2020

Active Lives South Australia Health Economic Analysis - an evidence base for potential of health promotion strategies to reduced public health costs with meeting of adult physical activity guidelines. A report prepared for SA Office of Recreation, Sport and Racing and SA Health.

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Keywords

meeting, adult, physical, activity, guidelines., report, prepared, sa, office, recreation, sport, racing, public, reduced, analysis, active, lives, south, australia, health, economic, strategies, costs, promotion, potential, base, evidence, -, health.

Publication Details

S. Eckermann, M. Crisp & A. Willan, Active Lives South Australia Health Economic Analysis - an evidence base for potential of health promotion strategies to reduced public health costs with meeting of adult physical activity guidelines. A report prepared for SA Office of Recreation, Sport and Racing and SA Health. (Centre for Health Service Development, Australian Health Services Research Institute, University of Wollongong, 2020).

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Active Lives South Australia Health Economic Analysis

An evidence base for potential of health promotion strategies to reduce public health costs with meeting of adult physical activity guidelines

May 2020

ahsri
australian health services research institute

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Suggested citation:

Eckermann S, Crisp M and Willan AR (2020) Active Lives South Australia Health Economic Analysis – an evidence base for potential of health promotion strategies to reduced public health costs with meeting of adult physical activity guidelines. A report prepared for SA Office of Recreation, Sport and Racing and SA Health. Centre for Health Service Development, Australian Health Services Research Institute, University of Wollongong.

Acknowledgement:

The authors acknowledge the support from the team at Population Health Surveys, Prevention and Population Health Directorate, Wellbeing SA.

Contents

Introduction

The South Australian Active Lives study and survey undertaken in April and May 2019 enables comparison of self-reported measures in adult populations who meet or do not meet physical activity guidelines defined in relation to whether they undertake 0-149 minutes or 150 minutes or more of physical activity per week. The survey was undertaken by computer-assisted telephone interview or online via phone or e-mail, with survey results weighted across population age, sex and location (metropolitan vs country) factors to estimate population level impacts consistent with 2016 ABS census data. The survey of 2,999 South Australian adults alongside physical activity survey questions adapted from the Active Lives survey published by Sports England covered subjective wellbeing, health status and health care utilisation, as well as individual development, community connectedness and social capital. Analysis of results in the main report considered differences in self-reported representatively weighted population level proportions for survey questions across these factors by level of self-reported physical activity per week (none, 1-149 minutes and 150 minutes or more).

That report found adult populations with higher levels of physical activity in meeting (150 or more minutes PA per week) relative to those not meeting (0-149 minutes PA per week) guidelines had associated improved wellbeing, individual development, social connectedness and social capital in analysis both without any covariate adjustment and adjusted for age, sex and SEIFA index. Trends were also found for adult populations with greater than 150 minutes PA having lower probability than populations with 0-149 minutes PA of visits in the last year to GP, specialist doctor or other health professional or hospital inpatient admissions, outpatient clinic and emergency department visits.

This report considers health economic aspects of the surveys, enriching the main report by reporting, analysing, and reflecting on:

1. Odds of populations utilising health services and mean rate of health service use per year reported by adult populations meeting (150 minutes or greater PA per week) or not meeting (149 minutes or less per week) PA guidelines.
2. Differences in estimated mean health service use per person year between populations meeting and not meeting PA guidelines for GP, specialist, other health professional, dental, hospital emergency department, inpatient and outpatient visits.
3. Expected cost to government of health service use per person year across populations meeting or not meeting guidelines with resource use priced at average cost per service in adult populations.

4. Potential of population health gains and cost savings from community health promotion environmental and whole of government policy initiatives supporting active populations in successful ageing and across the lifecycle.

The primary underlying aim of this health economic analysis is to start to inform the need for active live health promotion policy initiatives through robustly estimating potential population level health system cost savings from shifting adult populations from not meeting PA guidelines to meeting guidelines. In undertaking analysis in this report there are three levels of increasingly robust and instructive analysis towards that aim presented. The first analysis used population level aggregate weighted data in estimating resource use and cost differences for populations meeting and not meeting PA guidelines for 150 minutes or more provided by the main study without adjustment for the potential effects of differences in covariates between these populations, with a limiting assumption of normality in cost differences. The second uses the studies individual data to estimate cost differences under uncertainty both between populations meeting and not meeting guidelines and within populations in considering the 150 threshold and estimating marginal effects allowing for modelling to fit cost distributions, while still not adjusted for potential effects of differences in covariates. The third and most robust analysis uses individual data to estimate cost differences under uncertainty while adjusting for covariates in comparisons between populations meeting and not meeting guidelines. The second and third analyses also undertake sensitivity analysis to consider the impacts of including high cost respondents removed to allow robust modelling under uncertainty in conservative base case analysis.

Comparison between results from these three increasingly robust levels of analysis is instructive in seeing:

(i) In comparison between the second and first analysis the importance and impact of allowing for individual data distribution and modelling the cost data using a gamma distribution to account for the positive skewing.
(ii) In comparison between the third and second analysis the impact of allowing for covariate adjustment.
(iii) In comparison between the third and first analysis the combined impact of (i) and (ii).

1st Analysis of main report health service use in populations with 150+ vs 0-149 min PA/wk.

We start by considering survey evidence on the probability of having health service use across major categories of GP, specialist, other health professional, dental, hospital emergency department, inpatient and

outpatient use in adult populations with 150 minutes of physical activity (n=1730) versus those with 0-149 minutes (n=1259) in Table 1.

It has been shown to be important with relative comparisons of binary variables, such as the probability of visiting a health service provider or not, to use a symmetric metric such as the odds ratio to overcome problems of non-symmetric metrics such as relative risk that arise with alternative framing of the same binary evidence and its synthesis or translation (Eckermann, Coory and Willan 2008, 2011; Eckermann 2017 chapter 3).

Calculating odds of visiting health services in these populations from these probabilities then the odds ratio (OR) between populations meeting PA guidelines (150+ min/week) and those not (0-149 min/week) is simply the ratio of these odds[1]. The ORs in Table 1 suggest a lower relative chance of health service use in those meeting guidelines with OR less than 1 for each of GP, specialist doctor, other health professional and Hospital emergency department, inpatient admission and outpatient services; while higher chance (OR>1) of using dental services.

[1] Constructing a confidence interval or testing the statistical significance of these odds ratios is also simply undertaken given the natural logarithm relationship with odds ratios. Hence the standard error (SE) for the natural logarithm of the OR is simply the square root of the sum of the reciprocal for number of events and non-events in the compared populations. The lower and upper 95% CI around the natural logarithm of the mean OR simply subtract and add 1.96 of these standard errors. Taking the exponential of these natural logarithms of the mean OR and 95% CI enables the mean and 95% CI of the OR to be reported. Hence, for example for GP services with a mean OR of 0.48 ((1554/186)/(1194/65)), ln(0.48)=-0.733 has SE = $\sqrt{\frac{1}{1554}+\frac{1}{186}+\frac{1}{1194}+\frac{1}{65}}$=0.0796 and hence 95% CI is exp(-0.733±1.96(0.0796)) = (0.41, 0.56).

Table 1 Probability, odds and odds ratio for health service use in SA adult populations with 150+ min physical activity per week vs 0-149 min

	Minutes of activity per week							
	less than 150 minutes (N=1,259)			150 minutes or more (N=1,730)				
	n	P(visit)	odds visit	N	P(visit)	odds visit	OR	95% CI OR
GP	1,194	0.948	18.37	1,554	0.898	8.83	0.48	(0.41, 0.56)*
Specialist Doctor	663	0.527	1.11	785	0.454	0.83	0.75	(0.68, 082)*
Dentist	631	0.501	1.00	1,102	0.637	1.75	1.75	(1.58, 1.93)*
Other Health Professional	480	0.381	0.62	597	0.345	0.53	0.86	(0.77, 0.94)*
Hospital Admission	326	0.259	0.35	314	0.182	0.22	0.63	(0.56, 0.72)*
Hospital Outpatient Clinic	303	0.241	0.32	243	0.140	0.16	0.52	(0.45, 0.59)*
Hospital ED	265	0.210	0.27	269	0.155	0.18	0.69	(0.61, 0.79)*
*statistically significant with 5% type I error								

The odds ratios and their 95% CIs in Table 1 show a statistically significantly lower relative chance of health service use in those meeting guidelines for each of GP (OR=0.48), specialist doctor (OR=0.75), other health professional (OR=0.86) and Hospital emergency department (OR=0.69), inpatient admission (OR=0.63) and outpatient services (OR=0.52); while statistically significantly higher chance of using dental service (OR=1.75).

Symmetry of the odds ratio equivalently implies that the OR for not using services are simply their inverse or reciprocal of the OR for using services. That is, for the population meeting guidelines relative to that not meeting guidelines the OR of not using GP services (150+ vs 0-149 minutes of PA per week) is 2.08=1/0.48, OR for not using specialist doctor is 1.34=1/0.75, not using other health professional is 1.17=1/0.86, while for not using hospital admission is 1.58=1/0.63, not using hospital emergency department presentations is 1.45=1/0.69 and not using outpatient services is 1.94 = 1/0.52. The 95% confidence intervals for OR of not using services are similarly the reciprocal of those for using services. Hence the OR for not using services comparing populations meeting vs not meeting guidelines would equivalently and consistently be significantly greater than 1 for GPs, specialist, other health professional and hospital inpatient admissions, emergency department and outpatient services and less than 1 for dental services.

While differences in relative chance of health service utilisation in populations meeting or not meeting PA guidelines are consistently established with ORs in Table 1, implications for health system resource use and

costs needs to consider mean differences in health service use. Follow up questions in the Active Lives survey asking about how many times in the past year participants had used each service type enable mean resource use across each of the major health service areas to be calculated (Table 2).

Table 2 Healthcare use per year for populations who meet vs do not meet PA guidelines

	Minutes of activity per week						Difference		
	less than 150 minutes (N=1259)			150 minutes or more (N=1730)					
	N	mean	SD	N	mean	SD	Mean	SE Diff	p-value
GP	1,194	7.238	8.499	1,554	4.593	5.852	-2.645	0.278	<0.0001
Specialist Doctor	663	2.072	4.110	785	1.743	4.541	-0.329	0.159	0.0195
Dentist	631	1.091	1.705	1,102	1.240	1.584	0.148	0.061	0.0078
Other Health Professional	480	3.053	7.197	597	2.640	6.954	-0.413	0.263	0.0582
Hospital Admission	326	0.465	1.221	314	0.284	0.829	-0.181	0.040	<0.0001
Hospital Outpatient Clinic	303	0.882	3.236	243	0.350	1.568	-0.532	0.099	<0.0001
Hospital ED	265	0.385	1.037	269	0.211	0.574	-0.173	0.032	<0.0001

The direction of mean population health service utilisation (Table 2) mirrored that for the chance of using services. The population meeting PA guidelines with 150 minutes or more of weekly physical activity had lower GP, specialist doctor, other health professional and hospital admissions, outpatient clinics and hospital emergence department service use per year, while greater dental service use.

If utilisation was assumed normally distributed then p-values indicate highly statistically significant ($p<0.0001$) lower utilisation for GP and all hospital services, while still significant reductions in specialist services and increases in dental services and trend towards lower other health professional use. However, the large proportion of both populations with no use of healthcare services for other health professional services and indeed all services other than GP services points to the prior importance of robust relative comparison of probabilities as per Table 1 in indicating differences between populations. More generally the binary nature of use suggests that normality of population utilisation and costs is not supported for most services separately and more generally still all health services and their joint costs should be considered in comparison between populations to avoid perils of partialisation (Eckermann 2017, chapters 1-3) as well as support any assumption of normality in making inference about populations relative service use and cost. In that respect it should also be noted analysis with individual respondent data in the 2nd and 3rd sets of analyses use the gamma distribution as a better fit in allowing for positive skew of cost distribution data.

Table 3 applies relevant average relevant government scheduled fees given the mix of services across South Australian populations to the difference in service use per person year between adult populations who meet and do not meet PA guidelines (have 150+ vs 0-149 minutes of PA per week) to estimate the difference in total cost per person year.

Table 3 Average cost difference per person-year by health use for 150+ vs 0-149 minutes of physical activity per week

	Utilisation Difference 150+ vs 0-149	Average Scheduled Fee per Service ($)	Cost Difference per Person-year ($)
GP*	-2.645	44.23	-116.98
Specialist Doctor*	-0.329	73.42	-24.13
Dentist*	0.148	53.91	7.99
Other Health Professional*	-0.413	57.75	-23.83
Hospital Admission^	-0.181	6,053.00	-1,095.90
Hospital Outpatient Clinic^	-0.532	467.00	-248.46
Hospital ED^	-0.173	715.00	-123.91
Total government cost			**-1,625.23**

* SA adult price per MBS service type estimated from MBS data on the average cost of the service mix of relevant MBS scheduled fee items in SA populations 15 and over
(i.e. 15-24 and all older age-groups) in the 2018/19 financial year data.
^ average adult price per hospital service calculated from SA Health Department data on non-paediatric hospital services in 2017/18 financial year (latest available data at time of analysis).

For adult populations who meet versus don't meet physical activity guidelines (have 150 minutes or greater versus 149 minutes or less physical activity per week) combined net government health system costs of GP, Specialist, other health professional, dentist and hospital inpatient admissions, ED and outpatient services are estimated given average service prices in SA for utilisation to be $1,625 lower per person year. Hence, given a current adult (18 and over) population in SA of 1,369,751, of which Active Lives survey findings estimate 42.12% do not meet PA guidelines the potential cost savings at a population level of health promotion and whole of government strategies in reducing net health system expenditure is estimated at $937.685 million annually (Table 4).

Table 4 Potential for health system cost saving from adults meeting PA guidelines

SA adult population estimate June 2018	1,369,751
Survey population proportion not meeting guideline	42.12%
Estimated SA population not meeting guideline	576,954
Lower health cost per adult meeting vs not meeting PA guideline	$1,625.23
Potential annual lower net health care cost	$937.685 million

Hence, the first analysis suggests if health promotion and whole of government strategies in support of PA guidelines enabled shifting SA adult populations who currently undertake 0-149 minutes of physical activity to have physical activity reflecting that of populations who undertake 150+ minutes then net government health expenditure in SA has potential to reduce by $937 million annually. This would be attributable to an annual potential reduction of $632.3 million for hospital inpatient admissions, $71.5 million for hospital ED, $143.3 million for hospital outpatients, $67.5 million for cost of GP visits and $27.7 million for specialist and other health professionals, while the amount spent on dental services would be expected to increase by $4.6 million (Table 5).

Table 5 Potential annual health system savings from all adults meeting PA guidelines by major area utilisation

	Estimated Population not Meeting PA	Cost saving per person year ($)	Total annual potential cost saving ($ million)
GP*	576,954	116.99	67.495
Specialist Doctor*	576,954	24.13	13.922
Dentist*	576,954	-7.99	-4.612
Other Health Professional*	576,954	23.83	13.752
Hospital Admission^	576,954	1,095.91	632.287
Hospital Outpatient Clinic^	576,954	248.46	143.349
Hospital ED^	576,954	123.91	71.493
Total government cost		1,625.23	937.685

* SA adult price per MBS service type estimated from MBS data on the average cost of the service mix of relevant MBS scheduled fee items in SA populations 15 and over
(i.e. 15-24 and all older age-groups) in the 2018/19 financial year data.
^ average adult price per hospital service calculated from SA Health Department data on non-paediatric hospital services in 2017/18 financial year (latest available data at time of analysis).

While this represents the potential cost saving from shifting the health care utilisation of the adult populations who do not meet PA guidelines (have 0-149 minutes per week of physical activity) to populations who do (have 150+ minutes PA per week). In reality, any individual strategy or set of strategies while aiming to have greatest incremental effects in improving PA and reducing healthcare costs can not eliminate inactive populations. More generally strategies might be expected to have intramarginal effects in the population who may be amenable to change and/or inframarginal effects of for example nudge strategies aimed at marginal impacts across whole populations.

To this end below are considered the potential for cost savings from a series of potential 5% intra (extra population) and/or infra (across population) marginal effects:

(i) an absolute 5% reduction in the proportion of the population who don't meet PA guidelines, i.e. from 42.12% to 37.12%, which equates to potential cost savings of 0.05/0.4212 × $937.685 million = $111.3 million per year.

(ii) an **infra**marginal relative 5% reduction in the proportion of the population who don't meet guidelines - from 42.12% to 40.06%, which equates to potential health system cost savings of 0.05 × 576,954 × $1,625.23 = $46.9 million per year.

(iii) an **intra**marginal reduction in health care costs per person across the population who don't meet guidelines of 5% towards the level of that of populations who do meet guidelines which equates to potential health system cost savings of 0.05 × $937.7 million = $46.9 million per year, the same as (ii).

(iv) a 5% **intra**marginal reduction in health care costs per person across the population who don't meet guidelines which equates to potential health system cost savings of 0.05 × $4,211.01 × 576,954 people= $121.5 million per year.

(v) a 5% **intra**marginal reduction in health care costs per person across the whole population which equates to potential cost savings of (iv)+ 0.05 × $2,587 × 792,797 people= $121.5 million/year +$102.5 million/year = $224.0 million per year.

(vi) any combination of absolute (i) or infra marginal (ii) with different intramarginal (iii)- (v) factors noting that such intra and infra marginal impacts together are approximately additive.

These are potential costs savings of intra and or infra marginal effects for one year. One can also consider the marginal effects from changing the physical activity trajectory of an adult over a lifetime, noting that the Active Lives survey is weighted to be representative of the adult population by age and sex. Hence an average $1,625 per year cost saving is the age-sex weighted population average for adults in SA currently.

Hence, for a representative adult across the population if they shifted from what is observed in populations not meeting PA to meeting PA guidelines they would be expected at age 18 with life expectancy of 80 years to save a lifetime health expenditure of:
$1,625 per year × (80-18) years = $1,625.23/year × 62 years = $100,764 health system cost savings to government across a lifetime from age 18 from changing the trajectory of physical activity from that of populations who do not meet to meet adult PA guidelines for 150+ minutes of physical activity a week.

This lifetime estimate of government cost saving to the health system in SA of $100,750 of an individual at age 18 from changing trajectory in shifting from not meeting to meeting PA guidelines is in line with latest US estimates. The lifetime cost savings over lifetime from 12 year-old children becoming physically active for cardiovascular, cancer and diabetes alone of USD 62,418 across all children and more than USD 100,000 for populations with BMI of 30 or greater (Lee et al. 2017).

Even in a single year cohort of 21,259 SA 18 year-olds at June 30 2018 an additional 5% or 1062 individuals positively changing the trajectory of their physical activity to meet PA guidelines, applying the lifetime estimate for health system cost savings of $100,764 points to potential lifetime cost savings of $107.1 million with sustained change. Changing the trajectory of PA by 5% for a generation (10 years) of such young adults would have expected cost savings in the order of 10 fold this (more than $1 billion), while a long term 5% impact across all adults 30+ fold or $3+ billion. This highlights the potential health system cost saving of strategies which have long term population level effects on physical activity levels.

2nd Analysis of individual level effects under uncertainty with PA as a continuous variable, no covariate adjustment, and using a gamma distribution for cost to account for positive skewing

The second analysis uses individual respondent data and considers physical activity as a continuous variable to consider cost implications of marginal changes in population physical activity, the resulting dose effect and consequently implications for the potential appropriate cut-point in the number of minutes of physical activity per week for meeting vs not meeting guidelines. Using individual respondent data allows for modelling cost data using a gamma distribution to account for the positive skewing.

The marginal changes in total health system cost with additional activity and “dose effect” between minutes of physical activity and total cost is examined in Table 6 and Table 7. Table 6 shows mean annual health

system costs are highest at $5,551 in the 601 individuals with 0-29 minutes of PA per week, consistently reduce in populations with each hour of additional physical activity up to 209 minutes ($2,390 in 213 individuals), while beyond that show no consistent pattern. Notably, marginal increases in mean health expenditure are observed for populations with 210-329 minutes in comparison with those from 150-209 minutes. This marginal analysis provides support for a threshold between 150-209 minutes.

Table 6 Number of respondents (N) and mean total cost by level of activity; and mean difference between adjacent levels. Ninety-five percent confidence intervals are given.

minutes of activity/week	N	Mean ($)	lower limit ($)	upper limit ($)	Marginal mean difference ($)	lower limit ($)	upper limit ($)
0-29	601	5,551	4,880	6,222			
					-1,779	-2,670	-887
30-89	363	3,772	3,186	4,359			
					-181	-995	633
90-149	320	3,591	3,012	4,170			
					-1,201	-1,930	-473
150-209	213	2,390	1,930	2,851			
					464	-303	1,231
210-269	171	2,854	2,241	3,468			
					1392	176	2608
270-329	141	4,246	3,208	5,284			
					-1,879	-3,057	-700
330-389	117	2,367	1,752	2,982			
					973	-92	2,037
390-449	120	3,340	2,475	4,205			
					411	-1,128	1,950
450-509	76	3,751	2,495	5,007			
					-2,238	-3,474	-1,001
510-569	83	1,513	1,068	1,959			
					870	-34	1,775
570-629	68	2,384	1,600	3,168			
					306	-598	1,210
630+	713	2,690	2,392	2,988			

In interpreting the health cost implications from the choice of a threshold value, population level total health expenditure effects are a trade-off between the size of the reduction in mean total cost and the number of people who could realize the reduction by moving from below to above any threshold. As the threshold increases the reduction in mean total cost diminishes, but the number of people who could realize that reduction increases, see Table 7. The last column in Table 7 is the number of respondents below the threshold multiplied by the reduction in mean total cost, and represents the total potential cost saving in a sample of 2,986 people. This is maximised at 150 minutes per week, providing support for using 150 minutes physical activity per week as the threshold in maximizing potential population level health system cost savings.

Table 7 Comparison of total cost by various thresholds for defining the levels activity

minutes of activity per week	N	mean	lower limit	upper limit	mean difference	lower limit	upper limit	Potential saving** study population ($ millions)
		$						
0 – 29	601	5,551	4,890	6,213	-2,497	-3,184	-1811	-1.50
30 or more	2,385	3,054	2,871	3,236				
0 – 59	775	5,229	4,680	5,777	-2,258	-2,837	-1,680	-1.75
60 or more	2,211	2,970	2,786	3,155				
0 – 89	964	4,881	4,422	5,341	-1,957	-2,454	-1,460	-1.89
90 or more	2,022	2,925	2,735	3,115				
0 - 119	1,079	4,725	4,304	5,145	-1,829	-2,292	-1,366	-1.97
120 or more	1,907	2,895	2,701	3,089				
0 - 149	1,284	4,560	4,188	4,932	-1,761	-2,182	-1,339	-2.26
150 or more	1,702	2,799	2,601	2,998				
0 - 179	1,372	4,412	4,064	4,761	-1,584	-1,989	-1,179	-2.17
180 or more	1,614	2,829	2,623	3,035				
0 - 209	1,497	4,251	3,929	4,573	-1,394	-1,782	-1,005	-2.09
210 or more	1,489	2,858	2,641	3,075				
0 - 239	1,579	4,178	3,869	4486	-1,319	-1,700	-938	-2.08
240 or more	1407	2,859	2,636	3083				

** number of respondents below the threshold *multiplied by* the mean difference
e.g. for '0-29' *versus* '30 or more': 601 x (-2,497) = -1,500,697
i.e. potential cost saving $1.50 million in study sample

That is, Table 7, in comparing total health expenditure in the study population for all potential threshold up to 240 minutes, shows cost savings across the study sample would be maximised with a physical activity threshold of 150 minutes given a reduction in mean cost of $1,761 per respondent across 1,284 respondents maximises potential for health system cost savings at $2.26 million in the study sample.

Hence, Table 7 provides evidence from the study sample that the greatest health system cost savings (and potential for health gains in a publicly provided universal health system where use and cost proxies for health care needs) are in increasing physical activity of those not meeting guidelines whether in reaching toward or meeting the guideline of 150 minutes or more per week for adults. More generally, health system cost savings at the margins in Table 6, together with total population level health expenditure in Table 7, support the current guideline of 150 minutes as appropriate, while potentially could be increased toward 179 minutes.

Given adult physical activity guidelines for 150 minutes or more per week as well as Table 6 and Table 7 support for this as a threshold level to aim for in terms of health benefits in shifting populations which have health system cost savings the most meaningful comparison from Table 7 is that for 0-149 vs 150+. This is both substantial and highly significant in terms of average health system cost savings per person of $1,761 (95% CI $1,339, $2,182) and as a percentage reduction (1,761/4,932=35.7% reduction, with 95%CI from 27.1% to 44.2%). The implications of this second analysis at a population level are shown in Table 8, noting this analysis is still qualified in not adjusting for covariates, which the 3rd analysis undertakes.

Table 8 Second analysis potential for health system cost saving from adults meeting PA guidelines

SA adult population estimate June 2018	1,369,751
Survey population proportion not meeting guideline	42.12%
Estimated SA population not meeting guideline	576,954
Lower health cost per adult meeting vs not meeting PA guideline	$1,761
Potential annual lower net health care cost	$1.016 billion

Hence, the second analysis undertaken with individual level data and appropriate modelling of costs using a gamma distribution to account for positive skewing, suggests if health promotion and whole of government strategies in support of PA guidelines enabled shifting SA adult populations who currently undertake 0-149 minutes of physical activity to have physical activity reflecting that of populations who undertake 150+ minutes then net government health expenditure annually in SA has potential to reduce by $1.016 billion annually.

In terms of intra (extra population) and/or infra (across population) marginal effects this 2nd analysis from individual person data suggests, while still without covariate adjustment:

(i) an absolute 5% reduction in the proportion of the population who don't meet PA guidelines i.e. from 42.12% to 37.12%, which equates to potential cost savings of 0.05/0.4212 × $1.016 billion = $120.6 million per year.

(ii) an **infra**marginal relative 5% reduction in the proportion of the population who do not meet guidelines from 42.12% to 40.06%, which equates to potential health system cost savings of 0.05 × 576,954 × $1761 = $50.8 million per year.

(iii) an **intra**marginal reduction in health care costs per person across the population who don't meet guidelines of 5% towards the level of that of populations who do meet guidelines which equates to potential health system cost savings of 0.05 × $1.016 billion = $50.8 million per year.

(iv) a 5% **intra**marginal reduction in health care costs per person across the population who do not meet guidelines which equates to potential health system cost savings of 0.05 × $4,932 × 576,954 people = $142.3 million per year.

(v) a 5% **intra**marginal reduction in health care costs per person across the whole population which equates to potential cost savings of (iv) + 0.05 × $3171 × 792,797 people = $125.7 million/year + $142.3 million/year = $268.0 million per year.

(vi) any combination of absolute (i) or infra marginal (ii) with different intramarginal (iii)- (v) factors noting that such intra and infra marginal impacts together are approximately additive.

These estimates from the second analysis as with the first analysis assume that in estimating potential for cost savings across populations there are no exogenous confounding effect on cost savings associated with potential differences between those who meet and do not meet guidelines. Potential for confounding (age, sex, socio-economic status) are adjusted in the 3rd analysis.

3rd Analysis of individual level effects under uncertainty with covariate adjustment

For the 3rd analysis, as in the first two analyses, the outcome of interest is total annual health care cost and the predictor variable of interest is the level of physical activity per week. To enable robust interpretation of this relationship, other variables collected by the Active Lives study, 'ancillary variables' in Table 9, were examined as possible confounders, while all were examined as possible effect modifiers.

Table 9 Active Lives ancillary variables and adjustment for confounding and effect modification

Variable	Possible confounder	Possible effect modifier
Sex	X	X
Age	X	X
Income	X	X
Marital status	X	X
Education	X	X
Work status	X	X
Home ownership	X	X
General health		X
Ability to be physically active		X
Opportunity to be physically active		X
Disabled		X

Hence, the third analysis in considering these variables both adjust for possible confounders (age, sex and socio-economic status) in estimating the reduction in total health care cost due to physical activity and examines the potential for effect modification. Adjustment for potential confounders allows for exogenous population differences in estimating cost impacts of physical activity levels while effect modification (see appendix Tables 15 and 16 in Appendix 1) aims to answer questions such as: Does the reduction in total cost due to physical activity level differ between males and females?

The relationships between the ancillary variables and (i) level of physical activity and (ii) total cost are given in Tables 10A through 10K. A cross tabulation, showing the frequency and row percent, is given for the levels of each ancillary variable and the levels of physical activity (<150 vs ≥150 minutes/week). In addition, the mean total cost is given for each level of the ancillary variable. Comparing final columns of Table 10 shows both the potential impact that covariates independent of physical activity such as sex, age and socio-economic status can have on health expenditure if there were differences between those who meet and do not meet guidelines. Comparing proportions between these populations in the 2nd and/or 3rd Columns show the how these populations differ across these covariates. Hence, Table 10 shows what impact adjusting for these factors each partially and in interaction have on the difference in health care costs between those who meet guidelines and those who do not.

Table 10A Level of activity and mean total cost by sex

	Minutes of activity per week				Total cost
	less than 150 minutes		150 minutes or more		
Sex	N	row %	N	row %	Mean ($)
Male	453	38.4	726	61.6	3,375
Female	837	46.0	983	54.0	3,674

Table 10B1 Level of activity and mean total cost by age

	Minutes of activity per week				Total cost
	less than 150 minutes		150 minutes or more		
Age	N	row %	N	row %	mean ($)
34 years or younger	88	29.7	208	70.3	2,880
35 to 44 years	162	43.1	214	56.9	3,771
45 to 49 years	100	43.1	132	56.9	3,120
50 to 54 years	117	42.1	161	57.9	2,805
55 to 64 years	287	41.7	402	58.3	3,445
65 to 74 years	317	42.7	426	57.3	3,588
75 years or over	219	56.9	166	43.1	4,805

Table 10B2 Level of activity and mean total cost by age

	Minutes of activity per week				Total cost
	less than 150 minutes		150 minutes or more		
Age	N	row %	N	row %	mean ($)
Less than 75 years	1071	41.0	1543	59.0	3,372
75 years or over	219	56.9	166	43.1	4,805

Table 10C1 Level of activity and mean total cost by income

	Minutes of activity per week				Total cost
	less than 150 minutes		150 minutes or more		
Income ($)	N	row %	N	row %	mean ($)
Up to 12,000	36	57.1	27	42.9	3,601
12,001-20,000	133	57.6	98	42.4	4,504
20,001-40,000	261	49.2	270	50.8	4,689
40,001-60,000	159	43.8	204	56.2	2,990
60,001-80,000	133	42.9	177	57.1	3,601
80,001-100,000	113	41.4	160	58.6	2,866
100,001-150,000	106	31.6	229	68.4	2,799
150,001-200,000	44	23.9	140	76.1	3,216
Over 200,000	21	18.4	93	81.6	2,572

Table 10C2 Level of activity and mean total cost by income

	Minutes of activity per week				Total cost
	less than 150 minutes		150 minutes or more		
Income ($)	N	row %	N	row %	mean ($)
Up to 40,000	430	52.1	395	47.9	4,554
Over 40,000	576	36.5	1003	63.5	3,044

Table 10D Level of activity and mean total cost by marital status

	Minutes of activity per week				Total cost
	less than 150 minutes		150 minutes or more		
Marital status	N	row %	N	row %	mean ($)
Married	634	39.1	987	60.9	3,209
Living with a partner	101	38.0	165	62.0	3,577
Separated	72	49.3	74	50.7	4,037
Divorced	174	50.1	173	49.9	3,858
Widowed	147	56.1	115	43.9	5,136
Never Married	145	45.2	176	54.8	3,447

Table 10E Level of activity and mean total cost by education

	Minutes of activity per week				Total cost
	less than 150 minutes		150 minutes or more		
Education	N	row %	N	row %	mean ($)
Some primary school	9	60.0	6	40.0	3,932
Completed primary school	22	61.1	14	38.9	3,149
Some high school	300	50.8	290	49.2	4,351
Completed high school	220	46.6	252	53.4	3,370
TAFE, Trade or certificate	247	46.1	289	53.9	3,585
Diploma, advanced diploma	144	39.3	222	60.7	3,622
University or some other tertiary degree	340	35.1	630	64.9	3,085

Table 10F Level of activity and mean total cost by work status

	Minutes of activity per week				Total cost
	less than 150 minutes		150 minutes or more		
Work status	N	row %	N	row %	mean ($)
Full-time	290	33.0	588	67.0	2,529
Part-time	166	39.7	252	60.3	2,866
Casual	93	44.9	114	55.1	3,119
Unemployed	74	58.3	53	41.7	3,791
Engaged in home duties	53	56.4	41	43.6	3,480
Student	14	31.8	30	68.2	1,979
Retired	458	46.2	533	53.8	4,022
Unable to work	95	71.4	38	28.6	9,519
Carer	23	43.4	30	56.6	5,108
Volunteer work	16	48.5	17	51.5	2,716

Table 10G Level of activity and mean total cost by home ownership

	Minutes of activity per week				Total cost
	less than 150 minutes		150 minutes or more		
Owns home	N	row %	N	row %	mean ($)
No	367	49.9	369	50.1	4,015
Yes	923	40.8	1,340	59.2	3,407

Table 10H Level of activity and mean total cost by general health

	Minutes of activity per week				Total cost
	less than 150 minutes		150 minutes or more		
General health	N	row %	N	row %	mean ($)
Excellent	79	21.0	297	79.0	1,524
Very good	284	30.4	651	69.6	1,988
Good	457	47.5	505	52.5	3,121
Fair	287	58.8	201	41.2	6,111
Poor	178	78.1	50	21.9	9,599

Table 10I Level of activity and mean total cost by ability to be physically active

	Minutes of activity per week				Total cost
	less than 150 minutes		150 minutes or more		
Have the ability to be active	N	row %	N	row %	mean ($)
Strongly agree	151	18.5	666	81.4	2,211
Agree	499	38.3	804	61.7	2,828
Neutral	180	63.8	102	36.2	4,988
Disagree	295	73.9	104	26.1	6,247
Strongly disagree	154	84.6	28	15.4	6,488

Table 10J Level of activity and mean total cost by opportunity to be physically active

	Minutes of activity per week				Total cost
	less than 150 minutes		150 minutes or more		
Have the opportunity to be active	N	row %	N	row %	mean ($)
Strongly agree	169	20.0	675	80.0	2,443
Agree	642	43.6	831	56.4	3,223
Neutral	155	57.8	113	42.2	4,560
Disagree	213	76.3	66	23.7	6,419
Strongly disagree	97	82.9	20	17.1	6,041

Table 10K Level of activity and mean total cost by has a disability

	Minutes of activity per week				Total cost
	less than 150 minutes		150 minutes or more		
Has a disability	**N**	**row %**	**N**	**row %**	**mean ($)**
Yes	446	62.6	266	37.4	6,474
No	834	36.8	1,434	63.2	2,638

Examining Table 10A reveals that males are more likely to meet the threshold and have slightly less mean total cost. Examining Tables 10B1 and 10B2 reveals that older respondents are less likely to meet the threshold and have higher mean total cost. Examining Tables 10C1 and 10C2 reveals that as income increases the proportion of those meeting the threshold increases and the mean total cost decreases. Examining Table 10D reveals that those married or living with a partner are more likely to meet the threshold and have lower mean total cost than those in other categories. Examining Table 10E reveals that as the level of education increases the proportion of those meeting the threshold increases and the mean total cost decreases. Examining Table 10F reveals that students and those in full or part-time employment are more likely to meet the threshold and have lower mean total cost than those in other categories. Examining Table 10G reveals that those who own their home are more likely to meet the threshold and have lower mean total cost. Therefore, sex, age and measures of socio-economic status (income, marital status, education, work status, home ownership) are shown with their partial consideration across Table 10A to 10K to potentially confound the relationship between the level of activity and total cost.

To examine effects of confounding appropriately allowing for their multivariate interaction, regression models were used to estimate the difference in mean total cost between levels of physical activity (<150 vs ≥150 minutes/week) while adjusting for sex, age and measures of socio-economic status. Since the measures of socio-economic status are highly correlated, income was entered into the regression models first, followed by each of the other measures (marital status, education, work status, home ownership). After entering sex, age and income into the regression models, each of the other measures of socio-economic status, entered one at a time, were not statistically significant and had no appreciable effect on the estimate on the parameters in the model, indicating that income alone was sufficient to adjust for socio-economic status. The estimates and the 95% confidence interval of the difference in total costs between levels of physical activity, adjusted for all combinations of sex, age and income, are given in Table 11.

Table 11 Mean difference (≥150 minus <150 min/week) in total cost, with 95% confidence limits. This table is derived from the data from all respondents, N = 2986.

	Mean ($)	Lower Limit ($)	Upper Limit ($)
No Adjustment	-1,761	-2,182	-1,339
Adjusted for Sex	-1,748	-2,171	-1,326
Adjusted for Age	-1,666	-2,085	-1,247
Adjusted for Income	-1,572	-2,037	-1,107
Adjusted for Sex and Age	-1,624	-2,045	-1,202
Adjusted for Sex and Income	-1,569	-2,035	-1,104
Adjusted for Age and Income	-1,429	-1,891	-968
Adjusted for Sex, Age and Income	-1,393	-1,857	-928

The bottom line is that after adjusting for sex, age and income as covariates health care costs are lower by $1393 per person year for those who meet PA guidelines. While overall this is $368 lower than the $1,761 estimate without any adjustment, partial analysis for sex, age and income alone shows that income then age and sex had the greatest attribution in leading to this combined reduction.

The estimates in Table 11 includes the data from all respondents, allowing for the impact of high cost respondents, where four individuals had costs greater than $75,000, three of whom were in the population who did not meet the guidelines. Nevertheless, to allow the most robust analysis as well as a conservative base case analysis, the cost estimates in the population who do not meet guidelines and more importantly the potential incremental cost saving expected from shifting populations from those who do not meet guidelines to those who do can be significantly improved in terms of stability with removal of the four individuals with costs greater than $75,000. Table 12 is the same as Table 11, with the four respondents with total costs greater than $75,000 removed. The presence of these high cost respondents skew the distribution and raise concerns regarding the reliability of the 95% confidence intervals.

Table 12 Mean difference (≥150 minus <150 min/week) in total cost, with 95% confidence limits with the 4 respondents whose total cost exceeded $75,000 removed, N = 2,982

	Mean ($)	Lower Limit ($)	Upper Limit ($)
No Adjustment	-1,473	-1,863	-1,083
Adjusted for Sex	-1,460	-1,852	-1,067
Adjusted for Age	-1,434	-1,821	-1,046
Adjusted for Income	-1,144	-1,561	-726
Adjusted for Sex and Age	-1,407	-1,797	-1,017
Adjusted for Sex and Income	-1,145	-1,564	-727
Adjusted for Age and Income	-1,129	-1,5434	-714
Adjusted for Sex, Age and Income	-1,121	-1,538	-704

Removing the four high cost respondents from the sample, the incremental cost difference with covariate adjustment for sex, age and income between populations meeting and not meeting guidelines reduces from $1,393 per person year to $1,121 (95% CI $704, $1,538). This represents a $352 reduction compared to the unadjusted analysis where incremental costs are estimated as $1,473. Although removing the high cost respondents lowers the reduction in health care cost due to physical activity, the width of the confidence intervals remains mostly unchanged, demonstrating the robustness of the results in Table 11.

The $1,121 estimate, adjusting for sex, age and income and removing four high cost respondents, provides the most robust conservative base case estimate of overall potential cost savings. Overall, while confounder adjustment alone reduces the incremental cost saving on average by 20.9% from $1761 to $1,393 per person year, this increases to a 36.3% reduction or $1,121 per person year allowing for a conservative robust base case analysis removing four high cost respondents.

Table 13 contains the population level impact if health promotion and whole of government strategies in support of PA guidelines enabled shifting SA adult populations who currently undertake 0-149 minutes of physical activity to have physical activity reflecting that of populations who undertake 150+ minutes at a population level.

Table 13 Third analysis of potential for health system cost saving from adults meeting PA guidelines with covariate adjustment

SA adult population estimate June 2018	1,369,751
Survey population proportion not meeting guideline	42.12%
Estimated SA population not meeting guideline	576,954
Lower health cost per adult meeting vs not meeting PA guideline excluding the four high cost respondents	$1,121
Potential annual lower net health care cost	$646,765,434

Hence, the confounder adjusted analysis with a conservative base case suggests if SA adult populations who currently undertake 0-149 minutes of physical activity shifted to having physical activity reflecting that of populations who undertake 150+ minutes then net government health expenditure annually in SA has potential to reduce by $646 million annually. If high cost respondents are included, this increases to $803 million annually.

In terms of more realistic intra (extra population) and/or infra (across population) marginal effects this 2nd analysis from individual person data suggests, with removal of high cost tails as well as confounder adjustment:

(i) an absolute 5% reduction in the proportion of the population who do not meet PA guidelines i.e. from 42.12% to 37.12%, which equates to potential cost savings of 0.05/0.4212 × $646 million = $76.7 million per year.

(ii) an **infra**marginal relative 5% reduction in the proportion of the population who don't meet guidelines - from 42.12% to 40.06%, which equates to potential health system cost savings of 0.05 × 576,954 × $1,121 = $32.3 million per year.

(iii) an **intra**marginal reduction in health care costs per person across the population who don't meet guidelines of 5% towards the level of that of populations who do meet guidelines which equates to potential health system cost savings of 0.05 × $646 million = $32.3 million per year.

(iv) a 5% **intra**marginal reduction in health care costs per person across the population who do not meet guidelines which equates to potential health system cost savings of 0.05 × $4,932 × 576,954 people = $142.3 million per year.

(v) a 5% **intra**marginal reduction in health care costs per person across the whole population which equates to potential cost savings of (iv)+ 0.05 × $3,171 × 792,797 people= $125.7 million/year +$142.3 million/year = $268.0 million per year.

(vi) any combination of absolute (i) or infra marginal (ii) with different intramarginal (iii)-(v) factors noting that such intra and infra marginal impacts together are approximately additive.

Summary of health economic findings integrating across three analyses presented

The South Australian Active Lives study and survey undertaken in April 2019 enabled comparison of self-reported measures in 2,999 adults who meet or do not meet physical activity guidelines for undertaking 0-149 minutes or 150 minutes or more of physical activity per week. The main study estimated that 42.12% of the South Australian population do not currently meet physical activity guidelines and that adult populations relative to those not meeting guidelines had associated improved wellbeing, individual development, social connectedness and social capital. Trends were also found for adult populations meeting guidelines having lower probability of visits in the last year to GP, specialist doctor or other health professional or hospital inpatient admissions, outpatient clinic and emergency department visits.

The health economic analyses presented in this paper aimed to extend the main study analysis to start to inform the need for active live health promotion policy initiatives through robustly estimating potential population level health system cost savings from shifting adult populations from not meeting PA guidelines to meeting guidelines.

Findings to that end have been reported with three levels of increasingly robust and instructive analysis. The first analysis used population level aggregate weighted data in estimating resource use and cost differences for populations meeting and not meeting PA guidelines for 150 minutes or more provided by the main study without adjustment for the potential effects of differences in covariates between these populations, with a limiting assumption of normality in cost differences. The second used individual data to estimate cost differences under uncertainty both between populations meeting and not meeting guidelines and within populations in considering the 150 min of physical activity threshold and estimating marginal effects allowing for gamma distributions to fit cost data, while still not adjusted for potential effects of differences in covariates. This second analysis established health economic support for current adult physical activity guidelines of 150 minutes per week with the greatest population cost saving potential from meeting guidelines at that threshold level from 30 minute intervals considered. The third and most robust analysis uses individual data to estimate cost differences under uncertainty while adjusting for covariates in comparisons between populations meeting and not meeting guidelines. The second and third analyses also undertake sensitivity analysis to consider the impacts of including high cost respondents removed to allow robust modelling under uncertainty in conservative base case analysis. Analysis from the three levels of analysis as well as sensitivity analysis to allow for the potential effect of high cost respondents in the 2nd and 3rd analysis are summarised in Table 14.

Table 14 Lower costs meeting vs not meeting guidelines annually

			Whole population	Marginal shift	
		per adult	level*	abs. 5% population	5% of those not meeting
No covariate adjustment		$	$ million	$ million	$ million
1st analysis (based sample statistics)	High cost respondents included	1,625	938	111.30	46.88
2nd analysis (individual, continuous)	High cost respondents included	1,761	1,016	120.61	50.80
conservative	High cost respondents removed	1,473	850	100.88	42.94
Covariate adjustment		$	$ million	$ million	$ million
3rd analysis (individual, continuous)	High cost respondents included	1,393	804	95.41	40.18
3rd analysis (individual, continuous)	High cost respondents removed	1,121	647	76.78	32.34
* 42.12% of adult population not meeting guidelines or 576,954 of SA adult population 1,369,751 June 2018					

Comparison between results from these three increasingly robust levels of analysis and sensitivity analysis in Table 14 for the second and third analyses is instructive in seeing:

(i) In comparison between the second and first analysis the importance and impact of allowing for individual data distribution and modelling the cost data using a gamma distribution to account for the positive skewing distribution of costs.

(ii) In comparison between the third and second analysis the impact of allowing for covariate adjustment.

(iii) In comparison between the third and first analysis the combined impact of (i) and (ii); and

(iv) The impact of removing high cost respondents in comparison between sensitivity and base case analyses in the 2nd and 3rd analysis.

The advantages of analysing the individual-level data are three-fold:

(i) Provided evidence in support of using 150 minutes per week as the threshold.

(ii) Adjusted the estimates of health care cost saving in meeting the threshold for the confounders of sex, age and socio-economic status.

(iii) Provided evidence that there is no easily identifiable sub-group that would benefit most from meeting the threshold (see evidence on effect modification in Appendix 1 and Tables 15 and 16).

Overall, allowing for covariate adjustment mitigated somewhat the findings of potential for health system cost savings in meeting vs not meeting PA guidelines for individuals, at a population level and in terms of potential for cost savings with more 5% marginal effects without adjustment and to about the same extent as undertaking conservative base case analysis with removal of high cost respondents. Never-the-less for the most robust 3rd analysis with covariate adjustment even under the most conservative model with high cost respondents removed the potential annual cost saving remains more than $1,000 per adult ($1,121) from meeting vs not meeting PA guidelines and $646 million annually if the whole population were shifted. The potential cost saving to the SA health system from more achievable 5% marginal shifts with health promotion strategies in the population under this conservative assumption ignoring high cost respondents remains more than $30 million annually.

Policy implications – critical need for effective health promotion of active communities

In general, the extent to which such cost savings could arise in practice depends on the effectiveness, community ownership and associated population multiplier effects of community health promotion strategies (Eckermann et al. 2014, 2017 chapter 4; Hawe et al. 2008, 2009; Shiell et al. 1995, 2008, 2017; Rychetnik et al 2002). In that respect it is important to recognise that effective health promotion strategies and multiplier effects are associated with positive community network effects, social connections, and social capital formation. Hence, health promotion programs that in the long-term increase community connectedness and build social capital are key to the effectiveness of health promotion programs.

In ageing adult populations health promotion strategies that have been effective in promotion of active lives in communities and populations internationally are whole of government strategies for Age and Dementia friendly communities. Such strategies include age and dementia friendly transport systems, taxi drivers, shops, walking paths, community gardens and more generally amenity to and community programs in support of use of public spaces such as libraries and parks (Eckermann 2017, chapter 12; Eckermann, Phillipson and Fleming 2019). Activities in public places should also consider cultural appropriateness for any given community setting with for example socially and culturally appropriate activities in different community settings including tai chi, boules (lawn bowls, bocce or petanque), salsa dancing, community gardening or community food gathering and foraging, communal eating clubs or more generally cooking and/or eating together. Inexpensive environmental design solutions can also involve supporting carer and living arrangements of ageing populations in the community with flexible housing and more generally modified

homes and communal living arrangements such as co-housing, granny flats, laneway housing, naturally occurring retirement communities and virtual retirement villages (Newton 2015).

While such strategies are generally inexpensive relative to health care cost savings from more active healthier populations that such strategies enable, in over 65 populations even greater cost savings arise from avoiding age care costs (Kalache 2013; Eckermann 2017 chapter 12; Eckermann, Phillipson and Fleming 2019). In that respect it should be noted that the direct health and residential care costs of people living with dementia in South Australian residential aged care are estimated to be A$88,000 per resident per year, while $12,962 less with clustered residential versus larger institutional style care after adjusting for resident- and facility-related factors (Dyer et al. 2018; Gnanamanickam et al. 2018). Importantly in undertaking reform of age and health care environments towards budget constrained successful ageing these clustered, domestic scale models of residential aged care have also been shown to have significantly higher quality of life for residents than institutional aged care (EQ-5D-5L score greater by 0.107, p=0.008), while reducing hospitalisations and emergency department presentations (Harrison et al. 2018; Dyer et al. 2018).

More generally, as the WHO age friendly cities guidelines (WHO 2004) and Alzheimer's Disease International (ADI 2016) dementia friendly guidelines highlight and Alexandre Kalache emphasised in his case study and recommendations for South Australia, facing the challenge of baby boomer ageing there is an imperative to invest in age friendly communities to support successful ageing of baby boomer populations and reduce health and age care costs. In the absence of physically, mentally and socially active baby boomer populations South Australia, Australia and indeed the World more generally will face burgeoning health and aged care costs while not meeting Baby Boomer preferences for active successful ageing, what Kalache (2013) has coined 'Gerentolescence'.

Reforms in caring for aging populations, including those with dementia are increasingly being called for internationally in the context of a 3-fold increase in numbers associated with ageing of baby boomers projected from 2010 to 2050 (WHO 2012, 2015; Alzheimer's Disease International 2016; Eckermann 2017, chapter 12; Eckermann, Phillipson and Fleming 2019). What has emerged as clear in addressing this challenge with budget constraints is the importance of environmental and whole of governments solutions and the right policy balance of community and care based environmental strategies to enable budget constrained successful ageing across health and aged care systems (WHO 2002, 2007; Davis et al. 2009; Kalache 2013; Eckermann 2017, chapter 12; Phillipson et al. 2018; Eckermann, Phillipson and Fleming 2019). In practice supporting low cost whole of government approaches and avoiding high cost of health and aged care through the creation of age and dementia friendly communities is the most effective and efficient strategy.

Australia, as with other developed countries, has suffered from a chronic underfunding of community health promotion (Jackson and Shiell 2017). We have also failed to capitalise on the potential for the built environment to promote opportunities for our older populations to enable active ageing (WHO 2015). All of these point to a primary need for whole of government health and age care strategies and regulatory reform in creating age and dementia friendly environments to jointly address health and age care needs in research and practice (Eckermann 2017, chapter 12, Eckermann, Philipson and Fleming 2019).

Further, such environmental and whole of government strategies for age and dementia friendly communities are more generally supportive of active communities across the lifecycle. In the very young the same environmental and whole of government policies are key to supporting 24 hour integrated movement behaviours (joint physical activity, sedentary behaviour and sleep), and lifestyle for active early childhood populations (Okely et al. 2017) and the trajectory for positive habits and lifestyle behaviours from early years across their life cycle. Child populations meeting IMGs are associated with better body composition, cardiorespiratory and musculoskeletal fitness, cardiovascular and metabolic health, academic achievement and cognition, mental health and quality of life, emotional regulation, and pro-social behaviours in childhood and across the life cycle (Dumuid et al. 2018; Okely et al. 2017; Tremblay et al. 2016; Katzmarzyk et al. 2013, Walsh 2018, Saunders et al. 2016, Roman-Viñas et al. 2016). Hence, creating environments and whole of government policies for active communities is more generally supportive of active lives in all adult as well as young and ageing populations.

The importance of social connectedness and social capital formation in creating active communities and populations is also supported by evidence in the Active Lives survey and study itself. The Active Lives survey found consistent positive association between meeting PA guidelines (having 150+ versus 0-149 minutes of PA per week) and community connectedness, trust, identity, social capital formation, individual development, subjective health status and wellbeing.

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Appendix 1 Effect modification

The examination of effect modification is given in Table 15A through 15K. The number of respondents and mean cost is cross tabulated by the level of physical activity and each ancillary variable. In addition, the reduction in mean total cost due to physical activity is given for each level of the ancillary variable. The p-value provided relates to the comparison of the reduction in mean cost (due to physical activity) between levels of the ancillary variable. For example, the p-value of 0.0271 in Table 15G indicates that the value $-2,164 (the reduction in mean total cost due to the increase in physical activity for respondents that do not own their home) is significantly different from $-1,584 (the reduction in mean total cost for respondents that do own their home). The comparisons associated with these p values are adjusted for the confounders of sex, age and income. None of the other ancillary variables reach statistical significance, and none show any consistent pattern that would help identify subgroups for specific public health intervention.

The robustness of the approached is demonstrated in Tables 16A through 16K. These table are the same as Tables 15A through 15K with the four respondents whose total cost exceeded $75,000 removed. The results are same, and the only significant effect modifier is home ownership.

Table 15A Frequency and mean total cost by level of activity and sex (*p*=0.5742)

	Minutes of activity per week				Total cost
	less than 150 minutes		150 minutes or more		
Sex	**N**	**Mean ($)**	**N**	**Mean ($)**	**Difference ($)**
Male	451	4,425	725	2,722	-1,703
Female	833	4,633	977	2,856	-1,777
Overall	1,284	4,560	1,702	2,799	-1,761

Table 15B1 Frequency and mean total cost by level of activity and age (*p*=0.6738)

	Minutes of activity per week				Total cost
	less than 150 minutes		150 minutes or more		
Age	N	Mean ($)	N	Mean ($)	Difference ($)
34 years or younger	87	3,462	207	2,636	-826
35 to 44 years	162	4,965	214	2,867	-2,098
45 to 49 years	100	4,540	131	2,035	-2,504
50 to 54 years	116	3,702	161	2,159	-1,543
55 to 64 years	284	4,692	399	2,557	-2,136
65 to 74 years	316	4,125	425	3,189	-936
75 years or over	219	5,615	165	3,729	-1,886
Overall	1,284	4,560	1,702	2,799	-1,761

Table15B2 Frequency and mean total cost by level of activity and age (*p*=0.9720)

	Minutes of activity per week				Total cost
	less than 150 minutes		150 minutes or more		
Age	N	Mean ($)	N	Mean ($)	Difference ($)
Less than 75 years	1,065	4,343	1,537	2,699	-1,644
75 years or over	219	5,615	165	3,729	-1,886
Overall	1,284	4,560	1,702	2,799	-1,761

Table15C1 Frequency and mean total cost by level of activity and income (*p*=0.7945)

	Minutes of activity per week				Total cost
	less than 150 minutes		150 minutes or more		
Income ($)	N	Mean ($)	N	Mean ($)	Difference ($)
Up to 12,000	36	3,435	27	3,823	389
12,001-20,000	132	5,222	98	3,537	-1,685
20,001-40,000	261	5,465	270	3,938	-1,527
40,001-60,000	159	4,204	203	2,039	-2,165
60,001-80,000	132	5,055	177	2,516	-2,538
80,001-100,000	112	3,616	160	2,340	-1,276
100,001-150,000	106	3,330	229	2,554	-776
150,001-200,000	44	4,025	140	2,962	-1,062
Over 200,000	21	3,465	93	2,371	-1,094
Overall	1,003	4,569	1,397	2,840	-1,730

Table 15C2 Frequency and mean total cost by level of activity and income (*p*=0.9448)

	Minutes of activity per week				Total cost
	less than 150 minutes		150 minutes or more		
Income ($)	N	Mean ($)	N	Mean ($)	Difference ($)
Up to 40,000	429	5,220	395	3,831	-1,389
Over 40,000	574	4,083	1,002	2,449	-1,634
Overall	1,003	4,569	1,397	2,840	-1,730

Table 15D Frequency and mean total cost by level of activity and marital status (*p*=0.6021)

	Minutes of activity per week				Total cost
	less than 150 minutes		150 minutes or more		
Marital status	N	Mean ($)	N	Mean ($)	Difference ($)
Married	631	4,060	982	2,662	-1,398
Living with a partner	101	4,354	164	3,099	-1,255
Separated	72	4,527	74	3,560	-966
Divorced	172	4,745	173	2,976	-1,770
Widowed	147	6,474	115	3,426	-3,048
Never Married	144	4,954	176	2,214	-2,741
Overall	1,267	4,585	1,684	2,781	-1,806

Table 15E Frequency and mean total cost by level of activity and education (*p*=0.2840)

	Minutes of activity per week				Total cost
	less than 150 minutes		150 minutes or more		
Education	N	Mean ($)	N	Mean ($)	Difference ($)
Some primary school	9	5,369	6	1,777	-3,592
Completed primary school	22	2,866	14	3,594	728
Some high school	298	4,973	290	3,711	-1,262
Completed high school	220	4,647	250	2,247	-2,400
TAFE, Trade or certificate	247	4,061	288	3,177	-855
Diploma, advanced diploma	142	5,412	220	2,467	-2,945
University or some other tertiary degree	338	4,106	628	2,535	-1,572
Overall	1,276	4,526	1,696	2,800	-1,726

Table 15F Frequency and mean total cost by level of activity and work status (*p*=0.0949)

	Minutes of activity per week				Total cost
	less than 150 minutes		150 minutes or more		
Work status	**N**	**Mean ($)**	**N**	**Mean ($)**	**Difference ($)**
Full-time	288	3,051	588	2,273	-778
Part-time	166	3,399	251	2,513	-886
Casual	93	3,896	113	2,479	-1,417
Unemployed	74	4,421	52	2,894	-1,527
Engaged in home duties	53	4,702	41	1,901	-2,801
Student	14	4,324	29	847	-3,477
Retired	455	4,945	531	3,230	-1,715
Unable to work	94	10,294	37	7,551	-2,742
Carer	23	4,872	30	5,289	416
Volunteer work	16	2,113	17	3,283	1,170
Overall	1,276	4,550	1,689	2,788	-1,761

Table 15G Frequency and mean total cost by level of activity and home ownership (*p*=0.0271)

	Minutes of activity per week				Total cost
	less than 150 minutes		150 minutes or more		
Owns home	**N**	**Mean ($)**	**N**	**Mean ($)**	**Difference ($)**
No	365	5,101	368	2,938	-2,164
Yes	919	4,345	1,334	2,761	-1,584
Overall	1,284	4,560	1,702	2,799	-1,761

Table 15H Frequency and mean total cost by level of activity and general health (*p*=0.6054)

	Minutes of activity per week				Total cost
	less than 150 minutes		150 minutes or more		
General health	**N**	**Mean ($)**	**N**	**Mean ($)**	**Difference ($)**
Excellent	79	2,109	296	1,367	-742
Very good	284	2,087	648	1,944	-143
Good	455	3,339	502	2,924	-414
Fair	285	6,122	201	6,095	-26
Poor	176	10,214	50	7,435	-2,779
Overall	1,279	4,551	1,697	2,787	-1,764

Table 15I Frequency and mean total cost by level of activity and ability to be physically active (*p*=0.9737)

	Minutes of activity per week				Total cost
	less than 150 minutes		150 minutes or more		
Have the ability to be active	**N**	**Mean ($)**	**N**	**Mean ($)**	**Difference ($)**
Strongly agree	151	2,672	662	2,106	-566
Agree	497	2,880	801	2,795	-84
Neutral	178	5,443	102	4,194	-1,249
Disagree	294	6,585	104	5,291	-1,294
Strongly disagree	153	6,696	28	5,347	-1,349
Overall	1,273	4,528	1,697	2,805	-1,723

Table 15J Frequency and mean total cost by level of activity and opportunity to be physically active (*p*=0.0828)

	Minutes of activity per week				Total cost
	less than 150 minutes		150 minutes or more		
Have the opportunity to be active	**N**	**Mean ($)**	**N**	**Mean ($)**	**Difference ($)**
Strongly agree	169	3,160	671	2,262	-897
Agree	640	3,490	830	3,017	-473
Neutral	155	5,922	112	2,675	-3,247
Disagree	210	6,978	66	4,641	-2,336
Strongly disagree	97	5,867	19	6,930	1,063
Overall	1,271	4,500	1,698	2,803	-1,697

Table 15K Frequency and mean total cost by level of activity and has a disability (*p*=0.2711)

	Minutes of activity per week				Total cost
	less than 150 minutes		150 minutes or more		
Has a disability	**N**	**Mean ($)**	**N**	**Mean ($)**	**Difference ($)**
Yes	443	6,818	266	5,902	-915
No	831	3,364	1,428	2,216	-1,148
Overall	1,274	4,565	1,694	2,795	-1,770

Table 16A Frequency and mean total cost by level of activity and sex (*p*=0.6246) with the 4 respondents whose total cost exceeded $75,000 removed

	Minutes of activity per week				Total cost
	less than 150 minutes		150 minutes or more		
Sex	N	Mean ($)	N	Mean ($)	Difference ($)
Male	450	3,957	725	2,722	-1,235
Female	831	4,347	976	2,748	-1,599
Overall	1,281	4,210	1,701	2,737	-1,473

Table 16B1 Frequency and mean total cost by level of activity and age (*p*=0.6619) with the 4 respondents whose total cost exceeded $75,000 removed

	Minutes of activity per week				Total cost
	less than 150 minutes		150 minutes or more		
Age	N	Mean ($)	N	Mean ($)	Difference ($)
34 years or younger	87	3,462	207	2,636	-826
35 to 44 years	161	3,930	213	2,372	-1,558
45 to 49 years	100	4,540	131	2,035	-2,504
50 to 54 years	116	3,702	161	2,159	-1,543
55 to 64 years	283	4,443	399	2,557	-1,886
65 to 74 years	316	4,125	425	3,189	-936
75 years or over	218	4,655	165	3,729	-926
Overall	1,281	4,210	1,702	2,737	-1,473

Table 16B2 Frequency and mean total cost by level of activity and age (*p*=0.9225) with the 4 respondents whose total cost exceeded $75,000 removed

	Minutes of activity per week				Total cost
	less than 150 minutes		150 minutes or more		
Age	N	Mean ($)	N	Mean ($)	Difference ($)
Less than 75 years	1,063	4,119	1,536	2,631	-1,488
75 years or over	218	4,655	165	3,729	-926
Overall	1,281	4,210	1,701	2,737	-1,473

Table 16C1 Frequency and mean total cost by level of activity and income (*p*=0.7261) with the 4 respondents whose total cost exceeded $75,000 removed

	Minutes of activity per week				Total cost
	less than 150 minutes		150 minutes or more		
Income ($)	N	Mean ($)	N	Mean ($)	Difference ($)
Up to 12,000	36	3,435	27	3,823	389
12,001-20,000	132	5,222	98	3,537	-1,685
20,001-40,000	261	5,465	270	3,938	-1,527
40,001-60,000	159	4,204	203	2,039	-2,165
60,001-80,000	131	3,452	177	2,516	-936
80,001-100,000	111	2,102	160	2,340	238
100,001-150,000	106	3,330	229	2,554	-776
150,001-200,000	44	4,025	139	2,205	-1,820
Over 200,000	21	3,465	93	2,371	-1,094
Overall	1,001	4,192	1,396	2,764	-1,428

Table16C2 Frequency and mean total cost by level of activity and income (*p*=0.8803) with the 4 respondents whose total cost exceeded $75,000 removed

	Minutes of activity per week				Total cost
	less than 150 minutes		150 minutes or more		
Income ($)	N	Mean ($)	N	Mean ($)	Difference ($)
Up to 40,000	429	5,220	395	3,831	-1,389
Over 40,000	572	3,421	1,001	2,343	-1,078
Overall	1,001	4,192	1,396	2,764	-1,428

Table 16D Frequency and mean total cost by level of activity and marital status (*p*=0.5869) with the 4 respondents whose total cost exceeded $75,000 removed

	Minutes of activity per week				Total cost
	less than 150 minutes		150 minutes or more		
Marital status	**N**	**Mean ($)**	**N**	**Mean ($)**	**Difference ($)**
Married	630	3794	981	2554	-1,240
Living with a partner	101	4,354	164	3,099	-1,255
Separated	72	4,527	74	3,560	-966
Divorced	172	4,745	173	2,976	-1,770
Widowed	145	4562	115	3,426	-1,136
Never Married	144	4,954	176	2,214	-2,741
Overall	1,264	4230	1,683	2,719	-1,511

Table 16E Frequency and mean total cost by level of activity and education (*p*=0.2407) with the 4 respondents whose total cost exceeded $75,000 removed

	Minutes of activity per week				Total cost
	less than 150 minutes		150 minutes or more		
Education	**N**	**Mean ($)**	**N**	**Mean ($)**	**Difference ($)**
Some primary school	9	5,369	6	1,777	-3,592
Completed primary school	22	2,866	14	3,594	728
Some high school	297	4,736	290	3,711	-1025
Completed high school	220	4,647	250	2,247	-2,400
TAFE, Trade or certificate	246	3,380	288	3,177	-203
Diploma, advanced diploma	142	5,412	220	2,467	-2,945
University or some other tertiary degree	337	3,481	627	2,366	-1,114
Overall	1,273	4,174	1,696	2,738	-1,436

Table 16F Frequency and mean total cost by level of activity and work status (*p*=0.0791) with the 4 respondents whose total cost exceeded $75,000 removed

	Minutes of activity per week				Total cost
	less than 150 minutes		150 minutes or more		
Work status	**N**	**Mean ($)**	**N**	**Mean ($)**	**Difference ($)**
Full-time	288	3,051	587	2,093	-958
Part-time	165	2,379	251	2,513	134
Casual	92	3,120	113	2,479	-641
Unemployed	74	4,421	52	2,894	-1,527
Engaged in home duties	53	4,702	41	1,901	-2,801
Student	14	4,324	29	847	-3,477
Retired	454	4,482	531	3,230	-1,252
Unable to work	94	10,294	37	7,551	-2,742
Carer	23	4,872	30	5,289	416
Volunteer work	16	2,113	17	3,283	1,170
Overall	1,273	4,198	1,688	2,726	-1,472

Table 16G Frequency and mean total cost by level of activity and home ownership (*p*=0.0235) with the 4 respondents whose total cost exceeded $75,000 removed

	Minutes of activity per week				Total cost
	less than 150 minutes		150 minutes or more		
Owns home	**N**	**Mean ($)**	**N**	**Mean ($)**	**Difference ($)**
No	365	5,101	368	2,938	-2,164
Yes	916	3,855	1,333	2,682	-1,173
Overall	1,281	4,210	1,701	2,737	-1,473

Table 16H Frequency and mean total cost by level of activity and general health (*p*=0.6350) with the 4 respondents whose total cost exceeded $75,000 removed

	Minutes of activity per week				Total cost
	less than 150 minutes		150 minutes or more		
General health	**N**	**Mean ($)**	**N**	**Mean ($)**	**Difference ($)**
Excellent	79	2,109	296	1,367	-742
Very good	284	2,087	648	1,944	-143
Good	455	3,339	502	2,924	-414
Fair	283	5,139	200	5,585	446
Poor	175	9,291	50	7,435	-1,856
Overall	1,276	4,200	1,697	2,725	-1,475

Table 16I Frequency and mean total cost by level of activity and ability to be physically active (*p*=0.9395) with the 4 respondents whose total cost exceeded $75,000 removed

	Minutes of activity per week				Total cost
	less than 150 minutes		150 minutes or more		
Have the ability to be active	**N**	**Mean ($)**	**N**	**Mean ($)**	**Difference ($)**
Strongly agree	151	2,672	662	2,106	-566
Agree	497	2,880	801	2,795	-84
Neutral	177	4,504	102	4,194	-310
Disagree	292	5,636	103	4,292	-1,345
Strongly disagree	153	6,696	28	5,347	-1,349
Overall	1,270	4,175	1,696	2,743	-1,432

Table 16J Frequency and mean total cost by level of activity and opportunity to be physically active (*p*=0.0776) with the 4 respondents whose total cost exceeded $75,000 removed

	Minutes of activity per week				Total cost
	less than 150 minutes		150 minutes or more		
Have the opportunity to be active	N	Mean ($)	N	Mean ($)	Difference ($)
Strongly agree	169	3,160	671	2,262	-897
Agree	638	3,114	829	2,890	-223
Neutral	155	5,922	112	2,675	-3,247
Disagree	209	5,982	66	4,641	-1,341
Strongly disagree	97	5,867	19	6,930	1,063
Overall	1,268	4,147	1,697	2,741	-1,405

Table16K Frequency and mean total cost by level of activity and has a disability (*p*=0.3111) with the 4 respondents whose total cost exceeded $75,000 removed

	Minutes of activity per week				Total cost
	less than 150 minutes		150 minutes or more		
Has a disability	N	Mean ($)	N	Mean ($)	Difference ($)
Yes	442	6,347	265	5,516	-830
No	829	3,074	1,428	2,216	-859
Overall	1,271	4,212	1,693	2,732	-1,480