same time as health-related quality of life (SF-36 scores) in 1999, 2002, 2005 and 2008.

[c] MET.min equals the sum of total physical activity minutes after weighting time walking by 3.0, moderate-intensity mins by 4.0 and vigorous-intensity mins by 7.5.

[d] Health-related quality of life (SF-36 scores) was assessed in 2002, 2005 and 2008. PA was assessed 3 years earlier than each of these time periods.

4. Discussion and Conclusion

This is the first study of both the concurrent and prospective associations between PA and multidimensional aspects of HRQL in older adults who report a history of depressive symptoms. The study builds upon evidence showing a positive association between PA and HRQL in non-mental health samples, and the symptom reduction benefits of PA for those with poor mental health. In this study of women who reported depressive symptoms in 1999 when they were aged 73-78 years, concurrent associations were observed between PA and all HRQL outcomes in 1999, 2002, 2005 and 2008. Women doing the equivalent of <150 min/week of moderate-intensity PA had higher HRQL scores than those doing no PA, and those doing the equivalent of ≥150 min/week of moderate-intensity PA had the highest scores. This trend was significant across most concurrent models. Prospectively (in 3-year time-lagged models), associations were attenuated.

In all but one concurrent model, a strong significant trend was observed across PA levels, with greater levels of PA being associated with improved HRQL scores. Clinically meaningful improvements in scores (≥ 3-points) (Bize et al., 2007) were also noted: women doing recommended levels of PA had the greatest improvement in HRQL and these improvements were clinically meaningfully for four physical HRQL measures (PCS, bodily pain, physical functioning, and general health) and three mental HRQL measures (vitality, social functioning and mental health). Even women who reported doing some, but insufficient levels of PA had clinically meaningful improvements in three physical HRQL measures (bodily pain, physical functioning, general health) and two mental HRQL measures (vitality and social functioning). Strong associations between PA and both physical functioning and vitality support findings from a previous examination of PA and HRQL in women of the same age without depressive symptoms (Heesch et al., 2012). The moderate associations between PA and PCS, MCS, and mental health found in the current study were also demonstrated in that previous study. This suggests that PA is associated with improvements in HRQL similarly in older women with and without a history of depressive symptoms. Results are also consistent with a review study that found positive associations between PA and HRQL components of functional capacity, mental health, vitality and social relationships, and pain (Vagetti et al., 2014).

Research of mid-aged women with a history of depressive symptoms (Heesch et al., 2015) found that the strongest associations were between PA and physical functioning, vitality

and social functioning. Notably, the associations with physical and social functioning were much stronger for the older women in the current study (e.g., 12.5-point improvement in social functioning for women doing sufficient PA) than for the mid-age women in the previous study (8.6-point improvement). Therefore, the older women appear to have more improvements in some aspects of HRQL than do their mid-age counterparts. It may be that PA is particularly salient in older adults because of age-related declines that compromise physical and social functioning.

In prospective models, all HRQL scores were attenuated, likely reflecting that the HRQL impact of PA is stronger in the short- vs long-term for people with poor mental health. Attenuations were greater for mental HRQL outcomes than for physical HRQL outcomes. Associations were observed between PA and three physical HRQL outcomes, and improvements were clinically meaningful for two of these outcomes: physical functioning (8.2-point improvement) and general health (5.1-point improvement), for women doing sufficient PA. Improvements in vitality were also clinically meaningful (4.3-point improvement) for women who were doing sufficient levels of PA. Similarly, in the previous study of women of the same age without depressive symptoms, the strongest prospective association was with physical functioning (4.3 to 5.1-point improvements for women doing sufficient levels of PA) and secondly, with vitality (3.5 to 5.4-point improvements for women doing sufficient levels of PA).

The prospective findings are consistent with other prospective research indicating that positive associations between PA and HRQL in older adults (without mental health issues) are predominantly for physical functioning and vitality (Vagetti et al., 2014). In contrast to previous research with mid-aged women with a history of depressive symptoms (Heesch et al., 2015), the current study demonstrated more attenuation for mental than physical HRQL outcomes. The previous study found no clinically meaningful improvements in physical HRQL (scores <3.0), and social functioning was the only mental HRQL outcome that was clinically meaningful (3.4-point improvement for women doing sufficient levels of PA). Therefore, prospectively, there appear to be different associations between PA and HRQL for older women with a history of depressive symptoms than for mid-age women with these symptoms. This is consistent with other research suggesting stronger associations between PA and physical than psychological HRQL (Salguero et al., 2011; Stewart et al., 2003), and as previously discussed, may reflect that PA is particularly salient in older adults because of age-related declines in physical functioning.

4.1 Strengths and limitations

Examining the concurrent association between PA and HRQL over multiple time points, as well as the prospective association, is a novel approach, and enabled us to assess both the immediate and delayed effects of PA. A major strength of ALSWH is the collection of data from a large national population-based sample. For these analyses, data on PA levels, HRQL, and a large range of confounders were available at four time periods. The main limitation is the reliance on self-report measures, which are prone to recall and measurement bias. However, HRQL is a subjective judgement, and the SF-36 is a validated, well-used measure (Mishra and Schofield, 1998; Ware Jr., Kosinski, et al., 1998; Ware Jr. and Gandek, 1998). The PA survey has adequate reliability and validity (Brown et al., 2004; Brown et al., 2008). We excluded women who reported on more than one survey an inability to walk 100m; therefore, results may not be generalisable to non-ambulatory PA. In 1999, the number of women who reported depressive symptoms was small (n=555) compared with the number of ALSWH participants (n=10,030), and study attrition decreased the sample size over time. Given the attrition, missing data on confounders were imputed. In a sensitivity analysis, estimates changed slightly, but clinically meaningful findings in the imputed models (estimates $\geq$3.0) were clinically meaningful in un-imputed models, and the same trends in associations between PA and HRQL outcomes in the imputed models were also seen in the un-imputed models. However, without the use of imputation, the prospective models could not be computed, and a sensitivity analysis for those models was not possible. Although the PA categorization here reflects international PA guidelines for older adults (World Health Organization, 2016), it was not possible to create more PA categories for a more critical analysis of dose-response relationships. That would require a larger sample. In addition, study attrition in ALSWH limits the generalizability of the findings. Also of note is that a reasonably representative national sample of women in their 70s completed the baseline ALSWH survey in 1996 (Brown et al., 1998); however, women have withdrawn over time, as seen with all prospective studies. Women who were excluded from the study due to missing data or withdrawal did not differ significantly on demographic variables from those who were included, but they tended to be less healthy (see Supplementary Table 1). Excluded respondents were also more likely to report being diagnosed or receiving treatment for anxiety or other psychiatric conditions, which may have included women with more serious

symptomatology. The results of this study, therefore, may not be generalizable to those with a history of serious depression or poor health.

In conclusion, the current study documents associations between PA and dimensions of HRQL over a 9-year period. The findings suggest that for Australian women in their 70s-80s with a history of depressive symptoms, meeting international guidelines for ≥150 minutes of moderate-intensity PA (World Health Organization, 2016) is associated with improved HRQL. Doing less PA is also associated with some improvements in HRQL. These findings add to the evidence indicating that PA is positively associated with physical and mental dimensions of HRQL, and extend to older ambulatory women with a mental health condition.

Conflict of Interest Statement

The authors declare that there are no conflicts of interest.

Financial disclosure

All authors have no financial disclosures.

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Appendix A. Supplementary data

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Highlights

- Physical activity is associated with quality of life in older women with depression
- For QoL, accumulation of 150+ minutes of physical activity weekly is optimal.
- Older women who report lower levels of PA have better QoL than those who do no PA.