ACE Prevention Briefing Paper

Hip and knee replacement for osteoarthritis

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1. Summary

1.1 The interventions

Musculoskeletal conditions are a major cause of disability for Australian citizens. Among these, Osteoarthritis accounts for the largest burden. There is no cure for osteoarthritis. A number of conservative therapies exist to manage the condition. Once these therapies have been exhausted, surgical interventions can be administered.

This briefing paper evaluates the cost-effectiveness of joint replacement surgery of hips and knees for men and women with osteoarthritis aged 40 and over. Amongst various surgical options, primary conventional total hip replacement, primary total knee replacement, and their subsequent revisions are considered in this analysis.

1.2 Results

Both hip and knee replacement are very cost-effective.

Scenarios	ICER (hip replacement)		ICER (knee replacement)	
	Median	95%UI	Median	95%UI
Without time cost	3,600	3,200 – 4,200	9,900	8,400 – 12,000
With time cost	5,000	4,200 –6,200	12,000	10,000 –15,000

ICER: Incremental cost-effectiveness ratio, which is expressed as AUD per disability-adjusted life year (DALY) averted ; UI: uncertainty interval

1.3 Recommendations

Both hip and knee replacement surgeries are highly cost-effective under the AUD 50,000 per DALY threshold level.

1.4 Second stage filter analysis summary

Cost per DALY	Strength of evidence	Equity	Acceptability	Feasibility	Sustainability	Relevance to indigenous population	Side-effects better reword as 'other effects' (not captured in modelling)?
Without time cost: Hip:$3,600 Knee:$9,900 **With time cost:** Hip:$5,000 Knee:$12,000	Substantial evidence on efficacy measured in generic and arthritis-specific instruments, but less sufficient in preference-based instruments (utility)	The long waiting list at public hospitals may be of concern	Not an issue since this procedure is widely practiced	High, since this is an established procedure and is widely practiced	Although surgical interventions are costly, substantial costs on OA management can be off set	Lower relevance due to lesser burden of OA among indigenous population compared to other Australians	Positive: Implants may survive longer due to technological advancement Negative: Potential risks for infections could significantly increase disability

Decision point: The ICER is significantly lower than AUD 50,000 per DALY threshold level, and it is unlikely that the conclusion would change with more accurate information (e.g. intervention effects)

Policy Considerations: Unless effective preventive measures of OA onset would become available, hip and knee replacement surgeries should form a key role in OA management in conjunction with other effective non-surgical therapies.

2. Main body of document

2.1 Introduction

Musculoskeletal conditions constitute a major burden to Australian citizens. Over 6.1 million people are estimated to suffer from a musculoskeletal condition based on the National Health Survey 2004.[1] Musculoskeletal conditions, particularly osteoarthritis, are among the most frequently managed diseases by general practitioners accounting for 17% of consultations in 2003-2004.[2] In 2002, arthritis and musculoskeletal conditions were selected as the 7th National Health Priority Area.[3] The justifications for their addition included: that they affect one third of the population in Australia; are the second most common reasons to consult general practitioners; are the third leading causes of health expenditure; and significant limitations of people's activities are caused by these conditions.[3]

Osteoarthritis (OA) is the most common type of joint problems. According to the Australian Burden of Disease and Injury study 2003,[4] OA accounted for 34,578 DALYs and was the largest contributor to musculoskeletal disease burden. The health expenditure associated with OA was AUD 1.1 billion in 2000-2001 or 25% of all expenditure for musculoskeletal conditions[3]. Responding to the high burden of OA, the National Arthritis and Musculoskeletal Conditions Advisory Group prepared a National Action Plan.[5] One of the characteristics of OA is that the prevalence is higher amongst lower socio-economic quintiles, but not necessarily among indigenous population.[6]

Currently there are limited measures to prevent OA, and there is no cure.[3] However, various non-surgical and surgical procedures have become available to manage the symptoms associated with OA and improve physical mobility and quality of life. Guidelines for conservative therapies, including analgesia, exercise, non steroidal anti-inflammatory drugs and others, have been developed for Australia as the primary management of OA.[2] There is further guideline for surgical intervention when all conservative therapies have been exhausted.[7] Whilst several options are available for surgical interventions, joint arthroplasty for hip and knees has particularly been shown to be efficacious to improve the quality of life of people with OA.[8] The aim of this study is to evaluate the cost-effectiveness of total hip and knee replacements for OA patients in Australia.

2.2 Definition of interventions

The interventions are total replacement of hips and knees in men and women with OA aged over 40 years. Whilst alternative methods are available for primary surgeries (i.e. hip resurfacing, uni-compartmental knee arthroplasty etc.), only primary conventional total hip replacement and primary total knee replacement,[i] including their subsequent revisions, were considered in this analysis, as they constitute the majority of surgeries in Australia (91% of OA primary hip, 86% of OA primary knee),[9] and the evidence on efficacy of other types of implants has yet to be established.

2.3 Health states affected by the interventions

Approximately 90% of replacement surgeries conducted in Australia have OA as their primary diagnosis.[9] In the Australian Burden of Disease and Injury study 2003, OA was divided into four grades with different disability weights assigned (see Table 1). OA is a chronic non-fatal disease that significantly affects the well being of patients. Surgical intervention primarily aims to improve the quality of life of people with OA.

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[i] Although various expressions may be used for different categories of surgeries, the terminologies used in this paper are consistent with the National Joint Replacement Registry of the Australian Orthopaedic Association.

Table 1: Case definition and sequelae

OA sequelae	Definition	DW
Grade 2 (radiological)	Definite osteophytes in hip or knee	0.01
Grade 2 (symptomatic)	Grade 2 and pain for at least 1 month in last 12	0.14
Grade 3-4 (asymptomatic)	Osteophytes and joint space narrowing in hip or knee, deformity also present for Grade 4	0.14
Grade 3-4 (symptomatic)	Grade 3+ and pain for at least 1 month in last 12	0.42

Source: The Burden of Disease and Injury in Australia 2003[4]

2.4 Current practice

Between 1999 and 2007, a cumulative number of 121,636 hips and 186,042 knees have received surgical procedures among people with OA.[10] The Australian Burden of Disease and Injury study 2003 estimated the number of people with OA grade 2 (radiological) or higher to be approximately 300 thousand in 2003.[4] The number of replacement surgeries performed in 2003, on the other hand, was 18,606 for hips (primary conventional total hip replacement and primary total resurfacing hip replacement) and 25,835 for knees (primary total knee replacement and primary unicompartmental knee replacement), of which in excess of 90% were potentially due to OA.[9] If we consider that only the most advanced OA cases would qualify to be referred to surgical procedures, a substantial proportion of severe OA patients are undergoing surgical procedures.

2.5 Efficacy of the hip and knee replacement

The efficacies of hip and knee replacement surgeries have been evaluated by various instruments in the world. Such instruments can range from generic (e.g. SF-36: Medical Outcomes Study Short-Form 36),[11] arthritic-specific (e.g. WOMAC: Western Ontario and McMaster University Osteoarthritis Index),[12] or utility (e.g. EQ-5D: EuroQol 5-dimensions).[13] Whilst we use the disability weight (DW) from the Australian Burden of Disease and Injury study 2003 to quantify the disabilities faced by OA patients, we were not able to identify any study utilising this instrument to measure the effect of hip and knee replacement. Therefore, we estimated the effect size on DW from literature utilising other instruments under the assumption:

$$DW_{post} = DW_{pre} \times \frac{1 - Score_{post}}{1 - Score_{pre}}$$

where DW_{pre} is the DW of pre-surgery (0.42), DW_{post} the DW of post-surgery, $Score_{pre}$ the single index of pre-surgery score of other instruments, and $Score_{post}$ the single index of post-surgery scores from other instruments.[ii] For hip replacement, we used the regression model from Briggs et al.[14] utilising EQ-5D in their study.[iii] We used the median pre/post-quality of life scores for man and woman to estimate the effect size, since the scores did not substantially vary between ages. On the other hand, we were not able to identify an appropriate source for knee replacement providing a regression model like this. Therefore we referred to the literature included in a systematic review[8] reporting the effects in EQ-5D, HAQ (health assessment questionnaire),[15] and SF-36, and performed a non-parametric bootstrap amongst 13 studies with 16 indexes.[iv] In order to derive the effect sizes from studies using SF-36, we used the Transfer to Utility (TTU) technique developed by Segal et al.[16]

2.6 Modelling to health outcomes

The analysis employed a discrete event micro-simulation model to follow up all individuals with OA who were 40 years of age or older in 2003. We limited the inclusion criteria to males and females who had at least one hip or knee with grade 2 symptomatic OA or higher (DW 0.14-0.42). The number of individuals for each sex/age-group was obtained from the

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[ii] An extension of this form was used for knee replacement. See Appendix for details.

[iii] See Appendix for regression coefficients used for this analysis.

[iv] See Appendix for the list of literature included.

Australian Burden of Disease and Injury study 2003. Whilst the study did not distinguish people with hip and knee OA, we assumed that the proportion was the same as the proportion of the number of surgeries conducted for hip and knee replacements in 2003. 68,908 individuals (30,347males and 38,561 females) with hip OA and 100,657 individuals (42,930 males and 57,727 females) with knee OA entered the simulation who were followed-up until extinct.

The individuals would move from one state to another by means of time to progression of OA severity, time to decision for surgery, risk of surgical success and death, survival period of implants to revisions, and time to death. We accounted for two hips or knees for each individual under the assumption that the states of hips or knees are independent to each other. Random draws from continuous survival curves determined the time of transitions to the next state. The process repeats over the life course until the person dies. Other events, such as death from surgery, were determined by assessing whether a randomly drawn uniform number between 0 and 1 was less than the probability of that event. Figure 1 illustrates the state transitions the individuals may follow.

The input parameters were drawn from various sources. The Australian Burden of Disease and Injury study 2003 provided most of the population and epidemiological parameters. The Australian joint replacement registry provided information on surgeries such as numbers of operations, causes of operations, and short term revision rates of implants. Long term survival rates of implants, probability of surgical deaths, proportion of bilateral OA, progression of OA severities were derived from various international literature. Table 2 summarises the sources of information.

Figure 1: State transitions of people with osteoarthritis

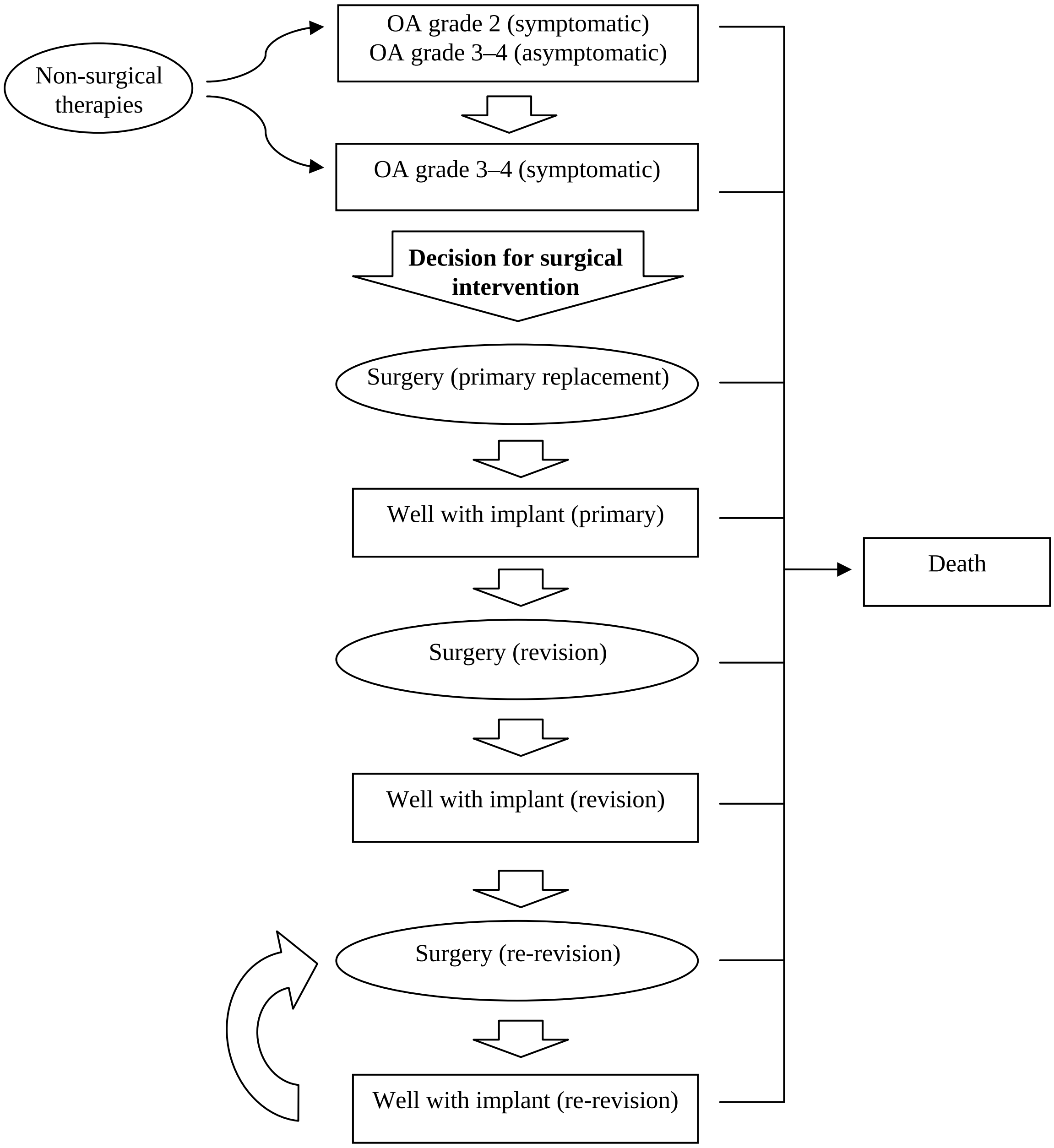


Table 2. Data sources

Parameters	Sources of information	Remarks
Population and demographic		
Population	ABOD 2003[4]	1y age-group
Mortality rate	ABOD 2003	5y age-group
PYLD	ABOD 2003	1y age-group
Osteoarthritis		
Prevalence (all)	NHS 2001[1]	All age-groups
Prevalence (grade 2 symptomatic+)	ABOD 2003	5y age-group
Proportion of number of people in each grade	ABOD 2003, Literature[17, 18]	<75, 75+
Mortality RR (OA)	ABOD 2003	All age-groups
Progression of OA severity	Literature,[19] ABOD 2003	
Proportion of bilateral OA	Literature[20-28]	
DW	ABOD 2003	
Intervention (hip and knee replacement)		
Proportion of OA as primary diagnosis	AJRR 2007[29]	All age-groups
Number of operations	AJRR 2004[30]	Five age-groups
Surgical death rate	CJRR 2007[31], AJRR 2007	Three age-groups
Revision rate (short term)	AJRR 2008[9]	
Revision rate (long term)	Literature[32-38]	
Effect	Literature[8, 14, 39-50]	
Cost		
Hip and knee replacement surgery	AHS (2003-2004), NHCDC (2003-04)[51, 52]	
Health expenditure for OA	DCIS (2000-01)[53]	
Patient's out of pocket payment	Literature[54]	
Patient's time cost	Average weekly earnings[55]	
Price deflator	Health expenditure in Australia (2003-04)[56]	

ABOD, Australian Burden of Disease and Injury study 2003; RR, relative risk; PYLD, prevalent years lived with disability, NHS: National Health Survey; AJRR: Australian Joint Replacement Registry; CJRRR, Canadian joint replacement registry, AHS: Australian Hospital Statistics; NHCDC, National hospital cost data collection; DCIS: Disease Costing and Impact Study

2.7 Costs of interventions and offsets

Costs for surgeries were drawn from the diagnosis-related group (DRG) weights for the relevant AR-DRGs[51, 52] and the Disease Costing and Impact Study 2000-01.[53] The average costs per surgery were calculated by combining both public and private services. Patients out of pocket costs related to surgery were obtained from March et al.[54] Cost offsets as the result of interventions were calculated from the OA expenditure obtained from the Disease Costing and Impact Study 2000-01. Costs for each category were assigned to each OA grades based on severities, which were assumed to be off set after successful interventions (patient cost were not included in the cost offset). However, some recurrent costs would be incurred post surgery, such as periodic radiographic check-ups. We assumed that the cost equivalent to the conservative treatment for OA grade 2 (asymptomatic) with radiography would continue to accrue every three years after the primary replacement. The estimated intervention costs are summarised in Table 3.

Table 3: Intervention cost (mean values per surgery) (Unit: AUD)

Cost item	Cost per surgery
Government cost	
Hip replacement surgery (primary–Cscc)	13,648
Hip replacement surgery (primary+Cscc & revision–Cscc)	16,744
Hip replacement surgery (revision+Cscc)	30,648
Knee replacement surgery (primary–Cscc)	13,640
Knee replacement surgery (primary+Cscc & revision–Cscc)	19,620
Knee replacement surgery (revision+Cscc)	35,912
Other costs related to surgery (non-admitted visits etc.)	2,254
Patient out of pocket cost	
Out of pocket cost pre- and post-surgery (hip)	839
Out of pocket cost pre- and post-surgery (knee)	1,019
Time cost	
Pre-surgical visits (hip)	168
Surgery & recuperation (hip, male, primary–Cscc)	2,227
Surgery & recuperation (hip, male, primary+Cscc & revision–Cscc)	3,781
Surgery & recuperation (hip, male, revision+Cscc)	5,629
Surgery & recuperation (hip, female, primary–Cscc)	1,576
Surgery & recuperation (hip, female, primary+Cscc & revision–Cscc)	2,677
Surgery & recuperation (hip, female, revision+Cscc)	3,985
Pre-surgical visits (knee)	171
Surgery & recuperation (knee, male, primary–Cscc)	2,096
Surgery & recuperation (knee, male, primary+Cscc & revision–Cscc)	4,197
Surgery & recuperation (knee, male, revision+Cscc)	6,246
Surgery & recuperation (knee, female, primary–Cscc)	1,484
Surgery & recuperation (knee, female, primary+Cscc & revision–Cscc)	2,970
Surgery & recuperation (knee, female, revision+Cscc)	4,422

Cscc: catastrophic or severe complications and comorbidities

2.8 Uncertainty and sensitivity analyses

Uncertainty distributions were provided for input parameters where appropriate in order to account for sampling uncertainties. The model underwent bootstrapping by re-sampling the values of parameters 2,000 times from the given distributions. The distributions provided for each parameter are shown in Table 4.

Table 4: Distributions assumed for each parameter

Parameters	Distributions
Time to revision of hip and knee implants	Weibull[a]
Intervention effect (regression coefficients for hip replacement)	Normal
Intervention effect (knee replacement)	Beta
Intervention cost (hip and knee surgeries)	Gamma
Patient's out of pocket payment pre/post-surgeries	Gamma, Triangular
Patient's time cost for surgeries	Gamma, Triangular
Average length of stay for hip and knee surgeries and recuperations	Gamma

[a] Time to failure due to short-run and long-run causes were distinguished. We assumed separate Weibull distributions for each cause, and modelled the time to revision as the normalised sum of these two (see Table B and Figures B-D in the Appendix)

We ran the simulation model under various scenarios to examine the sensitivity of cost-effectiveness results to different assumptions. A total of six scenarios were investigated: with/without cost offset; with/without patient cost; and with/without time costs. In all scenarios, future costs and health benefits were discounted at an annual rate of 3% to account for time preferences.

2.9 Results

Table 5-7 provide the costs, health gains, and incremental cost-effectiveness ratios (ICER) in median values and 95% uncertainty intervals (UI) for hip and knee replacements under different scenarios.

Table 5: Health benefits

	Hip		Knee	
	Median	95%UI	Median	95%UI
DALY averted (total)	116,000	98,800 – 129,000	113,000	93,200 – 133,000
DALY averted (per person)[a]	1.7 per person		1.1 per person	

[a] Median value divided by the number of people (68,908 for hip, 100,657 for knee)

Table 6: Costs under different scenarios (Unit: AUD Mil.)

Scenario	Hip		Knee	
	Median	95%UI	Median	95%UI
With cost offset				
Without time cost	420	400 – 440	1,100	1,100 – 1,200
With time costs	580	520 – 670	1,400	1,300 – 1,500
Without cost offset				
Without time cost	1,200	1,100 – 1,200	2,100	2,100 – 2,200
With time costs	1,300	1,300 – 1,400	2,400	2,300 – 2,500
Cost per person[a]				
With cost offset (without time costs)	6,100 per person		11,000 per person	
Without cost offset (without time cost)	17,000 per person		21,000 per person	
Patient's cost proportion[b]				
Without time cost	4.6%		5.5%	
With time cost	16.3%		15.9%	

[a] Median value without time cost (unit: AUD) divided by the number of people in the model
[b] Median patient's cost divided by median total cost

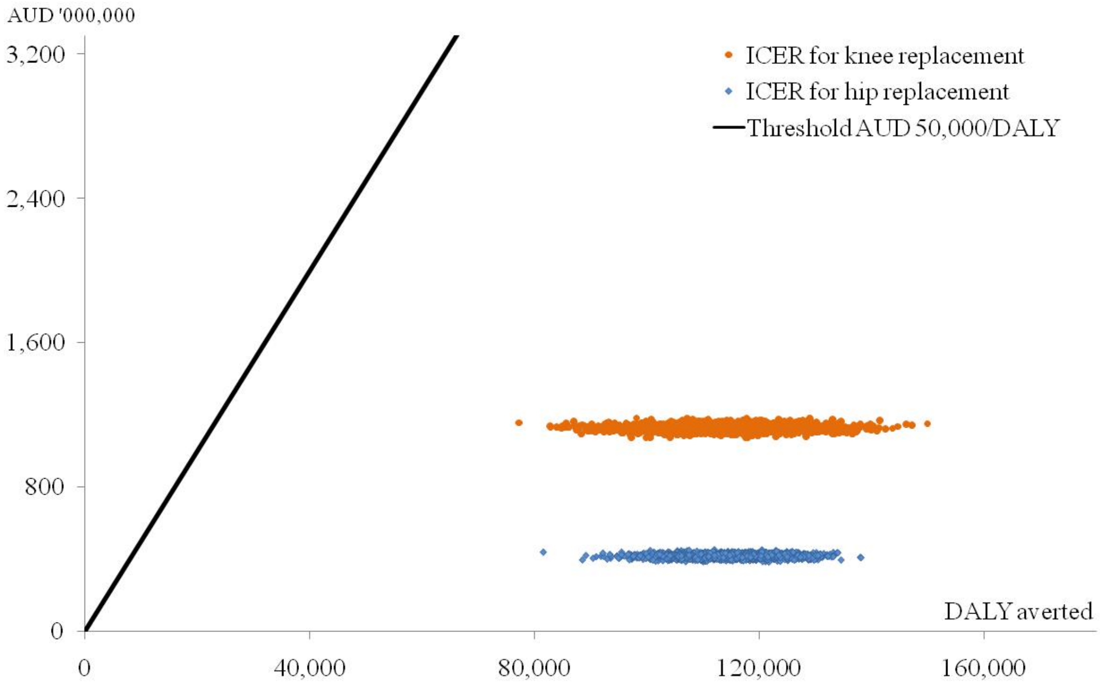
Table 7: Incremental cost-effectiveness ratio (Unit: AUD per DALY averted)

Scenario	Hip		Knee	
	Median	95%UI	Median	95%UI
With cost offset				
With time cost	3,600	3,200 – 4,200	9,900	8,400 – 12,000
Without time cost	5,000	4,200 – 6,200	12,000	10,000 – 15,000
Without cost offset				
With time cost	10,000	9,000 – 12,000	19,000	16,000 – 23,000
Without time cost	11,000	10,000 – 13,000	21,000	18,000 – 26,000

Both hip and knee replacements were cost-effective under all scenarios compared to the threshold level of AUD 50,000 per DALY averted. The results were consistent across all investigated scenarios. Given the significant size of burden of OA in Australia, the interventions contribute significantly to the improvement of people's quality of life at reasonable cost.

Hip replacement was more cost-effective than knee replacement. There are a number of reasons for the superior results of hip replacements. First, the post-surgery health outcomes for hip replacements consistently surpass that for knee replacements in the literature.[8] This was reflected in our result where the cumulative health benefit was similar for hip and knee replacement despite the smaller number of people included in the hip replacement analysis (Table 5). Second, more revisions were required for knee replacements (see Figure E in the Appendix for more details). Since hip replacements provide better health outcomes at lower costs compared to knee replacements, it is more cost-effective. The scatter plots of hip and knee replacement (with cost offsets) are provided in Figure 2.

Figure 2: Scatter plot



2.10 Discussion

This study has found favourable cost-effectiveness for hip and knee replacement in Australia. An earlier study in Australia by Segal et al.[16] also reported favourable cost-effectiveness ratios of AUD 4,535 – 6,953 per QALY for hip replacement and AUD 7,671 – 11,671 for knee replacement, although the findings are not directly comparable due to substantial methodological differences. Studies from other countries suggest the cost-effectiveness of hip replacement ranges between cost-saving and USD 7,280 per QALY, and between USD 6,020 and 16,240 per QALY for knee replacement.[57-59]

In the conduct of this study, however, the analyses were subject to a number of assumptions and limitations which are worth noting. First the quantification of the intervention effect was problematic. Whilst the change in DW for DALY plays a key role in measuring the intervention effects, we were not able to identify studies utilising this instrument to measure the effects of hip and knee replacements. Therefore we extrapolated the effects from other instruments which potentially could under- or over-estimate the true DW post-interventions. However, the extrapolations were at least in line with the findings from a systematic review that the post-replacement indexes are consistently better than pre-surgery, and hip replacements have consistently better health outcomes than knee replacements.

The potential infections after hip or knee replacements were not included in this analysis. This was due to the lack of data from the Australian joint replacement registry which did not provide such information. Extrapolating from other countries' statistics would further complicate the model with increased uncertainties, and so was not considered for this analysis. The health outcomes may therefore be potentially over-estimated, yet given the relatively less proportion of infections as the cause of revisions, the impact on the results is unlikely to be significant.[v]

Another limitation is that the durability of hip and knee implants were modelled from historical data, which may be under estimating the current survivorship of implants given the technological advancement over the last four decades. Further, the revision rates of hip implants obtained from the Australian joint replacement registry included replacement cases due to fractured neck of femur which is known to have shorter lifespan than from other causes. This may have potentially caused an under estimation of the true survivorship of implants from osteoarthritis. However, the proportion of replacements due to fractures is small (2.8% between 1999 and 2004),[61] and so is not likely to have affected the estimation significantly. Given these limitations, the costs of interventions have been potentially over-estimated due to excessive number of revisions modelled towards the future (which would anyway not alter the cost-effectiveness conclusions).

On the other hand, the study has its own strength. The nature of the intervention, which may or may not require repeated revisions at varying intervals for one or two joints, favoured the employment of discrete event micro-simulation model. The model has the potential to account for variations at both (or either) individual levels (first order) and population levels (second order). This is one of the advantages of this study which would reflect the variations at the population level more accurately. Another strength was that the model was able to account for two hips or knees for each individual with OA. Modelling two joints for a person separately would have been problematic with other methods like a Markov model.

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[v] The Canadian joint replacement registry reported infection as the 5th reason for revisions in 2002-03 for both hips and knees (10% and 8% respectively) after aseptic loosening (55% and 39%), osteolysis (33% and 20%), poly wear (30% and 36%), and instability (17% and 26%).[60]

In conclusion, the findings suggest that both hip and knee replacements are highly cost-effective with ICERs significantly lower than the AUD 50,000 per DALY threshold level. The interventions substantially contribute to the improvement of quality of life of population suffering from OA. Despite of limitations accompanying the study, the results are not likely to be affected by such uncertainties. Hip and knee replacements are both very cost-effective interventions in Australia.

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