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Title:
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Date:
2017-05-01

Citation:
Filbay, S. R., Ackerman, I. N., Russell, T. G. & Crossley, K. M. (2017). Return to sport matters—longer-term quality of life after ACL reconstruction in people with knee difficulties. Scandinavian Journal of Medicine and Science in Sports, 27 (5), pp.514-524. https://doi.org/10.1111/sms.12698.

Persistent Link:
https://hdl.handle.net/11343/291300

Received Date : 05-Nov-2015
Revised Date : 01-Apr-2016
Accepted Date : 11-Apr-2016
Article type : Original Article

Return to sport matters – longer-term quality of life after ACL reconstruction in people with knee difficulties

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Running heading: Longer-term QOL after ACL reconstruction

Key words: anterior cruciate ligament, psychological, body mass index, arthroscopic surgery, patient reported outcomes, pain, depression

ABSTRACT

Many individuals experience long-term quality of life (QOL) impairment following anterior cruciate ligament reconstruction (ACLR). Factors contributing to poor QOL and psychological health >5 years after ACLR remain unclear. This study aimed to describe QOL and psychological health outcomes in people with knee difficulties (pain, symptoms or functional limitations) 5-20 years following ACLR and identify factors explaining variability in these outcomes. Participants with knee difficulties 5-20 years following ACLR completed a battery of validated patient-reported outcomes (including the Knee injury and Osteoarthritis Outcome Score (KOOS), ACL-QOL and the Assessment of QOL (AQoL-8D) instrument). Multivariable linear regression was used to identify factors explaining variability in outcomes. 162 participants aged 38±9 (mean±SD) years completed questionnaires 9±4 (range 5-20) years following ACLR. 39% of participants returned to competitive sport, 28% returned to a lower level and 32% did not return to sport after ACLR. Not returning to sport after ACLR was associated with worse KOOS-QOL (β=.29, p=0.001 (mean±SD (55±20)), ACL-QOL (β=.48, p<0.001; (57±21)), and AQoL-8D (β=.22, p=0.02 (0.80 ± 0.14)) scores. Increased body mass index (56% were overweight/obese) was related to worse QOL and more depressive symptoms. Subsequent knee surgery and contralateral ACLR were also associated with poorer QOL outcomes in these individuals.

INTRODUCTION

Anterior cruciate ligament (ACL) rupture and subsequent reconstructive surgery can result in persistent knee pain, symptoms, physical activity restrictions and psychological issues (Ardern et al. 2012; Ardern et al. 2014; Lohmander et al. 2004; Wasserstein et al. 2015). Our recent systematic review revealed impaired knee-related quality of life (QOL) in people 5 to 20 years following ACL reconstruction (ACLR) (Filbay et al. 2014). However, few studies have focused on QOL as a primary outcome and consequently, research investigating factors related to longer-term QOL after ACLR is scarce. Furthermore, no studies to date have explored longer-term QOL or psychological health specifically in individuals with knee difficulties after ACLR (Filbay, Ackerman 2014). The impact of living with knee difficulties on the QOL of previously active ACL-reconstructed individuals is poorly understood. Considering ACLR is most prevalent in adolescents and young adults (Granan et al. 2008; Granan et al. 2009; Janssen et al. 2012; Joseph et al. 2013; Lind et al. 2009) persistent knee difficulties could impede on work responsibilities, sporting desires and parenting roles with great potential to impact upon QOL and psychological health.

A recent study found that all individuals undergoing ACLR expected to have normal or almost normal knee function within one year of ACLR, and 91% expected to return to their pre-injury level of sport (Feucht et al. 2014). Despite these high expectations, a large study of 1761 young ACL-reconstructed individuals found that over one in three reported knee difficulties six years following primary ACLR (Wasserstein, Huston 2015). Additionally, a recent meta-analysis found that as many as one in two ACL-reconstructed individuals do not return to non-elite sport (Ardern, Taylor 2014). A mismatch between an individual's desires or expectations and their perceived abilities may impact negatively on their QOL (Carr et al. 2001; Ruta et al. 1994). Investigating factors related to longer-term QOL and psychological health in people with knee difficulties following ACLR could assist in developing strategies to optimise longer-term outcomes after ACLR (Filbay 2015; Filbay, Ackerman 2014). The purpose of this study was to (i) describe QOL and psychological health outcomes and; (ii) identify factors related to variability in QOL and psychological health outcomes, in people with knee difficulties (pain, symptoms or functional limitations) 5 to 20 years following ACLR.

METHODS

Study design

A cross-sectional study design was used. Ethical approval for this study was obtained from The University of Queensland Medical Research Ethics Committee (approval number 2012001240).

Setting and participant recruitment

All individuals who had undergone a hamstring or patellar tendon autograft ACLR 5 to 20 years previously were identified from the surgical records of four orthopaedic surgeons (based in Melbourne, Brisbane, Toowomba and Nambour, Australia) and invited by letter to participate in the study. In total 2391 letters of invitation were sent to archived postal addresses of potentially eligible patients. Since only eligible individuals were asked to respond to the invitation and many archived postal addresses were outdated, the exact number of letters received remains unknown. Participants were also recruited from the general community through advertisements in public places and online. People having revision or contralateral ACLR more than 5 years ago, concomitant or subsequent surgery (meniscal, cartilage or other ligamentous repair) were eligible for the study. Individuals were considered ineligible if they: (i) reported a comorbidity likely to impact QOL (e.g. chronic back pain, cancer, acute injury); (ii) were aged under 18 years or over 55 years at the time of recruitment; (iii) underwent an ACLR (primary or revision) within the past five years; (iv) were not fluent in written English; (v) were asymptomatic according to predefined Knee Injury and Osteoarthritis Score (KOOS) cut-off criteria (as outlined below).

Symptomatic cut-off criteria

To ensure all participants experienced a degree of knee difficulties (knee pain, symptoms or functional limitations) we modified previously published KOOS criteria that were devised to identify individuals symptomatic enough to seek medical care (Englund et al. 2003). The published criteria required reporting less than optimal scores on at least 50% of questions for the KOOS-QOL and two of the additional four KOOS subscales (corresponding to cut-off values of ≤86.1 (Pain), ≤85.7 (Symptoms), ≤86.8 (ADL), ≤85.0 (Sport/Rec), and

≤87.5 (QOL)). We modified these criteria to include individuals reporting impairment in any two KOOS subscales. The rationale for this modification was to allow for the inclusion of individuals reporting high KOOS-QOL scores despite knee difficulties, since a primary aim of this study was to explore QOL variability in people with knee difficulties after ACLR.

Defining knee difficulties

For the purpose of this study, knee difficulties were defined as self-reported knee pain, symptoms or functional limitations determined by reporting less than optimal scores on at least 50% of questions on the KOOS Pain, KOOS Symptoms, KOOS Function in daily living (ADL) or KOOS Sport and recreation (Sport/Rec) subscale.

Defining quality of life

Due to the multiplicity of QOL definitions, it is recommended that researchers be as clear as possible in defining the concept of QOL to enable interpretation and comparisons between studies (Post 2014). Quality of life has been defined by the World Health Organisation as 'an individual's perceptions of their position in life taken in the context of the culture and value systems where they live and in relation to their goals, expectations, standards and concerns' (The World Health Organization Group 1995). One aspect of QOL is the concept of health-related QOL (Barcaccia et al. 2013), which refers to the discordance between an individual's health expectations or desires, and their current health experience (Carr, Gibson 2001). For this research, we have used the term 'knee-related QOL' to refer to the degree that an individual's QOL is impacted by knee-related factors.

Procedure

All participants completed the KOOS, the Assessment of Quality of Life 8D Utility Instrument (AQoL), the Anterior Cruciate Ligament Quality of Life questionnaire (ACL-QOL), the Workplace Activity Limitations Scale (WALS), the Hospital Anxiety and Depression Scale (HADS) and a questionnaire collecting participant characteristics and additional information (Table 1). Participants elected to complete questionnaires either online or in paper form. Online questionnaires were completed by participants following an email link to a custom built online questionnaire system (Mark-Rite PROMS, University of

Queensland, Brisbane). All participants provided informed consent prior to commencing questionnaires. Paper versions of the questionnaire were sent to participants if requested, with a postage paid reply envelope. All participants received a follow-up reminder if the questionnaires were not completed within eight weeks. Questionnaire responses were screened for age, comorbidities, time since surgery and application of the KOOS symptomatic cut-off criteria to confirm participant eligibility.

Patient reported outcomes

Participant demographics and characteristics

Information collected included age, body mass index (BMI), work status, time since most recent ACLR, time from injury to ACLR, mechanism of injury, postoperative symptoms, subsequent surgery (at least one additional knee surgery to an ACL-reconstructed knee (not including revision ACLR or concomitant surgery performed at the time of primary or revision ACLR)), current treatment and OA knowledge. Where there was potential for recall bias, participants were given an 'unsure' option. To evaluate return to sport, participants responded to the following question 'please tick the most appropriate statement regarding your level of sport participation after injuring your ACL' by selecting one of the following three options: 'I returned to competitive sport at the same or higher level than before ACL injury', 'I returned to competitive sport at a lower level than before ACL injury' or 'I did not return to competitive sport after my ACL reconstruction.' Individuals who did not return to the same or higher level of sport were then asked if this was because of their knee ('If you *did not* return to competitive sport, or returned to competitive sport at a *lower level* than prior to your ACL reconstruction, was this because of your knee?'). Participants were asked what sports they were participating in at the time of ACL injury, if they were not participating in a competitive sport when they ruptured their ACL, a 'not applicable' response was given to the return to sport question. Participants were also requested to nominate which of the following activities they would prefer to participate in, in the absence of knee pain or impairment: 'family duties', 'social activities', 'work-related activities', 'sport' or 'exercise.'

Knee-related QOL

Three measures were selected to provide a comprehensive overview of knee-related QOL; the KOOS (the most commonly used measure of knee-related QOL more than five years following ACLR (Filbay, Ackerman 2014; Filbay et al. 2015)) the ACL-QOL (contains items of high importance to ACL-reconstructed individuals compared to other knee-related measures (Tanner et al. 2007)) and a custom QOL question (allows the individual to provide an overall assessment of the impact of their knee on their QOL considering all important and relevant influences).

The KOOS is a patient reported questionnaire developed to assess an individual's opinion about their knee and associated problems (Roos 2003), it contains five subscales: Pain, Symptoms, ADL, Sport/Rec and QOL. The KOOS-QOL subscale contains four questions addressing knee awareness, knee-related lifestyle modification, knee confidence and knee-related difficulties. The KOOS is valid and reliable for use in ACLR and knee OA populations (Collins et al. 2011; Roos & Lohmander 2003; Salavati et al. 2011). The QOL and Sport/Rec subscales are more valid than other KOOS subscales for use within one year of ACLR (Comins et al. 2008). An individual score for each subscale can be calculated where 0 represents no impairment and 100 represents extreme impairment.

The ACL-QOL is the only patient administered QOL measure specific to an ACL population and is valid, reliable and responsive to change (Mohtadi 1998). The ACL-QOL contains 32-items and five domains (Symptoms/Physical, Work-Related, Sport/Rec, Lifestyle, Social/Emotional). Each ACL-QOL item is measured on a visual analogue scale from 0 (severe impairment) to 100 (no impairment). Domain scores are averages of all items in each domain and an overall ACL-QOL score represents the average of all domains.

We also included a custom 'knee impact question' that allowed individuals to evaluate the impact of their knee on their QOL in line with their expectations, priorities and values. Participants responded to the question: 'do you believe that your knee is impacting on your quality of life?' with one of four responses; 'not at all', 'slightly', 'moderately' and 'significantly'.

Health-related QOL

The AQoL-8D is a multi-attribute generic (non-disease-specific) measure of health-related QOL and comprises eight dimensions (Independent Living, Happiness, Mental Health, Coping, Relationships, Self-worth, Pain, Senses). The AQoL-8D has demonstrated strong psychometric properties including content validity (Hawthorne & Osborne 2005; Richardson et al. 2014), construct validity and discriminative validity in OA (Whitfield et al. 2006). An AQoL utility value is calculated where 1.00 and 0.00 represent full health and worst possible health, respectively. Summary scores can also be calculated, the 'Physical super-dimension' (covering independent living, pain and senses) and the 'Mental super-dimension' covering mental health, happiness, coping, relationships and self-worth. The minimal important difference in AQoL scores is considered to be 0.06 utility points (Hawthorne & Osborne 2005).

Psychological health

The HADS is comprised of 14 questions, 7 that evaluate depression, and 7 that evaluate anxiety. Higher scores indicate greater impairment, with a maximum anxiety or depression score of 21. Scores of 0 to 7 indicate no impairment, 8 to 10 a borderline case, and 11 or greater suggest the responder has depression or anxiety (Snaith 2003). HADS has demonstrated strong internal consistency, concurrent validity, sensitivity and specificity in assessing the symptom severity and presence of depression and anxiety disorders in a range of disease-specific patient groups and in the general population (Bjelland et al. 2002).

Work Limitations

The WALS is the preferred instrument for measuring productivity in workers with arthritis and is highly responsive to change in work ability over time (Tang et al. 2013). The WALS is comprised of 12 questions, each question addresses activity specific work-related difficulties and responses range from 'no difficulty' to 'not able to do' and higher scores indicate greater impairment.

Data and statistical analysis

All variables were normally distributed and independent t-tests were conducted to examine differences in demographic characteristics between participants and ineligible asymptomatic individuals. For the multivariable analyses, to avoid unnecessary adjustment of variables and potential over-adjustment bias (Schisterman et al. 2009) direct acyclic diagrams (featuring hypothesized causal relationships between variables) were used to identify covariates for inclusion in regression analysis (Shrier & Platt 2008). In line with the study aims, we focused on identifying variables that may be assessed at any time after ACLR (such as return to sport and surgical delay) rather than patient reported outcomes measured at the same time as QOL. The reasoning for this was that strong associations between patient reported outcomes assessed concurrently are expected and of limited clinical importance due to overlapping constructs in measures. Justification and selection of potential explanatory variables for use in causal diagrams were based upon current literature findings and clinical reasoning, whereby all variables with a potential to impact on longer-term QOL or psychological health were included. This resulted in the inclusion of theoretically meaningful variables in the absence of statistical significance exploration (Shmueli 2010). Any variables that were not a direct or indirect cause of an exposure, outcome or covariate were excluded from further analyses (Shrier & Platt 2008). This process resulted in the identification of six explanatory variables (years since ACLR, time from ACL injury to ACLR, revision ACLR, contralateral ACLR, return-to-sport) and three demographic variables (BMI, age, sex) with potential to impact upon longer-term QOL outcomes. These variables were assessed for collinearity, multicollinearity, univariate and multivariate outliers. Additionally, the normality, homoscedasticity and linearity of residuals were assessed.

To estimate the proportion of variance in QOL and psychological health scores that were accounted for by the explanatory variables, standard linear multiple regression analysis was performed. A sample size of 162 is greater than the minimal sample size recommended to assume a medium sized effect with 10 explanatory variables in multivariable analysis (Tabachnick & Fidell 2007). We present the unstandardized (B (95% CI)) and standardised coefficients (Beta (β)) for the adjusted analysis (adjusted for age and sex). Our recent systematic review found that the KOOS-Pain subscale was closely related to KOOS-QOL scores 5 to 20 years after ACLR (Filbay, Ackerman 2014). Therefore, we performed a

sensitivity analysis adjusting for KOOS-Pain scores (in addition to age and sex). The results of this sensitivity analysis are reported descriptively and presented in Appendix 1.

RESULTS

Recruitment

In total, 212 individuals consented to participate and completed questionnaires (Figure 1). Of these, 50 were excluded due to co-morbidities, not completing the KOOS or not meeting the predefined KOOS cut-off criteria (Figure 1). KOOS subscale scores are reported in Figure 2. Asymptomatic individuals did not differ in age, follow-up duration, BMI, or gender from eligible participants ($p > 0.16$ for all analyses). Data were available for analysis from 162 eligible participants, of which 83% were recruited from the records of four orthopaedic knee surgeons and 17% recruited through community advertisements.

Insert Figure 1 here.

Participant characteristics

Questionnaires were completed on average 9 ± 4 years (range 5 to 20 years) following participants' most recent ACLR. The mean age of participants at the time of questionnaire completion was 38 ± 9 (range 20 to 55) years and 54% were male. The majority of participants were in paid employment (91%) and over half had children (56%). Twenty-three participants (14%) had a revision ACLR more than 5 years ago, and 18 individuals (11%) reported having a previous ACLR on the contralateral knee; these individuals answered questions regarding their most symptomatic knee. One in two participants (48%) had received at least one additional knee surgery (not including revision ACLR or concomitant surgery performed at the time of primary or revision ACLR). Collectively, participants reported playing 26 different sports at the time of ACL rupture, the most common were netball (20%), rugby (11%), Australian rules football (11%), soccer/futsal (16%) basketball (9%), snow/water skiing (8%), and touch football (6%). Only one participant was not taking part in competitive sport at the time of ACL injury. Sixty-three (39%) participants returned to competitive sport after ACLR, 46 (28%) returned at a lower level of competition and 52 (32%) did not return to competitive sport following ACLR. One in two participants

nominated sport as the activity they would prefer to participate in, in the absence of knee pain or impairment (n=80. 49%). Full participant characteristics are provided in Table 1.

Insert Table 1. here.

Patient reported outcomes

Knee-related QOL

Participants reported a mean KOOS-QOL score of 55 ± 20, indicating impaired knee-related QOL (Figure 2). A mean ACL-QOL score of 57 ± 21 was reported, further indicative of impaired knee-related QOL; the domain with greatest impairment was sport and recreational function (41 ± 28) and the least impaired domain was work-related concerns (78 ± 21) (Figure 3). The knee impact question showed that 17% of participants did not perceive their knee as having an impact on their current QOL, 45% reported a slight impact, 28% a moderate impact and 10% reported that their knee significantly impacted their QOL.

Insert Figure 2. here.

Insert Figure 3. here.

Health-related QOL

Participants reported an average AQoL-8D utility score of 0.80 ± 0.14, super dimension mental score of 0.50 ± 0.19 and super dimension physical score of 0.76 ± 0.14 (Figure 4).

Insert Figure 4. here.

Psychological health

Participants reported an average HADS anxiety score of 5.5 ± 3.7 and HADS depression score of 2.7 ± 2.6. According to published criteria (Snaith 2003), 93% of participants did not have scores indicative of depression, 10 people (6%) had scores indicating borderline depression, and 2 people (1%) had scores corresponding to symptoms of clinical depression.

For items pertaining to anxiety, 73% of participants reported scores reflecting no anxiety, 19% reported scores corresponding to borderline anxiety and 4 people (2%) could be considered likely to have anxiety.

Explaining variability in quality of life and psychological health outcomes

Knee-related QOL

Multivariable analysis showed that non-return to sport (compared with returning to sport at the same or higher level), higher BMI and subsequent surgery were independently associated with poorer KOOS-QOL scores. Together, all variables accounted for an estimated 24% of the variability in KOOS-QOL scores (Table 2). Return to sport explained the greatest proportion of variance in KOOS-QOL scores (β =.29, p=0.001) where returning to sport at the same or higher level predicted an estimated 12 points higher KOOS-QOL score, compared to not returning to sport after ACLR. All three variables remained significant explanatory factors after adjusting for KOOS-Pain scores, even though pain explained a large amount of variance in KOOS-QOL scores (Appendix 1).

Non-return to sport (compared with return to sport at any level), higher BMI, subsequent knee surgery and contralateral ACLR were independently associated with worse ACL-QOL scores. Specifically, all variables in combination accounted for 36% of the variability in ACL-QOL scores (Table 2). Return to sport (at the same or higher level) explained the greatest proportion of variance in ACL-QOL scores (β=.48, p<0.001), where returning to sport predicted an estimated 21 point higher ACL-QOL score, compared to those who did not return to sport. After adjustment for KOOS-Pain scores, BMI no longer explained ACL-QOL scores (β =-0.11, p=0.06), and waiting greater than six months from injury to surgery was found to be significantly associated with worse ACL-QOL scores (β = -.13, p=0.03). Return to sport, subsequent and contralateral injury remained significant explanatory factors after adjustment for KOOS-Pain (Appendix 1). Time since ACLR, revision surgery, age and sex were not significantly associated with knee-related QOL outcomes.

Insert Table 2. here.

Health-related quality of life

All explanatory variables in combination explained approximately 19% of the variability in AQoL-8D scores. Return to sport at the same or higher level (compared to not returning to sport at all) and BMI significantly explained the greatest proportion of variance in health-related QOL scores, where returning to sport predicted an estimated .06 higher AQoL-8D scores compared to those who did not return to sport (Table 3). These relationships remained after adjustment for KOOS-Pain (Appendix 1).

Insert Table 3. here.

Psychological health

In combination, all variables accounted for 18% of variability in HADS depression scores; specifically, male sex and greater BMI were associated with more depressive symptoms, before and after adjustment for KOOS-Pain scores. There was a trend for return to sport at the same or higher level to be associated with less depressive symptoms (p=0.058). In contrast, none of the included variables significantly explained the variability in HADS anxiety scores (Table 4). KOOS-Pain did not explain a significant proportion of variance in HADS anxiety or depression scores in a multivariable model (Appendix 1).

Insert Table 4. here.

DISCUSSION

Returning to sport at the same or higher level was related to better knee-related and general health-related QOL in people with knee difficulties 5 to 20 years after ACLR. This relationship remained after adjusting for KOOS-Pain scores despite a clear relationship between knee pain and QOL. Subsequent surgery, increased BMI and contralateral ACLR were also associated with poorer scores on one or more QOL measures. Higher BMI and male sex were associated with more depressive symptoms. Age, gender, time since surgery and revision ACLR were not associated with QOL or psychological health outcomes in individuals with knee difficulties after ACLR.

KOOS-QOL scores in individuals with knee difficulties more than five years following ACLR were impaired compared with Swedish population norms aged 18 to 54 years (Paradowski et al. 2006), amateur soccer players with minor (14%), severe (23%), or no (63%) history of knee injury (Frobell et al. 2008), and U.S military recruits with no history of knee ligament injury (Cameron et al. 2013). A mean AQOL-8D utility score of 0.80 ± 0.14 reported by participants in this study is similar to the mean score reported by Australians who rated their health status as 'good' (mean 0.81 ± 0.19) as opposed to 'excellent' (0.91 ± 0.14), 'very good' (0.88 ± 0.14), 'fair' (0.68 ± 0.23), or 'poor' (0.42 ± 0.30) in an earlier population-based study (Hawthorne & Osborne 2005). Unfortunately no physically active reference groups, who are likely to report higher health-related QOL than less active counterparts (Huffman et al. 2008) are available for comparison.

This is the first study to evaluate the relationship between return to sport and longer-term QOL after ACLR. We did not expect to find such consistent relationships between return to sport and QOL outcomes 5 to 20 years after ACLR in people with knee difficulties. Although return to sport was associated with better QOL, the longer-term impact of returning to sport with knee difficulties on future joint health should be considered (Culvenor & Crossley 2015). The high rate of participants reporting a preference to take part in sport in the absence of knee difficulties, over and above other activities including family or occupational duties, suggests that sport participation remains a priority for many individuals. Despite this, one in three participants did not return to any level of competitive sport after ACLR and 79% of individuals reported their knee as the reason for not returning to pre-injury sport. This potential mismatch between sporting desires and outcomes in people with knee difficulties may have contributed to the observed impairment in QOL. A study exploring pre-operative expectations of ACLR found that 91% of participants expected to return to sport one year following surgery with no or slight restrictions (Feucht, Cotic 2014). This contrasts with the actual return to sport rates in our cohort and findings from a recent literature review (Ardern, Taylor 2014). Notably, health-related QOL has been described as 'the gap between our expectations of health and our experience of it' (Carr, Gibson 2001) and discordance between surgical expectations and actual outcomes may have contributed to the identified impairments in QOL. Patients may benefit from pre-operative education to promote realistic expectations prior to ACLR.

Average HADS depression scores for this sample were less impaired than published population norms (Breeman et al. 2015; Mutrie & Hannah 2007). However, lower rates of depressive symptoms have been associated with increased rates of moderate-to-vigorous physical activity and sports participation (Brunet et al. 2013; Mutrie & Hannah 2007; Pinto Pereira et al. 2014; Sabiston et al. 2013) and ACL-reconstructed individuals may have had less depressive symptoms than the general population prior to injury. We found that people with knee difficulties who returned to the same or higher level of sport after ACLR tended to report less depressive symptoms compared with those who did not return to sport (B (95% CI) -0.94 (-1.9 to 0.0), p=0.06). Furthermore, a large study of similarly aged participants identified physical activity as a key factor contributing to the observed relationship between obesity and increased rates of depression (de Wit et al. 2010). It is possible that for some individuals, ceasing sport resulted in reduced levels of moderate-to-vigorous physical activity, which could be associated with weight gain, depressive symptoms and reduced QOL. Further research is needed to explore these relationships as we did not collect longitudinal data on physical activity levels, dietary intake or pre-injury BMI. Of concern is that over half the study participants were overweight or obese at the time of questionnaire completion and higher BMI was associated with worse QOL. Management strategies aimed at improving QOL following ACLR could include weight maintenance strategies, addressing barriers to returning to sport or facilitating a transition to a healthy lifestyle incorporating regular moderate-to-vigorous physical activity when ceasing sport participation.

A key strength of this study was the use of patient-reported measures and the inclusion of knee-specific, ACL-specific and generic (non-disease-specific) health-related QOL measures that provided complementary information and enabled a comprehensive picture of QOL to be generated. We also included a custom QOL question that enabled each individual to evaluate the impact of their knee on their QOL in the context of their personal goals, priorities and values. To minimise selection bias, we included recruitment of participants from community advertisements and these participants did not differ in age, gender, BMI or follow-up duration to participants recruited through orthopaedic surgeons' records. Nevertheless, as most participants were recruited through orthopaedic surgeons, a degree of selection bias may exist. These surgeons worked in the private health care system and consequently, these findings may not be generalisable to people undergoing ACLR in public hospital settings. Furthermore, the results of this study are not generalisable to all ACL-reconstructed

individuals, as we only included individuals reporting knee pain, symptoms or activity limitations. We also acknowledge the potential for recall bias relating to questions that required participants to answer retrospectively (for example, mechanism of injury, time from injury to surgery). We sought to minimise the likelihood of recall error by including an 'unsure' response option for these items. Due to the cross-sectional study design, we were unable to make any causal inferences and due to the nature of recruitment, we could not collect detailed data for all participants on surgical techniques or concomitant surgeries. However, all participants recruited through orthopaedic surgeons underwent a hamstring or patellar tendon autograph ACLR, and no differences in QOL have been reported between these techniques 5 to 20 years following ACLR (Filbay, Ackerman 2014). We also acknowledge that KOOS-QOL and ACL-QOL scores may be negatively biased by sport-related lifestyle modifications or difficulty participating in sport. Due to the nature of questions in these measures, sport-related limitations would result in reduced QOL scores irrespective of the importance that each individual places on sport participation.

PERSPECTIVES

Poorer longer-term QOL outcomes were related to not returning to sport, higher BMI, contralateral ACLR and subsequent knee surgery in people with knee difficulties 5-20 years after ACLR, and return to sport explained the greatest variability in QOL. Individuals with knee difficulties who do not return to sport may benefit from targeted strategies to optimise longer-term QOL following ACLR.

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TABLES

TABLE 1. Participant characteristics (n=162)

Age at follow-up (years)	38 ± 9

Gender (% female)	n = 75 (46%)
Follow-up duration (years)	9 ± 4
Body mass index	27 ± 6
normal range	n = 71(44%)
Overweight	n = 55 (34%)
Obese	n = 36 (22%)
Percentage with children	n = 90 (56%)
Time from injury to surgery	
< 6 months	n = 117 (72%)
> 6 months	n = 43 (27%)
Unsure	n = 2 (1%)
Revision ACLR	n = 23 (14%)
Left ACLR	n = 68 (42%)
Right ACLR	n = 76 (47%)
Bilateral ACLR	n = 18 (11%)
Subsequent surgery*	n = 77 (48%)
Contact injury	n = 64 (41%)
Return to sport rates	
same or higher level than before ACL injury	n = 63 (39%)
lower level than before ACL injury	n = 46 (28%)
did not return to sport after ACLR	n = 52 (32%)
not applicable	n = 1 (1%)
Return to sport at lower level or not at all due to knee	n = 89 (79%)
Currently receives knee treatment	n = 26 (16%)
Pain/impairment free participation preference (%)	
family duties	n = 22 (14%)
social activities	n = 7 (4%)
Work	n = 3 (2%)
Sport	n = 80 (49%)
Exercise	n = 50 (31%)
Current work status (%)	
full-time	n = 118 (73%)
part-time/casual	n = 29 (18%)

Student	n = 10 (6%)
stay at home parent/carer	n = 3 (2%)
Unemployed	n = 2 (1%)
Work Activity Limitation Scale score	3.9 ± 2.8

ACLR: anterior cruciate ligament reconstruction; Revision ACLR: percent having one or more revision ACLR; Bilateral ACLR: percent having at least one ACLR on each knee; * Subsequent surgery: percent having at least one additional knee surgery to an ACL-reconstructed knee (excluding revision ACLR or concomitant surgery performed at the time of primary or revision ACLR); All results are reported as mean ± standard deviation, or percentage and corresponding number of participants reporting each response.**TABLE 2**. Knee-related quality of life linear regression multivariable analyses

Explanatory variables:	**KOOS-QOL (n=158)**			**ACL-QOL (n=157)**		
	B (95% CI)	Beta (β)	p value	B (95% CI)	Beta (β)	p value
Years since ACLR	-0.3 (-1.1 to 0.6)	-0.05	0.54	0.0 (-0.8 to 0.9)	0.00	1.00
Injury to ACLR	-4.4 (-11.1 to 2.2)	-0.10	0.19	-6.2 (-12.7 to 0.3)	-0.13	0.06
Revision ACLR	-4.7 (-13.3 to 3.9)	-0.08	0.28	-3.0 (-11.3 to 5.3)	-0.05	0.48
Contralateral ACLR	-7.4 (-16.3 to 1.6)	-0.12	0.11	**-16.3 (-24.9 to -7.8)**	**-0.25**	**<0.001**
Subsequent surgery	**-7.6 (-13.8 to -1.5)**	**-0.19**	**0.02**	**-6.8 (-12.7 to -0.8)**	**-0.16**	**0.03**
RTS same/higher level*	**12.0 (4.8 to 19.1)**	**0.29**	**0.001**	**20.9 (14.0 to 27.8)**	**0.48**	**<0.001**
RTS lower level*	0.3 (-7.3 to 7.8)	0.01	0.94	**7.8 (0.5 to 15.2)**	**0.17**	**0.04**
BMI	**-0.9 (-1.4 to -0.3)**	**-0.24**	**0.002**	**-0.8 (-1.3 to -0.3)**	**-0.21**	**0.003**
Age	0.1 (-0.2 to 0.5)	0.06	0.45	0.1 (-0.2 to 0.5)	0.06	0.45
Sex	4.7 (-1.1 to 10.5)	0.12	0.11	3.4 (-2.3 to 9.0)	0.08	0.24
R^2 (p value)	**.24 (p<0.001)**			**.36 (p<0.001)**		

B (95% CI): unstandardised coefficient (95% confidence interval); Beta (β): standardised coefficient; Subsequent surgery: at least one additional knee surgery to an ACL-reconstructed knee (excluding revision ACLR or concomitant surgery performed at the time of primary or revision ACLR); RTS: return to sport; BMI: body mass index; ACLR: anterior cruciate ligament reconstruction; KOOS: Knee Injury and Osteoarthritis Outcome score; ACLQOL: Anterior Cruciate Ligament Quality of Life questionnaire; * Did not return to sport = reference category; Sample size does not equal 162 for these analyses due to n=1 not participating in sport at the time of injury, n=2 selected 'unsure' options, and n=1 did not complete the ACL-QOL; injury to ACLR was dichotomised as >6 months (yes/no); All

dichotomous variables were coded as no=0, yes=1; Sex was coded as male=0, female=1; Years since surgery, BMI and age were continuous variables.**TABLE 3.** Health-related quality of life linear regression multivariable analyses

	AQOL-8D (n=157)		
Explanatory variables:	B (95% CI)	Beta (β)	p value
Years since ACLR	0.00 (-0.0 to 0.0)	-0.05	0.55
Injury to ACLR	-0.03 (-0.1 to 0.0)	-0.09	0.25
Revision ACLR	0.05 (0.0 to 0.1)	0.12	0.13
Contralateral ACLR	0.00 (-0.1 to 0.1)	0.01	0.90
Subsequent surgery	-0.01 (-0.1 to 0.0)	-0.05	0.54
RTS same/higher level*	**0.06 (0.0 to 0.1)**	**0.22**	**0.02**
RTS lower level*	0.00 (-0.1 to 0.1)	0.00	0.96
BMI	**-0.01 (0.0 to 0.0)**	**-0.24**	**0.002**
Age	0.00 (0.0 to 0.0)	-0.11	0.16
Sex	0.01 (0.0 to 0.0)	0.02	0.79
R^2 (p value)	**.19 (p<0.001)**		

B (95% CI): unstandardised coefficient (95% confidence interval); Beta (β): standardised coefficient; RTS: return to sport; BMI: body mass index; ACLR: anterior cruciate ligament reconstruction; Subsequent surgery: at least one additional knee surgery to an ACL-reconstructed knee (excluding revision ACLR or concomitant surgery performed at the time of primary or revision ACLR); * Did not return to sport = reference category; Sample size does not equal 162 for these analyses due to n=1 was not participating in sport at the time of injury, n=2 selected 'unsure' options, and n=1 did not complete the AQoL-8D; injury to ACLR was dichotomised as >6 months (yes/no); All dichotomous variables were coded as no=0, yes=1; Sex was coded as male=0, female=1; Years since surgery, BMI and age were continuous variables.

TABLE 4. Psychological health linear regression analyses

	HADS Depression (n=157)			HADS Anxiety (n=157)		
Explanatory variables:	B (95% CI)	Beta (β)	p value	B (95% CI)	Beta (β)	p value

Years since ACLR	0.07 (-0.1 to 0.2)	0.10	0.24	0.06 (-0.1 to 0.2)	0.06	0.48
Injury to ACLR	0.68 (-0.2 to 1.6)	0.12	0.14	0.29 (-1.1 to 1.6)	0.04	0.68
Revision ACLR	-0.30 (-1.5 to 0.9)	-0.04	0.62	0.36 (-1.4 to 2.2)	0.03	0.69
Contralateral ACLR	0.16 (-1.0 to 1.4)	0.02	0.79	-1.32 (-3.1 to 0.5)	-0.12	0.16
Subsequent surgery	0.34 (-0.5 to 1.2)	0.06	0.43	-0.62 (-1.9 to 0.6)	-0.08	0.33
RTS same/higher level*	-0.94 (-1.9 to 0.0)	-0.18	0.06	-0.65 (-2.1 to 0.8)	-0.09	0.39
RTS lower level*	-0.68 (-1.7 to 0.3)	-0.12	0.19	0.44 (-1.1 to 2.0)	0.05	0.58
BMI	**0.11 (-0.4 to 0.2)**	**0.24**	**0.003**	0.06 (-0.5 to 0.2)	0.09	0.26
Age	0.01 (-0.0 to 0.1)	0.02	0.77	-0.05 (-0.1 to 0.0)	-0.13	0.15
Sex	**-0.94 (-1.7 to -0.2)**	**-0.18**	**0.02**	0.24 (-1.0 to 1.4)	0.03	0.69
R^2 (p value)	**.18 (p=0.001)**			.07 (p=0.39)		

B (95% CI): unstandardised coefficient (95% confidence interval); Beta (β): standardised coefficient; Subsequent surgery: at least one additional knee surgery to an ACL-reconstructed knee (excluding revision ACLR or concomitant surgery performed at the time of primary or revision ACLR); RTS: return to sport; BMI: body mass index; ACLR: anterior cruciate ligament reconstruction; HADS: Hospital Anxiety and Depression Scale; * Did not return to sport = reference category; Sample size does not equal 162 for these analyses due to n=1 was not participating in sport at the time of injury, n=2 selected 'unsure' options, and n=1 did not complete the HADS; injury to ACLR was dichotomised as >6 months (yes/no); All dichotomous variables were coded as no=0, yes=1; Sex was coded as male=0, female=1; Years since surgery, BMI and age were continuous variables.

636 # FIGURES

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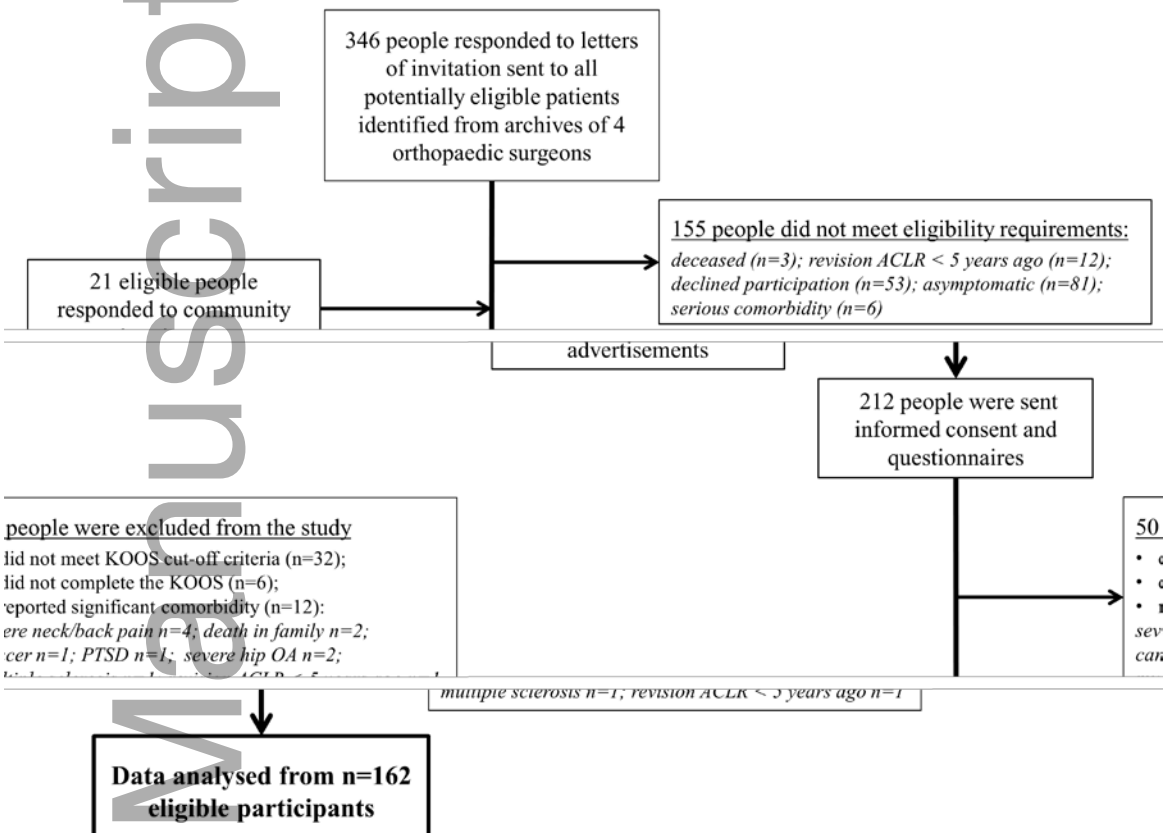

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641 **FIGURE 1.** Recruitment flow chart

642 ACLR: anterior cruciate ligament reconstruction; KOOS: Knee Injury and Osteoarthritis

643 Outcome Score; PTSD: post-traumatic stress disorder; OA: osteoarthritis

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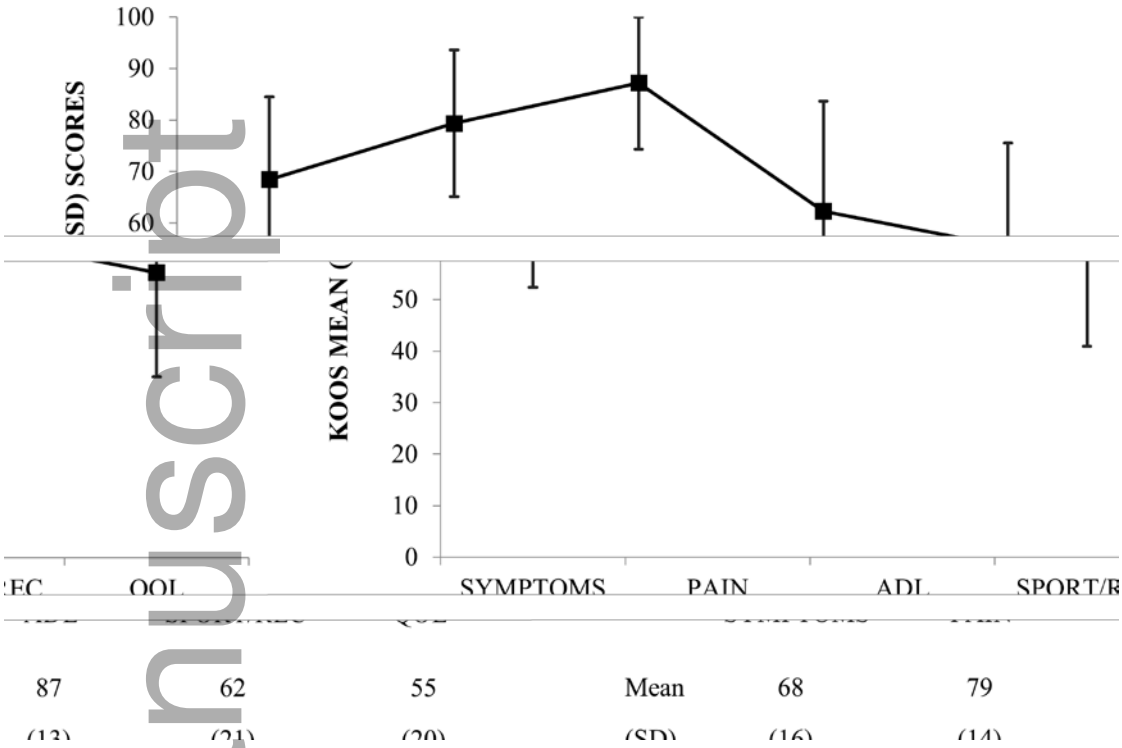

FIGURE 2. Knee injury and Osteoarthritis Outcome Score (KOOS) mean scores (boxes) and SDs (whiskers)

n=162; a lower score indicates poorer outcomes in all subscales; SD: standard deviation; ADL: Activities of Daily Living; Sport/Rec: function in Sport and Recreation; QOL: Quality of Life; KOOS: Knee Injury and Osteoarthritis Outcome Score.

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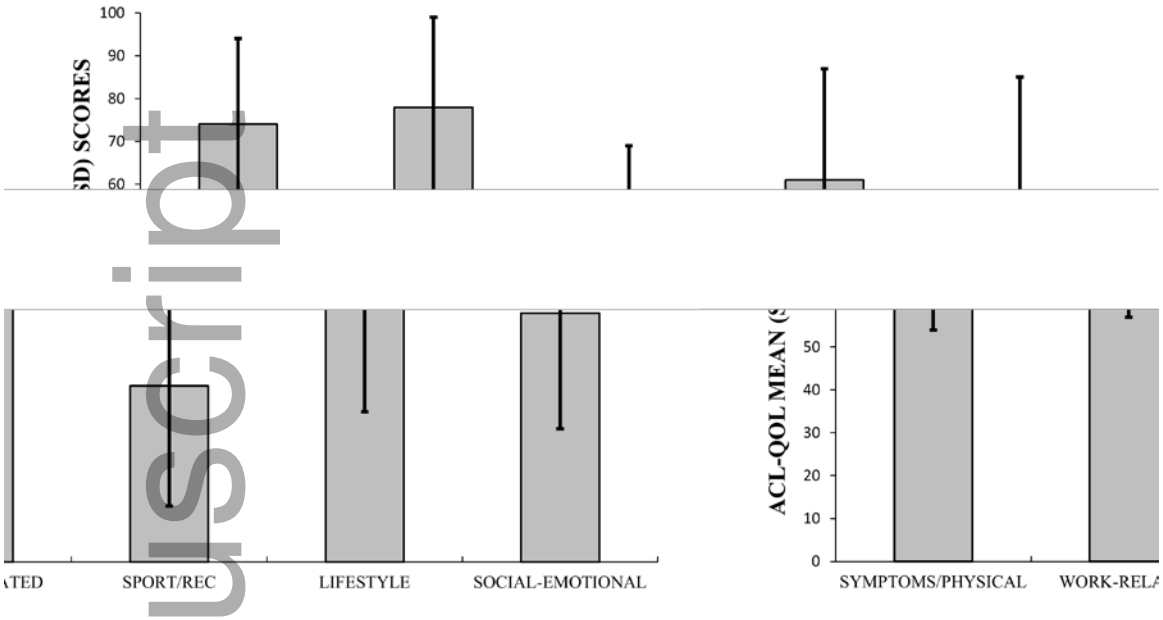

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655 **FIGURE 3.** Anterior Cruciate Ligament Quality of Life questionnaire (ACL-QOL) mean

656 domain scores (bars) and SDs (whiskers)

657 n=161; SD: standard deviation; a lower score indicates poorer outcomes in all domains.

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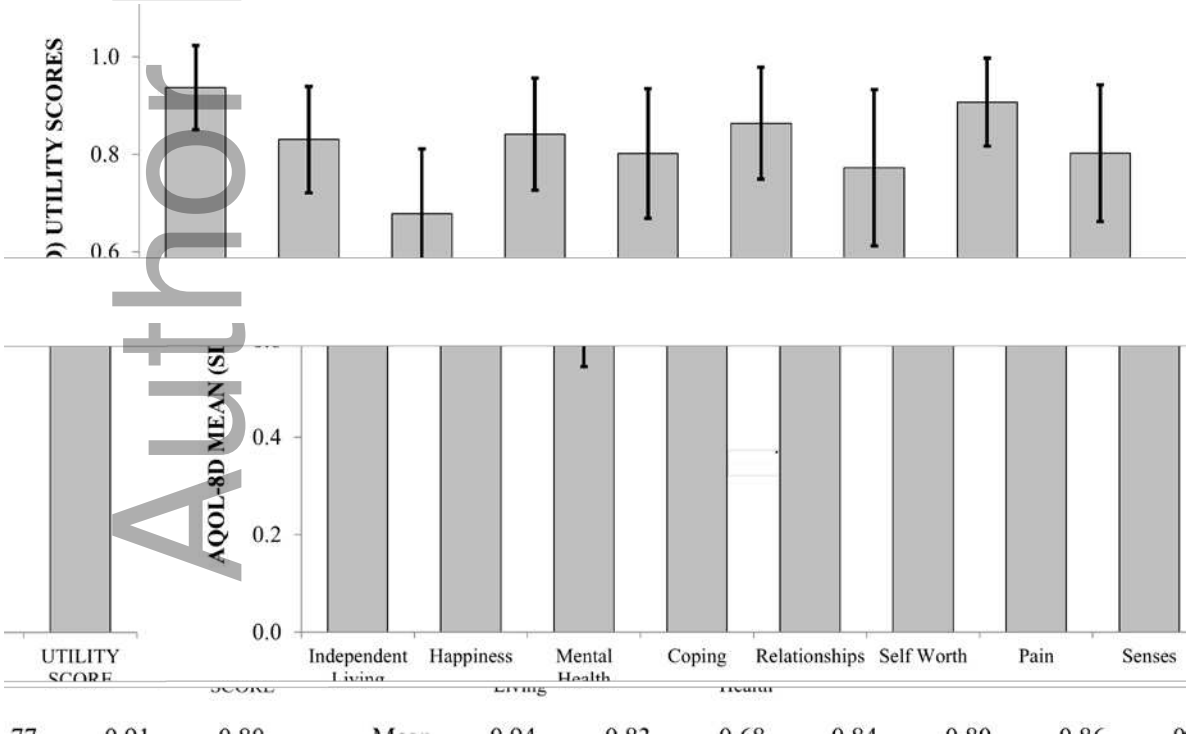

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FIGURE 4. The Assessment of Quality of Life (AQoL-8D) measure mean dimension scores and utility scores (bars) and SDs (whiskers)

n=161; SD: standard deviation; utility scores of 1.0 represent full health and 0.0 worst possible health.