*Risk Factors for Contralateral Anterior Cruciate Ligament Injury: a Systematic Review*

BY,

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**A scientific journal article submitted to the University of Birmingham as partial requirement for MSc (Pre-Registration) Physiotherapy**

**September 2019**

**submitted within the guidelines of the British Journal of Sports Medicine**



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*Abstract*

**Background** Contralateral anterior cruciate ligament (ACL) injury is highly prevalent following ipsilateral injury, however, there is a lack of clarity into significant risk factors. Therefore, it is important to identify and understand risk factors for contralateral rupture to inform clinicians of considerations for assessment, prevention and rehabilitation of ACL injuries.

**Objective** To systematically review and provide an analysis of significant risk factors for contralateral ACL injury.

**Study design** Prospective, retrospective and observational studies on risk factors for contralateral ACL injury were systematically reviewed.

**Data sources** MEDLINE and CINAHL databases were searched up to May 2019.

**Eligibility criteria** To answer the identified research question, prospective, retrospective and observational studies published in English were selected. Diagnostic and therapeutic investigation studies, papers including participants absent of ACL injury and papers excluding non-contact mechanisms were excluded.

**Results** Six full text articles met criteria. Two case-controls, two prospective cohorts, one retrospective cohort and one case series were selected. Total number of participants across all studies was 21,718, with follow-up periods range between 2 and 15 years. Four studies were of good methodological strength, two studies of fair methodological strength. Fair-good evidence found significant link between age, activity levels, and biomechanical factors on contralateral ACL injury, but contrasting results for BMI and family history. Good strength research found that female gender is not a significant risk factor for contralateral ACL injury.

**Conclusion** Age, activity levels, BMI and a variety of anatomical factors are the most significant risk factors for contralateral ACL injury. Family history is unclear in its role for predicting contralateral ACL injury. Female gender did not predict contralateral ACL injury, despite known ipsilateral risk. Development of assessment methods, rehabilitation and preventative protocols using these findings is required to quantify their effects on contralateral ACL injury incidence.

**Introduction**

Anterior cruciate ligament (ACL) injury has a high prevalence amongst the sporting population, particularly in those sports involving frequent change of direction and pivoting motions (Joseph et al., 2013; Beynnon et al., 2014; Padua et al., 2018) . Football, basketball, American football and skiing have the highest incidence rates, (Carter et al., 2018, Bulat et al., 2019; McPherson et al., 2019) with 72% occurring as a result of non-contact mechanisms (Boden et al., 2000; Laible and Sherman, 2014; Webster and Hewett, 2018).

Certain predisposing factors cause injury risk, which are categorised as internal and external in nature according to research (Alentorn-Geli et al., 2009; Tran et al.,2016). Risk factors for ipsilateral ACL injury are well documented, with internal factors identified as hormonal, neuromuscular, anatomical and congenital in nature (Ireland, 2002; Eiling et al., 2007; Mariani et al., 2016). This systematic review will focus on internal risk factors. Extrinsic risk factors include playing surface (Ryder et al., 1997; Olsen et al., 2003; Dragoo et al., 2013), footwear (McDaniel et al., 2010; Silvers and Mandelbaum, 2011) and weather (Orchard et al., 2005; Ruedl et al., 2011). Psychological risk factors have also been shown to negatively impact ACL functional outcome measures and patient perceptions following ipslaterlal reconstruction (Christino et al., 2016)

Despite great depth of research into identifying ipsilateral ACL injury risk factors (Dai et al., 2012; Spindler et al., 2013), there is a distinct lack of clarity and synthesis of research surrounding contralateral injury risk factors. Following ipsilateral ACL injury, patients are found to be twice as likely to sustain a contralateral ACL injury (Wright et al., 2011), with research finding a 16% incidence rate in contralateral injuries after ipsilateral reconstruction (Webster et al., 2014; Fältström et al., 2016; Wiggins et al., 2016). Given the high incidence of contralateral ruptures, research is warranted to understand the factors putting patients at risk of contralateral ACL injury. The results of this study aim to provide evidence to inform clinicians of factors to consider during assessment and when designing ACL injury prevention and rehabilitation programmes. Previous somewhat dated research has found strong relationship between femoral notch width and contralateral ACL injury, with others potentially linking younger age, gender and activity levels to contralateral ACL injury, with small sample sizes. Therefore, further research is needed to prove or disprove these links.

This review aims to identify and critically analyse previous research into contralateral ACL injury risk factors. To date, there has only been one review into risk factors for contralateral ACL injury in the past decade (Swärd, Kostogiannis and Roos, 2010). Their systematic review only utilised one database during their literature search, highlighting the necessity to identify risk factors for contralateral ACL injuries from a more substantial pool of available research.

**Methodology**

A systematic review of the evidence into contralateral ACL injury risk factors was conducted. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) for systematic reviews and guidelines from the British Journal of Sports Medicine were followed for this review.

Inclusion criteria was limited to papers written in the English language, and studies investigating contralateral ACL injury of prospective, retrospective and observational in nature, following suggestions from a previously published systematic review of contralateral ACL injury risk factors (Swärd, Kostogiannis and Roos, 2010). Papers including participants absent of an ACL injury, papers excluding non-contact mechanisms and papers examining diagnosis and therapeutic investigations were excluded. Articles not translated into English and previous meta-analysis and systematic reviews were also excluded.

*Literature search*

The electronic literature search was conducted using the Medline and CINAHL databases for relevant articles from inception through May 2019.

The databases were searched through the recommended methodology by research (Swärd, Kostogiannis and Roos, 2010; Boland, Cherry and Dickson, 2017) and the Cochrane Handbook for Systematic Reviews of Interventions for formatting purposes. The search terms adopted by Swärd, Kostogiannis and Roos (2010) and Neal et al. (2018) were duplicated for this review, consisting of the following words: Anterior Cruciate Ligament OR ACL AND contralateral AND injury AND risk factor. Keywords for risk factors were: risk factor OR association.

*Study selection*

2,943 papers were identified following the database search after removal of duplicates. The title and abstract were reviewed for relevance, followed by screening for inclusion and exclusion for eligibility. For the selected papers, full text was sought for review. As suggested by previous research (Neal et al., 2018), citations were searched using Google Scholar up to May 2019 to optimise the likelihood of identifying relevant research.

*Risk of Bias and methodological quality*

Selected studies were assessed using the Downs-Black tool (Downs and Black, 1998), consisting of a 27-item tool to assess study quality (10 items), external validity (3 items), study bias (7 items), confounding and selection bias (6 items) and power (1 item). The tool has a maximum score of 31 and studies are rated based on previous research (Hooper et al., 2008) recommending the following scores: excellent (26-28); good (20-25); fair (15-19); and poor (≤14). The tool has previously been identified as one of the most reliable and valid risk of bias tools, with a strong methodological rating (Deeks et al., 2003). The tool is also recommended for use in both randomised and non-randomised trials for a range of study methods, further explaining its application to this study. For full breakdown of study RoB and methodological testing, see appendix 1.0

*Data extraction*

Study characteristics were extracted for each selected paper, including authors, period of time conducted, country, sample size, participant characteristic and population, follow-up period, study design, study focus, investigated risk factor, results (*P* values, odds ratio, confidence intervals) and source of funding.

**Results**

*Study selection*

Six full text articles were assessed for risk of bias and methodological quality (see figure 1 for PRISMA flow diagram of included and excluded papers).

Additional records identified through other sources  
(n =5)

Records identified through database searching  
(n = 3,081)

## Identification

Records after duplicates removed  
(n = 2,943)

## Screening

Records excluded  
(n = 2,891)

Records screened  
(n = 2,943)

Full-text articles assessed for eligibility  
(n = 52)

Full-text articles excluded,   
(n = 46)

## Eligibility

Studies included in qualitative synthesis  
(n = 6 )

## Included

Studies included in quantitative synthesis (meta-analysis)  
(n = 0 )

Figure 1 – PRISMA flow diagram

*Study characteristics*

The characteristics of each study are reported in table 2. Each of the selected studies reviewed potential risk factors for contralateral ACL injury.

*Study summaries*

Six studies investigated risk factors associated with contralateral ACL injury. Two studies were case-control, two prospective cohort studies, one retrospective study and one case series. The collective number of participants was 21,718, with follow-up periods ranging between 2-15 years.

*Risk of Bias within studies*

Risk of bias is reported in table 1. The scores ranged between 14-22 (out of possible 30, with a mean of 20). All studies except one had significant power to detect clinically important effects.

Table 1 – Black-Downs checklist scores

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Study** | **Reporting (10)** | **External validity (3)** | **Bias**  **(7)** | **Confounding**  **(6)** | **Power (5)** | **Total (31)** |
| Kaeding et al., 2015 | 9 | 1 | 4 | 3 | 5 | 22 (good) |
| Webb et al., 2013 | 5 | 1 | 4 | 3 | 5 | 18 (fair) |
| Webster et al., 2014 | 7 | 1 | 4 | 4 | 5 | 21 (good |
| Paterno et al., 2010 | 8 | 1 | 4 | 2 | 3 | 17 (fair) |
| Salmon et al., 2005 | 7 | 3 | 4 | 3 | 5 | 22 (good) |
| Maletis et al., 2014 | 8 | 1 | 4 | 2 | 5 | 20 (good) |
|  |  |  |  |  |  |  |

Table 2 – study characteristics

| **Study** | **Period conducted** | **Country** | **Sample** | **Participant characteristics and population.** | **Follow-up period** | **Study design** | **Study focus** | **Investigated risk factor** | **Results (***P)* | **Odds ratio (CI 95%)** | **Source of funding** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Webb et al., 2013 | 1997-2012 | Australia | 181n | 90 females  91 males  26 years mean age at surgery  Patients undergoing isolated ACL reconstruction between October 1993 and March 1996 | 15 years | Case-control study | Investigative study into determining whether increased posterior tibial slope in ACL reconstructed patient increases future ipsilateral or contralateral rupture. | PTS > 12°  Age  Gender | .001  .016  .683 | 5.2 (2.0-13.8)  2.9 (1.2-6.7)  0.9 (0.4-1.8) | Not stated |
| Webster et al., 2014 | 2004-2008 | Australia | 750n | 370 males  191 females  28 years median age  Patients at 3-years following ACL reconstruction | 4.8 years. | Case control study | Determining the characteristics potentially leading to graft rupture and contralateral ACL rupture in reconstructed patients. | Age, y <20  Family history  Strenuous activity/returning to cutting/pivoting sport  Gender | .001  .02  .001  09 | 1.9 (0.9-3.9)  2.2 (1.2-4.4)  4.9 (2.0-12.2)  1.9 (0.9-3.9) | Perpetual I8 grant |
| Paterno et al., 2010 | 2007-2009 | USA | 56n | 16.41 mean years  167.26cm mean height  66.82kg mean weight  35 female  21 male  23.54 mean BMI  Male and female athletes following return to play after ACL reconstruction | 10 years | Cohort study | To measure neuromuscular control and postural stability in athletes following ACL reconstruction and determine whether they may predict secondary or contralateral injury. | Hip rotation moment impulse  Lateral knee movement upon landing  Postural stability | .001  .03  Not stated | 8.4 (2.1-33.3)  3.5 (1.3-9.9)  2.3 (1.1-4.7) | NFL charities, University of Cincinnati, University Research Council, NAIMS Grant, Children’s Hospital Institutional Clinical and Translational Science Award |
| Salmon et al., 2005 | 1993-2000 | Australia | 612n | Median age 28 (14-62)  383 male, 289 female  248 underwent BPTB reconstruction  364 4-strange semiteninosus and gracilis HT reconstruction  Patients with ACL reconstructions at 5-year follow up | 5 years | Case series | Determine rates of contralateral ACL injury and identify patient characteristics potentially increasing injury risk. | IKDC activity level (moderate to strenuous)  Gender  Family history | .05  .10  .83 | 2.1 (1.0-4.6)  1.9 (0.9-4.1)  1.1 (0.5-2.5) | Not stated |
| Maletis et al., 2014 | 2005-2012 | USA | 17,436n | 27.2 median age (IQR 18.7-37.7 years)  64% male, 36% female  Males and females with primary ACL reconstructions at 5-years post-operatively from ACLR Registry database | 2.4 years | Retrospective cohort study | Determine risk factors for primary and contralateral ACLR. | Age (per 1-y increment)  BMI 25-29 vs <25  BMI More than 30 vs less than 25 | .001  .004  .004 | 0.96 (0.95-0.97)  0.70 (0.55-0.89)  0.62 (0.46-0.86) | Not stated |
| Kaeding et al., 2015 | 2002-2010 |  | 2683n | 27 +/- 11 years mean (56% male)  25.5 +/- 4.8 mean BMI  Marx score 11.3 +/- 5.3  Subjects with primary ACLR, no history of contralateral injury, minimum of 2-year follow up. | 2 years | Prospective longitudinal cohort | Identify risk factors for ipsilateral and contralateral ACL ruptures following initial reconstruction. | Age  Marx score  Gender | .004  .001  .09 | 0.96 (0.93-0.99)  1.12 (1.04-1.22)  1.52 (0.91-2.54) | National Institute of Health, Department of Health and Human Services |

Each study investigated the risk factors associated with contralateral ACL injury within adult populations. Five studies searched registries and questioned patients on contralateral ACL injury incidence, with one study quantifying biomechanical measures following primary ACL injury to identify contralateral injury incidence. Papers focused on age, activity, gender, family history and a variety of anatomical factors on their potential link to contralateral ACL injuries.

*Age and activity*

Multiple studies focused on the link between age and susceptibility to developing contralateral ACL injuries, with four finding significant links between younger age and contralateral ACL injury. Kaeding et al. (2015) and Maletis et al. (2014) found that for every year increase in age, chance of developing contralateral ACL injury decreased by 9% (*P<*.01) and 4% (*P =* .001) respectively, highlighting young age as a significant risk factor for contralateral ACL injury. Webster et al. (2014) found that 29% of participants aged 20 or younger sustained a contralateral ACL injury (*P =* .001), with Webb also finding that those under 18 were three-fold at risk of contralateral ACL injury (*P =* .016).

Three papers found a significant relationship between high activity levels and contralateral injury incidence (Salmon et al., 2005; Webster et al., 2014; Kaeding et al., 2015). Using International Knee Documentation Committee scores (P = .05), Marx scores (*P<*.01) and survey questions (*P =* .001), participants at higher levels of activity were at higher risk of contralateral ACL injury compared to those exposed to lower levels of strenuous activity.

*Gender*

Studies found no link between the female gender and risk of sustaining a contralateral ACL injury (Salmon et al., 2005; Webb et al., 2013; Webster et al., 2014; Kaeding et al., 2015). Webster et al. (2014) found that just nine females and thirty-two males developed contralateral ACL injuries, showing that females are not more susceptible to sustaining contralateral ruptures (*P* = .09). Salmon et al. (2005) found that just 7% of females and 5% of males sustained secondary injuries at a 5-year follow up (*P =* .10), whilst Kaeding et al. (2015) found that females and males had contralateral injury rates of 4.1% and 4.6% respectively (*P =* .11). Webb et al. (2013) also found no difference in contralateral ACL injury incidence between males and females (*P =* .683)

*Family history*

Webster et al. (2014) found that family history was significant in predicting contralateral injury (*P. =*.02), with a two-fold increase in prevalence compared to those with no ACL reconstructed relative. Conversely, Salmon et al. found no significant increase in contralateral ACL injuries for those with a direct relative having experienced ACL injuries (*P =* .83).

*Anatomical factors*

A number of these studies focused on anatomical factors leading to contralateral injury risk, including one paper focusing on posterior tibial slope angle. Webb et al. (2013) found that an increase in PTS was a significant risk factor for contralateral ACL injury as participants sustaining contralateral injury had a mean PTS of 9.9° compared to 8.5° in those absent of secondary rupture (*P* = .001). It was found that those with a PTS of above 12° were almost 60% more likely to develop injury than those with a lower PTS angle (*P* = .001).

Body Mass Index (BMI) was investigated in two studies, with contrasting results (Maletis et al., 2014; Kaeding et al., 2015). With data from the Kaiser Permanente ACLR registry, Maletis et al. (2014) found that contralateral injury risk was reduced in patients with higher BMI. When comparing injury rates between those with normal and higher BMI ranges, those above 30kg/m2 (*P* = .004) and those between 25-29kg/m2 (*P* = .004) being found to be 37% and 30% less susceptible to contralateral injury respectively, compared to those below 25kg/m2. Conversely, Kaeding et al. (2015) found no such evidence in a search of Swedish and Norwegian registries, disputing BMI as an independent risk factor for contralateral ACL injury (*P<.*05).

Regarding biomechanical risk factors, Paterno et al. (2010) found a significant relationship between hip and knee landing kinematics and contralateral ACL injury. More specifically, limited hip mobility, strength and higher hip rotation moment impulse was found to put patients at higher risk of contralateral ACL injury (*P* <.001). Increase in lateral knee movement in sagittal plane during initial landing was also found to predict contralateral injury, with a four-fold increase in injury risk compared to those with lesser movement upon landing (*P =* .03).

**Discussion**

*Age and activity*

Age is arguably the most consistent link to contralateral injury susceptibility in these findings, with Webster et al. (2014) finding that 29% of those undergoing secondary reconstruction were aged below 20 years old, at 5-years follow up. The Swedish National ACL registry suggests that adolescents account for up to 32% of contralateral ruptures, but given that the registry only records surgical reconstructions, these figures are likely to be somewhat conservative and not representative of the entire population. A further limitation of their research was the low number of ruptures, despite its modest sample size of 750 participants, therefore they were not able to perform multivariate analyses, and recommended future research to do so. Maletis et al. suggested that incidence rates of contralateral ACL injury increased by 4% for every year their participants grew older, which in consistent with previous findings (Bourke et al., 2012; Lind, Menhert and Pedersen, 2012; Hettrich et al., 2013). Whilst their sample size was a modest 17,436 participants, they experienced an 18% attrition rate to consequently cause substantial bias claims, although their prospective nature and methodological strength indicate it has respectful internal validity. The concept of injury reducing with each passing year is substantiated by a found reduction of re-tear odds by 9.1% in Kaeding et al.’s (2015) level 3 cohort study. However, their findings combined the power of both age and activity levels on effect size, suggesting an interacting relationship between these factors. They quantified activity levels through Marx scores, shown to be the most significant subjective predictor of activity levels for participants in research, finding that every point increase on the Marx score decreased injury chance by 11%. Finally, these studies each concluded that it was difficult to identify age as an independent risk factor given its link with activity levels. A plausible explanation of the seemingly increased injury risk in young participants is that this particular demographic is shown to take part in higher levels of strenuous activity than older populations. Another potential reason is that the younger population are more likely to undergo surgical reconstruction, thus accounting for higher numbers in scientific research that focuses on re-tears and secondary reconstruction.

*Gender*

Despite significant links between the female gender and ipsilateral ACL injuries, with contemporary research suggesting an 8-fold increase in injury risk, the female gender does not appear to result in increased risk of contralateral ACL injury. Kaeding et al. (2015) concluded that a multivariable analysis of their results, combined with results from Scandinavian registries, showed that neither female gender does not predispose increased risk of contralateral ACL injury (*P =* .11). To further emphasise the point, whilst it has been theorised that females with BPTB and HT autografts sustain contralateral injuries at a higher rate than males, Salmon et al. (2005) found no significant link (*P =* .10*)*. The results found no significant difference between male and female contralateral injury rates, irrespective of surgical graft type (Webb et al., 2013; Webster et al., 2014). These findings may be flawed, however, as research shows that female athletes return to activity at a lower competitive level than their male athlete counterparts (Webster and Feller, 2018), therefore potentially skewing the significance of these findings, due to decreased activity levels and workloads.

*Family History*

Supporting previous research that participants were twice as likely to develop an ACL injury if a direct relative has already had a knee ligament rupture themselves (Flynn et al., 2005), Webster et al. (2014) found family history to be a significant risk factor for contralateral ACL ruptures (*P =* .02). However, despite this positive finding, the number of studies having shown this positive correlation is limited, and therefore one should adopt caution. Further casting doubt on this link, Salmon et al. reported non-significant findings (*P =* .83), concluding that whilst it is possible congenital factors contribute towards contralateral injury risk, it is likely that the apparent link may be explained by the families being at higher risk as a result of taking part in higher strenuous activity more frequently than lesser active families.

*Anatomical factors*

Contralateral ACL ruptures are shown to be significantly more prevalent in those with abnormal neuromuscular control and poor postural stability (*P =* <.001). This research was the first of its kinds in terms of proving a modifiable rehabilitation protocol. Supporting previous research through 3D motion analysis (Paterno et al., 2010), decreased hip range and strength may result in increased knee valgus to put increased strain on the ACL (Hewett, Myer and Ford, 2006; Krosshaug et al., 2007). Therefore, hip range and strength deficits should be addressed in rehabilitation protocols to reduce the risk of contralateral ACL injuries in the future. Rehabilitation protocols shown to aid with retraining neuromuscular control should incorporate squat jumps, plyometric and balance work, to potentially reduce secondary ACL rupture. Asymmetry in lateral knee movement during landing may also predispose increased secondary injury risk, supporting previous findings (*P =* .03). These results suggest that patients with poor neuromuscular control and postural stability are more likely to sustain contralateral ACL injury as they are less able to absorb landing forces adequately. Therefore, rehabilitation protocols should aim to incorporate neuromuscular training and proprioceptive work to aim to reduce the risk and incidence rates for contralateral ACL rupture.

Webb et al. (2013) found a significant increase in contralateral ACL injury risk in those with a PTS of >12° (*P =* .001), which, to the best of our knowledge, is the only study to have investigated this link following reconstruction. Despite the apparent link between increased PTS angle and contralateral injury, it should be considered that there are many methods of quantifying PTS through MRI and radiographic imagery, which may cause inconsistencies when measuring. In this particular study, two orthopaedic surgeons measured the PTS through radiographs, showing a high interrater reliability. However, one major limiting factor of this research is that using just one radiographic image might not be satisfactory in measuring tibial plateaus, given their anatomical complexity. Research concludes that there is almost certainly a role in contralateral ACL development played by PTS, as it is theorised for every 1° increase in PTS angle, anterior tibial translation also increases by 0.6mm. These results are consistent with cadaveric findings (Giffin et al., 2004; Shelburne et al., 2011), potentially explaining that the increased risk may be due to exposing the ligament to higher loading and strain.

The finding that those with a higher BMI were less susceptible to suffering from contralateral ACL ruptures is not consistent with previous research, as hamstring strength improvement during rehabilitation following ACL reconstruction for obese patients is generally hampered, indicating that they may be more at risk due to the hamstrings role in protecting the knee (Tsepis et al., 2004; Hansen et al., 2017). Maletis et al. (2014) found significant reduction in ACL incidence in those with a BMI above 30kg/m2 (*P =* .004), which may potentially be as a result of lower activity levels in obese participants.

**Limitations**

There are a number of limitations associated with this study. The first is that only the MEDLINE and CINAHL databases were searched to identify relevant papers, thus limiting the number of studies that could have potentially fulfilled the set criteria. A Google Scholar citation search was conducted in an attempt to limit the risk of missing relevant papers. A further limiting factor for finding appropriate studies was the language restriction, as only English papers were selected. This may be problematic given the high number of contemporary studies published in Scandinavian countries. However, the likelihood of having a large impact on overall results of the study are minimal. Despite not specifying the number of papers excluded for language reasons, which may present a limitation in itself, the chances of papers being excluded solely for language barrier reasons was unlikely.

A further cause of concern is the low sample size of certain papers included in this study. One paper only assessed risk factors from thirteen contralateral ACL rupture incidences, suggesting low statistical power compared to the other included papers. Subsequently, it may be difficult for one to generalise to the wider population, despite the authors concluding high confidence in their results. The lack of studies specifying the type of graft used amongst participants is another limitation, as it is well known that certain graft types predispose secondary ipsilateral and contralateral ligamentous injuries. Future studies need to specify into graft type selected for primary reconstruction to be able to determine whether the identified risk are truly independent of other risk factors.

Given that the general purpose of prospective cohort studies is to find links between potential factors and risk of contralateral ACL injury, this is limited as it is only able to focus on independent variables. As this study has identified that age, BMI and female gender may interact with overall activity levels, it would seem logical to conclude that research needs to adopt an approach taking into consideration the complexity of identifying risk factors for contralateral ACL injury. Finally, one major limitation that may have skewed the results of this review as a result, is that Webb et al. (2013) failed to consider graft type within their patient demographics. Given that those undergoing allograft reconstruction are 5.2 times more susceptible to re-rupture than those with an autograft, this may have potentially altered their findings and thus make their conclusions less assuring as a result.

**Conclusion**

After reviewing literature surrounding risk factors for contralateral ACL ruptures, young age is one of the most significant predictors of injury. Higher stenuous activity, which may interact with age, BMI and female gender, is also a significant risk factor for contralateral ACL injury. Despite strong ipsilateral links, the female gender does not result in an increase in susceptibility to contralateral ACL rupture. Interestingly, those with a high BMI were found to be at lower risk of sustaining secondary injury when compared to those with “normal” BMI. Family history still requires further clarity into whether it can act as an independent risk factor, whilst poor neuromuscular control and stability are significant risk factors for contralateral ACL injury. Biomechanical factors such as higher hip rotation moment impulse and lateral knee movement upon landing are also significant predictors for contralateral ACL injury. PTS of <12°  is a significant risk factor for contralateral ACL injury. Future research should aim to quantify the effect of neuromuscular programmes on incidence rates of contralateral ACL injury, given its obvious link. Researchers should also aim to investigate family history further given its current lack of clarity and psychological risk factors should be reviewed due to its reported links to negative ACL functional outcomes and patient perceptions. Given that this study has identified a number of factors potentially combining to increase contralateral ACL injury risk, future research should aim to consider an interactive relationship between variables, rather than analysing risk factors as independent predictors.

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**Appendices**

Appendix 1.0 – Downs-Black checklist in full.

|  | Kaeding et al., 2015 | Webb et al., 2013 | Webster et al., 2014 | Paterno et al., 2010 | Salmon et al., 2005 | Maletis et al., 2014 |
| --- | --- | --- | --- | --- | --- | --- |
| Q1: Aim clearly described? | Yes | No | Yes | Yes | Yes | Yes |
| Q2: Outcomes clearly described? | Yes | Yes | Yes | Yes | Yes | Yes |
| Q3: Patients characteristics clearly described? | Yes | No | Yes | Yes | Yes | Yes |
| Q4: Interventions clearly described? | Yes | Yes | No | Yes | Yes | Yes |
| Q5: Principal confounders clearly described? | Yes | No | No | No | No | Yes |
| Q6: Main findings clearly described? | Yes | Yes | Yes | Yes | Yes | Yes |
| Q7: Random variability for main outcome provided? | Yes | Yes | Yes | Yes | No | No |
| Q8: Adverse events reported? | No | No | No | Yes | No | No  No |
| Q9: Loss-to-follow up reported? | Yes | No | Yes | No | Yes | Yes |
| Q10: Actual p-value reported? | Yes | Yes | Yes | Yes | Yes |  |
| Q11: Sample asked to participate representative of the population? | Unable to determine | Unable to determine | Unable to determine | Unable to determine | Yes | Unable to determine |
| Q12: Sample agreed to participate representative of the population? | No | Unable to determine | Unable to determine | No | Yes | Unable to determine |
| Q13: Staff participating representative of the patients’ environment? | Yes | Yes | Yes | Yes | Yes | Yes |
| Q14: Attempt to blind participants? | No | No | No | No | No | No |
| Q15: Attempt to blind assessors? | No | No | No | No | No | No |
| Q16: Data dredging results stated clearly? | No | No | No | No | No | Yes |
| Q17: Analysis adjusted for length of follow up? | Yes | Yes | Yes | Yes | Yes | Yes |
| Q18: Appropriate statistics? | Yes | Yes | Yes | Yes | Yes | Yes |
| Q19: Reliable compliance? | Yes | Yes | Yes | Yes | Yes | Yes |
| Q20: Accurate outcome measures? | Yes | Yes | Yes | Yes | Yes | Yes |
| Q21: Same population? | Yes | Yes | Yes | Yes | Yes | Unable to determine |
| Q22: Participants recruited at the same time? | Yes | Yes | Yes | Unable to determine | Yes | Yes |
| Q23: Randomised? | No | No | No | Yes | No | No |
| Q24: Adequate allocation concealment? | No | No | Yes | No | No | No |
| Q25: Adequate adjustment for confounders? | No | No | No | No | No | Yes |
| Q26: Loss of follow up reported? | Yes | Yes | Yes | No | Yes | Unable to determine |
| Q27: Power calculation? | Yes | Yes | Yes | Yes | Yes | Yes |