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The Impact of First and Second Eye Cataract Surgery on Physical Activity: A Prospective Study

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ABSTRACT

Objectives: To investigate the impact of first eye and second eye cataract surgery on the level of physical activity undertaken by older adults with bilateral cataract.

Design: Prospective cohort study

Setting: Three public ophthalmology clinics in Western Australia

Participants: Fifty-five older adults with bilateral cataract aged 55+ years, awaiting first eye cataract surgery.

Outcome Measures: The primary outcome measure was participation in moderate leisure-time physical activity. The secondary outcomes were participation in walking, gardening and vigorous leisure-time physical activity. Participants completed a researcher-administered questionnaire, containing the Active Australia Survey and visual tests before first eye cataract surgery, after first eye surgery and after second eye surgery. A Generalized Estimating Equation (GEE) linear regression model was undertaken to analyse the change in moderate leisure-time physical activity participation before first eye surgery, after first eye surgery and after second eye surgery, after accounting for relevant confounders.

Results: Participants spent significantly less time per week (20 minutes) on moderate leisure-time physical activity before first eye cataract surgery compared to after first eye surgery (p=0.04) after accounting for confounders. After second eye cataract surgery participants spent significantly more time per week (32 minutes) on moderate physical activity compared to after first eye surgery (p=0.02). There were no significant changes in walking, gardening and vigorous physical activity throughout the cataract surgery process.

Conclusion: First and second eye cataract surgery each independently increased participation in moderate leisure-time physical activity. This provides a rationale for timely first and second eye cataract surgery for bilateral cataract patients, even when they have relatively good vision.

Keywords: Cataract surgery, physical activity, vision

Article Summary

Strengths and limitations of this study

Strengths

- Data was collected at three distinct time points: before first eye, after first eye and after second eye cataract surgery

Limitations

- The sample size of the study was relatively small
- Recall bias related to physical activity participation was a possible limitation
- Some potential confounding factors were not collected in this study

INTRODUCTION

Physical activity is extremely important for health, wellbeing and quality of life.[1] In Australia, physical inactivity was the fourth leading contributor to the burden of disease.[2] Lack of sufficient physical activity can increase the risk of a wide range of diseases, such as cardiovascular disease, type 2 diabetes, cancer, and can also impact mental wellbeing.[3] For older adults, physical activity may play an important protective role against mild cognitive impairment, Alzheimer's Disease and dementia.[4 5] It can also benefit older adults by increasing muscle strength, balance[6] and can also prevent injurious falls.[7]

Cataract is a leading cause of visual impairment globally, accounting for 33% of visual impairment,[8] with most adults aged over 70 years developing some degree of cataract.[9] Fortunately, cataract surgery, which is the most commonly performed ophthalmic procedure globally, can remove cataract and correct for impaired vision.[10]

Since previous research has found that physical activity participation is related to visual function,[11 12] it is likely that cataract impacts on physical activity levels. Cataract frequently affects both eyes, meaning two surgeries are often required. It is currently unknown however, whether physical activity levels change throughout the cataract surgery process and which types of physical activity are affected. Evidence has found that confidence levels may increase after cataract surgery due to improved vision,[13] which could lead to some older adults undertaking more physical activity. However, during the waiting period between first and second eye cataract surgery there can be major differences in vision between the operated eye and un-operated eye, and for some patients, vision may be equal or worse than before first eye surgery,[14 15] negatively impacting on physical activity levels.

To date, there are limited studies which have examined the separate impact of first and second eye cataract surgery on physical activity levels. Therefore, the research question for this study was: Does first eye and second eye cataract surgery increase the level of physical activity undertaken by older adults with bilateral cataract.

METHODS

This study is based on a subset of participants who were recruited as part of the Cataract Extraction and Driving Ability Research (CEDAR) Study.[16] This study includes the 55 participants who completed all three assessments.

Study Design

A prospective cohort study of older adults aged 55+ with bilateral cataract, who were awaiting first eye cataract surgery in Perth, Western Australia (WA) was undertaken. The sample size of 55 participants was sufficient to detect a change in moderate leisure-time physical activity (increase or decrease) of 27 minutes (effect size of 0.45) at the different stages of cataract surgery with 90% power at 0.05 significance. This was based on the Active Australia Survey population who had an average of 68 minutes (SD: 61) of moderate leisure-time physical activity per week.[17]

Participants

The recruitment of participants occurred consecutively through either a letter of invitation or a direct approach by an ophthalmologist in three public hospital eye clinics in WA between December 2014 and February 2017. Participants had to be at least 55 years of age and have a diagnosis of bilateral cataract. Those with other significant eye conditions (such as glaucoma, macular degeneration or diabetic retinopathy) were excluded from the study. Participants were also excluded if they were wheelchair-bound or diagnosed with one of the following conditions: dementia, Alzheimer's disease or Parkinson's disease, did not speak English, lived in a residential

care facility or had previously undergone cataract surgery. All cataract surgeries were carried out one eye at a time using phacoemulsification.

Patient involvement

Patients were not involved in the design of the study or recruitment. Results of the study were disseminated to participants by mail.

Data Collection

Data collection for this study involved researcher-administered questionnaires and three objective visual assessments. Data collection occurred at three time points: in the month before first eye cataract surgery, between first eye and second eye surgery and at least one month after second eye surgery. In this study, the three different stages of cataract surgery are referred to as 'before first eye surgery', 'after first eye surgery' and 'after second eye surgery'. Informed written consent was obtained from participants prior to collection of the data. Ethics approval was obtained from all participating hospitals and from the Curtin University Human Research Ethics Committee.

Socio-Demographic Data

Information on age, gender, marital status, country of birth, education level, living arrangements, self-reported medications, co-morbid medical conditions and employment status were obtained from the researcher-administered questionnaire. The Mini-Mental State Examination[18] of cognitive ability was also undertaken.

Physical Activity

The Active Australia Survey[17] was used to collect information on physical activity participation. Validity of this survey has been established for older adults.[17] The questionnaire asked participants how many times and the total time (minutes) they spent on the following categories of physical

activity in the previous week: (1) walked continuously, for at least 10 minutes, for recreation, exercise or to get to or from places, (2) vigorous gardening or heavy work around the yard, (3) vigorous leisure-time physical activity (e.g. jogging, cycling, aerobics, competitive tennis), (4) moderate leisure-time physical activity (e.g. gentle swimming, social tennis, golf). These categories were mutually exclusive. Only collecting information on physical activity in the previous week minimised recall bias.

Visual Measures

Three visual assessments were undertaken at each of the three time-points in the study. These assessments were carried out under the guidance of an ophthalmologist under standard conditions, constant luminance and without mydriasis.

Monocular and binocular visual acuity measurements were obtained by using an Early Treatment Diabetic Retinopathy Study acuity chart (ETDRS), calibrated for a distance of three metres and expressed as the logarithm of the minimum angle of resolution (logMAR). A lower logMAR score represented better visual acuity. Monocular and binocular contrast sensitivity measurements were obtained using the Mars Letter Contrast Sensitivity Test (Mars Perceptrix ©), calibrated at a distance of 50 centimetres and expressed as log units. Higher log units indicated better contrast sensitivity. Measurement of stereopsis was carried out using the Titmus Fly Stereotest (Stereo Optical Co., Inc.). Stereopsis was expressed as log seconds of arc, with a lower score indicating better stereopsis.

Statistical Analysis

Descriptive statistics were used to describe the socio-demographic characteristics, visual measurements, and physical activity levels during the past week for the cohort. Repeated measures analysis of variance (ANOVA) was also used to analyse the changes in visual measurements and

the four categories of physical activity before first eye cataract surgery, after first eye surgery and after second eye surgery.

The main outcome of interest was change in the total minutes of moderate leisure-time physical activity as this was significant at the univariate level. Moderate leisure-time physical activity is defined as activity at a "…*level that causes the heart to beat faster and some shortness of breath, but during which a person can still talk comfortably*".[19]

A Generalized Estimating Equation (GEE) linear regression model was undertaken to analyse the change in the average weekly minutes of moderate leisure-time physical activity before first eye surgery, after first eye surgery and after second eye surgery, after accounting for relevant confounders. The after first eye surgery time point was used as the reference category in the model so that we could examine the change from before first eye surgery to after first eye surgery *and* from after first eye surgery to after second eye surgery. The GEE method is suitable for this type of longitudinal study design as the observations within each participant are not independent.[20]

Potential confounders included in the GEE model were: gender (female, male), age group (55-64, 65-74, 75+ years), marital status (single/ separated/ divorced/ widowed versus married/de facto), co-morbid medical conditions (yes, no), prescription medication (yes, no) employment status (unemployed/retired/on pension versus employed/self-employed), binocular visual acuity (logMAR), binocular contrast sensitivity (log units) and stereopsis (log seconds of arc). Refractive management of visual impairment was not included as a confounding factor as all visual assessments were undertaken with habitual eyewear where applicable. Analyses were carried out using SAS software (v9.4; SAS Institute Inc., Cary, NC, USA.). P-values less than 0.05 were considered to be statistically significant.

This work was supported by Curtin University. The financial sponsors played no role in the design, execution, analysis and interpretation of data or writing of the study.

RESULTS

Population Demographics

There were 55 participants in the study who completed all three interviews and assessments, which provided a total of 165 observations. The socio-demographic characteristics of participants are outlined in Table 1.

The mean age of participants before first eye cataract surgery was 73.3 years (SD=7.8) with a range from 56.1 to 87.8 years. Most participants were female (n=30, 54.6%), married/ de facto (n=34, 61.8%), did not live alone (n=30, 54.6%), had higher than secondary education (n=32, 58.2%), were not born in Australia (n=34, 61.8%), were on at least one prescription medication (n=48, 87.3%), had at least one co-morbid medical condition (n=54, 98.2%), and were retired (n=34, 61.8%). At baseline, the mean MMSE score was 27.6 (SD=2.2).

The wait time between first and second eye cataract surgery ranged between 9 to 417 days with a mean of 99.6 days (SD=73.7). The assessment after second eye cataract surgery occurred between 135 to 420 days, with an average of 283 days after second eye surgery.

Insert Table 1 here

Visual Measures

Visual measures during the three stages of cataract surgery are presented in Table 2. Mean binocular visual acuity significantly improved from 0.15 (SD=0.15) logMAR at baseline, to 0.08 (SD=0.21) logMAR after first eye surgery, and then to -0.02 (SD=0.19) logMAR after second eye surgery ($p<0.001$). Binocular contrast sensitivity also significantly improved from 1.64 (SD=0.14)

log units at baseline, to 1.67 (SD=0.25) log units after first eye surgery, to 1.75 (SD=0.08) log units after second eye cataract surgery (p<0.001). Stereopsis significantly worsened from 2.14 (SD=0.64) log seconds of arc, to 2.31 (SD=0.72) after first eye surgery, and then improved to 1.96 (SD=0.6) log seconds of arc after second eye surgery (p=0.002).

Insert Table 2 here

Average Weekly Levels of Physical Activity

Table 3 presents the average weekly levels of physical activity for the four categories (walking, gardening, vigorous leisure-time physical activity and moderate leisure-time physical activity). For the walking, gardening and vigorous physical activity categories, average minutes per week decreased after first eye surgery and increased again after second eye surgery, however these changes were not statistically significant (p>0.05). Average minutes of moderate leisure-time physical activity per week however, significantly increased from 27 (SD=92.3) minutes before first eye surgery, to 35 (SD=101.0) minutes after first eye surgery, to 61 (SD=151.3) minutes after second eye surgery (p=0.01).

Insert Table 3 here

Multivariate Analysis - Moderate Leisure-Time Physical Activity

Table 4 presents the results of the GEE linear regression model examining change in moderate leisure-time physical activity through the cataract surgery process. The model found that participants spent significantly less time per week (20 minutes) on moderate leisure-time physical activity before first eye cataract surgery, compared to after first eye surgery (p=0.04) after accounting for all confounders. After second eye cataract surgery participants spent significantly more time per week (32 minutes) on moderate physical activity, compared to after first eye surgery (p=0.02). Therefore, time spent participating in moderate leisure-time physical activity significantly increased from before first eye to after first eye surgery and significantly increased again from after

first eye surgery to after second eye surgery. Finally, those who took at least one prescription medication spent 49 minutes less time on moderate leisure-time physical activity per week (p=0.01).

Insert Table 4 here

DISCUSSION

This study found that participation in moderate leisure-time physical activity significantly increased by approximately 20 minutes per week after first eye cataract surgery and by a further 30 minutes per week after second eye surgery. This suggests that both first and second eye surgery have separate positive effects on increasing or restoring participation in moderate physical activity for bilateral cataract patients. This is a positive finding since the physical activity recommendations for older Australians state that older people should accumulate 30 minutes of moderate intensity physical activity on most, preferably all, days, in order to achieve health and well-being benefits.[19]

Moderate physical activity (eg. gentle swimming, social tennis, golf) by definition, is likely to be deliberate, planned, require good vision and may also require transport to a location.[21] Previous research has found that visual impairment is associated with significantly decreased physical activity.[22 23] For participants in this study, it is likely that visual impairment from cataract resulted in reduced participation in moderate physical activity while awaiting surgery. Then participation in moderate physical activity increased or was restored as vision improved through first and second eye cataract surgery.

Interestingly, this study did not find significant changes in the other types of physical activity throughout the cataract surgery process, including gardening, walking or vigorous leisure-time physical activity. Activities like gardening and walking are more incidental[21] and may not require a high level of vision like moderate physical activity and this may explain why they did not

significantly change as a result of cataract surgery. It should also be noted that the small sample size may have led to the non-significant findings. Vigorous physical activity is similar in nature to moderate activity but only a small number of cataract patients in this study reported participating so this is likely why no significant change was found.

This study highlighted the importance of second eye cataract surgery, as well as first eye surgery for increasing/ restoring participation in moderate physical activity. While it is known that first eye surgery brings about larger improvements in bilateral vision than second eye surgery, some patients experience major differences in vision between the operated eye and un-operated eye after first eye surgery.[14 15] Since second eye surgery corrects these differences, this may explain the important significant increase in moderate physical activity following second eye surgery. It should also be noted that this cohort of cataract patients had relatively good baseline vision compared to previous studies examining outcomes of cataract surgery.[13-15] Therefore, the findings suggest that cataract surgery has positive benefits for physical activity participation, even among patients with relatively good vision. This should be further investigated with a larger sample and in other countries to determine whether the findings are generalisable.

Strengths of this study include the three distinct time points in which data was collected. However, the sample size of the study was relatively small, with 55 participants providing 165 observations. This may not have been a large enough sample to detect all associations. Furthermore, socio-economic status, overweight and obesity, diet and smoking have been shown to be associated with physical activity,[24] but were not included in our study. Recall bias was another possible limitation as participants were asked to recall the total minutes spent physical activity in the previous week. Future studies should consider implementing a diary or objective measures such as accelerometers[25] to more accurately record participation in physical activity.

In conclusion, this study found that first and second eye cataract surgery each independently increased/ restored participation in moderate leisure-time physical activity. Since physical activity is associated with quality of life and reduced morbidity and mortality,[1 3] this provides a rationale for timely first and second eye cataract surgery for bilateral cataract patients, even when they have relatively good baseline vision.

Author contributions

LM led the design of the study, collected the data, conducted the data analysis, interpretation of data, and drafted the manuscript. YF conducted the data analysis and drafted the manuscript. MF made substantial contributions to the conception and design of the study, interpreted the data and was involved in drafting and revising the manuscript. KB contributed the analysis of data and drafting and revising the manuscript. KC contributed to the design of the study, analysis of data and drafting and revising of the manuscript.

Data sharing statement

No additional data is available.

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Competing interests: None declared

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Table 1. Socio-demographic characteristics of study population before first eye surgery (n=55)

Variables	N	%
Gender		
Female	30	54.55
Male	25	45.45
Age Group		
55-64	10	18.18
65-74	21	38.18
75+	24	43.64
Marital Status		
Single, separated, divorced, widowed	21	38.18
Married, de facto	34	61.82
Living Arrangements		
Alone	25	45.45
Not alone	30	54.55
Education Level		
Primary or secondary school	23	41.82
Higher education	32	58.18
Country of Birth		
Not Australia	34	61.82
Australia	21	38.18
Prescription Medication		
No	7	12.73
Yes	48	87.27
Co-morbid Medical Conditions		
No	1	0
Yes	54	98.18
Employed		
Yes	10	18.18
No	45	81.82

Table 2. Visual measurements for participants before first eye cataract surgery, after first eye surgery and after second-eye surgery (n=55)

	Before first eye surgery	After first eye surgery	After second eye surgery	
Variable	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**p-value**
Visual Acuity (logMAR)				
Better eye	0.18 (0.15)	0.10 (0.22)	0.00 (0.19)	<.0001
Worse eye	0.39 (0.24)	0.36 (0.26)	0.11 (0.19)	<.0001
Binocular	0.15 (0.15)	0.08 (0.21)	-0.02 (0.19)	<.0001
Contrast Sensitivity (log units)				
Better eye	1.57 (0.14)	1.62 (0.28)	1.68 (0.11)	<0.001
Worse eye	1.41 (0.29)	1.47 (0.27)	1.61 (0.13)	<.0001
Binocular	1.64 (0.14)	1.67 (0.25)	1.75 (0.08)	<0.001
Stereopsis (log seconds of arc)				
Binocular	2.14 (0.64)	2.31 (0.72)	1.96 (0.60)	0.002

Table 3. Average weekly physical activity participation for participants before first eye cataract surgery, after first eye surgery and after second eye surgery (n=55)

	Before first eye surgery			After first eye surgery			After second eye surgery			p-value
	Minutes (previous week)	SD	%	Minutes (previous week)	SD	%	Minutes (previous week)	SD	%	
Walking	246.3	586.8	56.6	159.5	270.6	55.7	202.5	394.4	45.7	p=0.52
Gardening	125.2	273.4	28.8	79.0	161.2	27.6	142	229.7	32.0	p=0.24
Vigorous Physical Activity	36.3	109.0	8.3	12.7	36.4	4.4	36.8	110.9	8.3	p=0.07
Moderate Physical Activity	27.4	92.3	6.3	35.0	101.0	12.2	61.4	153.3	13.9	p=0.01

Table 4: GEE model for the impact of first and second eye cataract surgery on total minutes of moderate physical activity (n=55)**

Variable	Parameter Estimate	95% Confidence Limits		P-Value
Cataract Surgery				
After first eye surgery	1.00			
Before first eye surgery	-20.39	-40.08	-0.71	0.04*
After second eye surgery	32.17	5.07	59.27	0.02*
Prescription Medication				
No	1.00			
Yes	-49.22	-83.83	-14.61	0.01*

**Significant at p<=0.05*

*** Adjusted for gender, age group, marital status, employment status, co-morbidities, prescription medication, binocular visual acuity, binocular contrast sensitivity and stereopsis, which were not significant (p>0.05)*

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	2
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	5
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	N/A
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*6-7*
Bias	9	Describe any efforts to address potential sources of bias	7
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7-8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7-8
		(*b*) Describe any methods used to examine subgroups and interactions	7-8
		(*c*) Explain how missing data were addressed	N/A
		(*d*) If applicable, explain how loss to follow-up was addressed	N/A
		(*e*) Describe any sensitivity analyses	N/A
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	5
		(b) Give reasons for non-participation at each stage	5
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9
		(b) Indicate number of participants with missing data for each variable of interest	N/A
		(c) Summarise follow-up time (eg, average and total amount)	9
Outcome data	15*	Report numbers of outcome events or summary measures over time	10
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10-11
		(*b*) Report category boundaries when continuous variables were categorized	8
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
Discussion			
Key results	18	Summarise key results with reference to study objectives	11-12
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12
Generalisability	21	Discuss the generalisability (external validity) of the study results	12
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	13

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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The Impact of First and Second Eye Cataract Surgery on Physical Activity: A Prospective Study

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ABSTRACT

Objectives: To investigate the impact of first eye and second eye cataract surgery on the level of physical activity undertaken by older adults with bilateral cataract.

Design: Prospective cohort study

Setting: Three public ophthalmology clinics in Western Australia

Participants: Fifty-five older adults with bilateral cataract aged 55+ years, awaiting first eye cataract surgery.

Outcome Measures: The primary outcome measure was participation in moderate leisure-time physical activity. The secondary outcomes were participation in walking, gardening and vigorous leisure-time physical activity. Participants completed a researcher-administered questionnaire, containing the Active Australia Survey and visual tests before first eye cataract surgery, after first eye surgery and after second eye surgery. A Generalized Estimating Equation (GEE) linear regression model was undertaken to analyse the change in moderate leisure-time physical activity participation before first eye surgery, after first eye surgery and after second eye surgery, after accounting for relevant confounders.

Results: Participants spent significantly less time per week (20 minutes) on moderate leisure-time physical activity before first eye cataract surgery compared to after first eye surgery (p=0.04) after accounting for confounders. After second eye cataract surgery participants spent significantly more time per week (32 minutes) on moderate physical activity compared to after first eye surgery (p=0.02). There were no significant changes in walking, gardening and vigorous physical activity throughout the cataract surgery process.

Conclusion: First and second eye cataract surgery each independently increased participation in moderate leisure-time physical activity. This provides a rationale for timely first and second eye cataract surgery for bilateral cataract patients, even when they have relatively good vision.

Keywords: Cataract surgery, physical activity, vision

Article Summary

Strengths and limitations of this study

Strengths

- Data was collected at three distinct time points: before first eye, after first eye and after second eye cataract surgery

Limitations

- The sample size of the study was relatively small
- Recall bias related to physical activity participation was a possible limitation
- Some potential confounding factors were not collected in this study

INTRODUCTION

Physical activity is extremely important for health, wellbeing and quality of life.[1] In Australia, physical inactivity was the fourth leading contributor to the burden of disease.[2] Lack of sufficient physical activity can increase the risk of a wide range of diseases, such as cardiovascular disease, type 2 diabetes, cancer, and can also impact mental wellbeing.[3] For older adults, physical activity may play an important protective role against mild cognitive impairment, Alzheimer's Disease and dementia.[4 5] It can also benefit older adults by increasing muscle strength, balance[6] and can also prevent injurious falls.[7]

Cataract is a leading cause of visual impairment globally, accounting for 33% of visual impairment,[8] with most adults aged over 70 years developing some degree of cataract.[9] Fortunately, cataract surgery, which is the most commonly performed ophthalmic procedure globally, can remove cataract and correct for impaired vision.[10]

Since previous research has found that physical activity participation is related to visual function,[11 12] it is likely that cataract impacts on physical activity levels. Cataract frequently affects both eyes, meaning two surgeries are often required. It is currently unknown however, whether physical activity levels change throughout the cataract surgery process and which types of physical activity are affected. Evidence has found that confidence levels may increase after cataract surgery due to improved vision,[13] which could lead to some older adults undertaking more physical activity. However, during the waiting period between first and second eye cataract surgery there can be major differences in vision between the operated eye and un-operated eye, and for some patients, vision may be equal or worse than before first eye surgery,[14 15] negatively impacting on physical activity levels.

To date, there are limited studies which have examined the separate impact of first and second eye cataract surgery on physical activity levels. Therefore, the research question for this study was: Does first eye and second eye cataract surgery increase the level of physical activity undertaken by older adults with bilateral cataract.

METHODS

This study is based on a subset of participants who were recruited as part of the Cataract Extraction and Driving Ability Research (CEDAR) Study.[16] For the CEDAR Study, a total of 111 participants were recruited consecutively from three public hospitals in WA and completed the first assessment. Previous papers have been published from this study based on the naturalistic driving data collected[17-19], a falls diary component[20] and further examinations of driving simulator performance are also planned. The current analysis of physical activity outcomes includes only the 55 participants who completed the first, second and third assessments. This is the same subset of participants included in the study of fall outcomes[20] but these results are based on data collected from a detailed questionnaire administered as part of the study.

Study Design

A prospective cohort study of older adults aged 55+ with bilateral cataract, who were awaiting first eye cataract surgery in Perth, Western Australia (WA) was undertaken. The sample size of 55 participants was sufficient to detect a change in moderate leisure-time physical activity (increase or decrease) of 27 minutes (effect size of 0.45) at the different stages of cataract surgery with 90% power at 0.05 significance. This was based on the Active Australia Survey population who had an average of 68 minutes (SD: 61) of moderate leisure-time physical activity per week.[21]

Participants

The recruitment of participants occurred consecutively through either a letter of invitation or a direct approach by an ophthalmologist in three public hospital eye clinics in WA between December 2014 and February 2017. Participants had to be at least 55 years of age and have a diagnosis of bilateral cataract. Those with other significant eye conditions (such as glaucoma, macular degeneration or diabetic retinopathy) were excluded from the study. Participants were also excluded if they were wheelchair-bound or diagnosed with one of the following conditions: dementia, Alzheimer's disease or Parkinson's disease, did not speak English, lived in a residential care facility or had previously undergone cataract surgery. All cataract surgeries were carried out one eye at a time using phacoemulsification.

Patient involvement

Patients were not involved in the design of the study or recruitment. Results of the study were disseminated to participants by mail.

Data Collection

Data collection for this study involved researcher-administered questionnaires and three objective visual assessments. Data collection occurred at three time points: in the month before first eye cataract surgery, after first eye surgery and after second eye surgery. In this study, the three different stages of cataract surgery are referred to as 'before first eye surgery', 'after first eye surgery' and 'after second eye surgery'. Informed written consent was obtained from participants prior to collection of the data. Ethics approval was obtained from all participating hospitals and from the Curtin University Human Research Ethics Committee.

Socio-Demographic Data

Information on age, gender, marital status, country of birth, education level, living arrangements, self-reported medications, co-morbid medical conditions and employment status were obtained

from the researcher-administered questionnaire. The Mini-Mental State Examination[22] of cognitive ability was also undertaken.

Physical Activity

The Active Australia Survey[21] was used to collect information on physical activity participation. Validity of this survey has been established for older adults.[21] The questionnaire asked participants how many times and the total time (minutes) they spent on the following types of physical activity in the previous week: (1) walked continuously, for at least 10 minutes, for recreation, exercise or to get to or from places, (2) vigorous gardening or heavy work around the yard, (3) vigorous leisure-time physical activity (e.g. jogging, cycling, aerobics, competitive tennis), (4) moderate leisure-time physical activity (e.g. gentle swimming, social tennis, golf). Only collecting information on physical activity in the previous week minimised recall bias.

Visual Measures

Three visual assessments were undertaken at each of the three time-points in the study. These assessments were carried out under the guidance of an ophthalmologist under standard conditions, constant luminance and without mydriasis.

Monocular and binocular visual acuity measurements were obtained by using an Early Treatment Diabetic Retinopathy Study acuity chart (ETDRS), calibrated for a distance of three metres and expressed as the logarithm of the minimum angle of resolution (logMAR). A lower logMAR score represented better visual acuity. Monocular and binocular contrast sensitivity measurements were obtained using the Mars Letter Contrast Sensitivity Test (Mars Perceptrix ©), calibrated at a distance of 50 centimetres and expressed as log units. Higher log units indicated better contrast sensitivity. Measurement of stereopsis was carried out using the Titmus Fly Stereotest (Stereo

Optical Co., Inc.). Stereopsis was expressed as log seconds of arc, with a lower score indicating better stereopsis.

Statistical Analysis

Descriptive statistics were used to describe the socio-demographic characteristics, visual measurements, and physical activity levels during the past week for the cohort. Repeated measures analysis of variance (ANOVA) was also used to analyse the changes in visual measurements and the four types of physical activity before first eye cataract surgery, after first eye surgery and after second eye surgery.

The main outcome of interest was change in the total minutes of moderate leisure-time physical activity as this was significant at the univariate level. Moderate leisure-time physical activity is defined as activity at a "*…level that causes the heart to beat faster and some shortness of breath, but during which a person can still talk comfortably*".[23]

A Generalized Estimating Equation (GEE) linear regression model was undertaken to analyse the change in the average weekly minutes of moderate leisure-time physical activity before first eye surgery, after first eye surgery and after second eye surgery, after accounting for relevant confounders. The after first eye surgery time point was used as the reference category in the model so that we could examine the change from before first eye surgery to after first eye surgery *and* from after first eye surgery to after second eye surgery. The GEE model also took account of the time between the three assessments. This method is suitable for this type of longitudinal study design as the observations within each participant are not independent.[24]

Potential confounders included in the GEE model were: gender (female, male), age group (55-64, 65-74, 75+ years), marital status (single/ separated/ divorced/ widowed versus married/de facto),

co-morbid medical conditions (yes, no), prescription medication (yes, no) employment status (unemployed/retired/on pension versus employed/self-employed), binocular visual acuity (logMAR), binocular contrast sensitivity (log units) and stereopsis (log seconds of arc). Refractive management of visual impairment was not included as a confounding factor as all visual assessments were undertaken with habitual eyewear where applicable. Analyses were carried out using SAS software (v9.4; SAS Institute Inc., Cary, NC, USA.). P-values less than 0.05 were considered to be statistically significant.

This work was supported by Curtin University. The financial sponsors played no role in the design, execution, analysis and interpretation of data or writing of the study.

RESULTS

Population Demographics

There were 55 participants in the study who completed all three interviews and assessments, which provided a total of 165 observations. The socio-demographic characteristics of participants are outlined in Table 1.

The mean age of participants before first eye cataract surgery was 73.3 years (SD=7.8) with a range from 56.1 to 87.8 years. Fifty-four percent of participants were female (n=30), 61.8% were married/ de facto (n=34), 54.6% did not live alone (n=30), 58.2% had higher than secondary education (n=32), 61.8% were not born in Australia (n=34), 87.3% were on at least one prescription medication (n=48), 98.2% had at least one co-morbid medical condition (n=54) and 61.8% and were retired (n=34). At baseline, the mean MMSE score was 27.6 (SD=2.2).

The wait time between first and second eye cataract surgery ranged between 9 to 417 days with a mean of 99.6 days (SD=73.7). The second assessment (after first eye surgery) occurred on average

59.7 days after surgery (SD=41.3) with a range of 9 to 254 days. The third assessment (after second eye surgery) occurred between 28 to 238 days, with an average of 111.4 days after second eye surgery (SD=40.2).

Insert Table 1 here

Visual Measures

Visual measures during the three stages of cataract surgery are presented in Table 2. Mean binocular visual acuity significantly improved from 0.15 (SD=0.15) logMAR at baseline, to 0.08 (SD=0.21) logMAR after first eye surgery, and then to -0.02 (SD=0.19) logMAR after second eye surgery ($p<0.001$). Binocular contrast sensitivity also significantly improved from 1.64 (SD=0.14) log units at baseline, to 1.67 (SD=0.25) log units after first eye surgery, to 1.75 (SD=0.08) log units after second eye cataract surgery ($p<0.001$). Stereopsis significantly worsened from 2.14 (SD=0.64) log seconds of arc, to 2.31 (SD=0.72) after first eye surgery, and then improved to 1.96 (SD=0.6) log seconds of arc after second eye surgery ($p=0.002$).

Insert Table 2 here

Average Weekly Levels of Physical Activity

Table 3 presents the average weekly levels of physical activity for the four types of physical activity (walking, gardening, vigorous leisure-time physical activity and moderate leisure-time physical activity). For the walking, gardening and vigorous physical activity, average minutes per week decreased after first eye surgery and increased again after second eye surgery, however these changes were not statistically significant ($p>0.05$). Average minutes of moderate leisure-time physical activity per week however, significantly increased from 27 (SD=92.3) minutes before first eye surgery, to 35 (SD=101.0) minutes after first eye surgery, to 61 (SD=151.3) minutes after second eye surgery ($p=0.01$).

Insert Table 3 here

Multivariate Analysis - Moderate Leisure-Time Physical Activity

Table 4 presents the results of the GEE linear regression model examining change in moderate leisure-time physical activity through the cataract surgery process. The model found that participants spent significantly less time per week (20 minutes) on moderate leisure-time physical activity before first eye cataract surgery, compared to after first eye surgery (p=0.04) after accounting for all confounders. After second eye cataract surgery participants spent significantly more time per week (32 minutes) on moderate physical activity, compared to after first eye surgery (p=0.02). Therefore, time spent participating in moderate leisure-time physical activity significantly increased from before first eye to after first eye surgery and significantly increased again from after first eye surgery to after second eye surgery. Finally, those who took at least one prescription medication spent 49 minutes less time on moderate leisure-time physical activity per week (p=0.01).

Insert Table 4 here

DISCUSSION

This study found that participation in moderate leisure-time physical activity significantly increased by approximately 20 minutes per week after first eye cataract surgery and by a further 30 minutes per week after second eye surgery. This suggests that both first and second eye surgery have separate positive effects on increasing or restoring participation in moderate physical activity for bilateral cataract patients. This is a positive finding since the physical activity recommendations for older Australians state that older people should accumulate 30 minutes of moderate intensity physical activity on most, preferably all, days, in order to achieve health and well-being benefits.[23]

Moderate physical activity (eg. gentle swimming, social tennis, golf) by definition, is likely to be deliberate, planned, require good vision and may also require transport to a location.[25] Previous

research has found that visual impairment is associated with significantly decreased physical activity.[26 27] For participants in this study, it is likely that visual impairment from cataract resulted in reduced participation in moderate physical activity while awaiting surgery. Then participation in moderate physical activity increased or was restored as vision improved through first and second eye cataract surgery.

Interestingly, other physical activity including walking, gardening and vigorous physical activity appeared to decrease following first eye surgery, although this change was not significant possibly due to the small sample size. Activities like gardening and walking are more incidental[25] and may not require a high level of vision like moderate physical activity and this may explain why they did not significantly change as a result of cataract surgery. Vigorous physical activity is similar in nature to moderate activity but only a small number of cataract patients in this study reported participating so this is likely why no significant change was found. The impact of cataract surgery on these other activities should be investigated further however, since the possible decrease in these activities after first eye surgery would support the need to operate on the second eye as soon as possible for bilateral cataract patients.

This study highlighted the importance of second eye cataract surgery, as well as first eye surgery for increasing/ restoring participation in moderate physical activity. While it is known that first eye surgery brings about larger improvements in bilateral vision than second eye surgery, some patients experience major differences in vision between the operated eye and un-operated eye after first eye surgery.[14 15] Since second eye surgery corrects these differences, this may explain the important significant increase in moderate physical activity following second eye surgery. However, while recovery from cataract surgery is usually rapid (within a few days), it is possible that those who had first and second eye surgery in short succession had not fully recovered by their second assessment. In addition, the average time to assessment after second eye surgery was longer than after first eye

surgery. These factors may have contributed to the smaller increase in moderate physical activity following first eye surgery, compared to the larger increase after second eye surgery. It should also be noted that this cohort of cataract patients had relatively good baseline vision compared to previous studies examining outcomes of cataract surgery.[13-15] Therefore, the findings suggest that cataract surgery has positive benefits for physical activity participation, even among patients with relatively good vision. This should be further investigated with a larger sample and in other countries to determine whether the findings are generalisable.

Strengths of this study include the three distinct time points in which data was collected. However, the sample size of the study was relatively small, with 55 participants providing 165 observations. This may not have been a large enough sample to detect all associations. Furthermore, socio-economic status, overweight and obesity, diet and smoking have been shown to be associated with physical activity,[28] but were not included in our study. Recall bias was another possible limitation as participants were asked to recall the total minutes spent physical activity in the previous week. Future studies should consider implementing a diary or objective measures such as accelerometers[29] to more accurately record participation in physical activity.

In conclusion, this study found that first and second eye cataract surgery each independently increased/ restored participation in moderate leisure-time physical activity. Since physical activity is associated with quality of life and reduced morbidity and mortality,[1 3] this provides a rationale for timely first and second eye cataract surgery for bilateral cataract patients, even when they have relatively good baseline vision.

Author contributions

LM led the design of the study, collected the data, conducted the data analysis, interpretation of data, and drafted the manuscript. YF conducted the data analysis and drafted the manuscript. MF made substantial contributions to the conception and design of the study, interpreted the data and was involved in drafting and revising the manuscript. KB contributed the analysis of data and drafting and revising the manuscript. KC contributed to the design of the study, analysis of data and drafting and revising of the manuscript.

Data sharing statement

No additional data is available.

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Competing interests: None declared

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Table 1. Socio-demographic characteristics of study population before first eye surgery (n=55)

Variables	N	%
Gender		
Female	30	54.55
Male	25	45.45
Age Group		
55-64	10	18.18
65-74	21	38.18
75+	24	43.64
Marital Status		
Single, separated, divorced, widowed	21	38.18
Married, de facto	34	61.82
Living Arrangements		
Alone	25	45.45
Not alone	30	54.55
Education Level		
Primary or secondary school	23	41.82
Higher education	32	58.18
Country of Birth		
Not Australia	34	61.82
Australia	21	38.18
Prescription Medication		
No	7	12.73
Yes	48	87.27
Co-morbid Medical Conditions		
No	1	0
Yes	54	98.18
Employed		
Yes	10	18.18
No	45	81.82

Table 2. Visual measurements for participants before first eye cataract surgery, after first eye surgery and after second-eye surgery (n=55)

	Before first eye surgery	After first eye surgery	After second eye surgery	
Variable	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**p-value**
Visual Acuity (logMAR)				
Better eye	0.18 (0.15)	0.10 (0.22)	0.00 (0.19)	<.0001
Worse eye	0.39 (0.24)	0.36 (0.26)	0.11 (0.19)	<.0001
Binocular	0.15 (0.15)	0.08 (0.21)	-0.02 (0.19)	<.0001
Contrast Sensitivity (log units)				
Better eye	1.57 (0.14)	1.62 (0.28)	1.68 (0.11)	<0.001
Worse eye	1.41 (0.29)	1.47 (0.27)	1.61 (0.13)	<.0001
Binocular	1.64 (0.14)	1.67 (0.25)	1.75 (0.08)	<0.001
Stereopsis (log seconds of arc)				
Binocular	2.14 (0.64)	2.31 (0.72)	1.96 (0.60)	0.002

Table 3. Average weekly physical activity participation for participants before first eye cataract surgery, after first eye surgery and after second eye surgery (n=55)

	Before first eye surgery			After first eye surgery			After second eye surgery			p-value
	Minutes (previous week)	SD	%	Minutes (previous week)	SD	%	Minutes (previous week)	SD	%	
Walking	246.3	586.8	56.6	159.5	270.6	55.7	202.5	394.4	45.7	p=0.52
Gardening	125.2	273.4	28.8	79.0	161.2	27.6	142	229.7	32.0	p=0.24
Vigorous Physical Activity	36.3	109.0	8.3	12.7	36.4	4.4	36.8	110.9	8.3	p=0.07
Moderate Physical Activity	27.4	92.3	6.3	35.0	101.0	12.2	61.4	153.3	13.9	p=0.01

Table 4: GEE model for the impact of first and second eye cataract surgery on total minutes of moderate physical activity (n=55)**

Variable	Parameter Estimate	95% Confidence Limits		P-Value
Cataract Surgery				
After first eye surgery	1.00			
Before first eye surgery	-20.39	-40.08	-0.71	0.04*
After second eye surgery	32.17	5.07	59.27	0.02*
Prescription Medication				
No	1.00			
Yes	-49.22	-83.83	-14.61	0.01*

**Significant at p<=0.05*

*** Adjusted for gender, age group, marital status, employment status, co-morbidities, binocular visual acuity, binocular contrast sensitivity and stereopsis, which were not significant (p>0.05)*

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	2
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	5
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	N/A
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*6-7*
Bias	9	Describe any efforts to address potential sources of bias	7
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7-8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7-8
		(*b*) Describe any methods used to examine subgroups and interactions	7-8
		(*c*) Explain how missing data were addressed	N/A
		(*d*) If applicable, explain how loss to follow-up was addressed	N/A
		(*e*) Describe any sensitivity analyses	N/A
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	5
		(b) Give reasons for non-participation at each stage	5
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9
		(b) Indicate number of participants with missing data for each variable of interest	N/A
		(c) Summarise follow-up time (eg, average and total amount)	9
Outcome data	15*	Report numbers of outcome events or summary measures over time	10
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10-11
		(*b*) Report category boundaries when continuous variables were categorized	8
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
Discussion			
Key results	18	Summarise key results with reference to study objectives	11-12
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12
Generalisability	21	Discuss the generalisability (external validity) of the study results	12
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	13

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.