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# Weak associations between body mass index and self-reported disability in people with unilateral anterior cruciate ligament reconstruction

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**Abstract**

*Purpose and hypothesis* Individuals with an anterior cruciate ligament reconstruction (ACLR) are susceptible to persistent disability, weight gain and the development of knee osteoarthritis. It remains unclear whether body mass index (BMI) is a factor that influences disability following ACLR. The purpose of this study was to determine the association between BMI and self-reported disability [International Knee Documentation Committee (IKDC) Index] in individuals with a unilateral ACLR. We hypothesized that lower BMI would associate with higher IKDC.

*Methods* BMI and IKDC were measured in 668 individuals with a unilateral ACLR (60.9% female, BMI 24.4 ± 3.7 kg/m$^2$, IKDC 84.7 ± 11.9%). Bivariate associations were conducted between BMI and IKDC for the entire sample and selected subsets (gender, ACLR graft type and history of meniscal injury). Multiple regression analyses were used to determine the impact of potential covariates (Tegner score, age and months since ACLR) for significant bivariate

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associations. After accounting for covariates, there were no significant associations between BMI and IKDC when separately evaluating the cohort based on either gender or history of a concomitant meniscal injury. The odds of achieving age- and gender-matched healthy population average IKDC scores for those with low (<25) and high (≥25) BMI were determined.

*Results* Lower BMI associated with higher IKDC ($r = -0.08$, $P = 0.04$). For the entire sample, BMI did not uniquely predict variance in IKDC ($\Delta R^2 > 0.001$, n.s.) after accounting for covariates. BMI uniquely predicted a significant but negligible amount of variance in IKDC in individuals with a patellar tendon autograft ($\Delta R^2 = 0.015$, n.s.). Individuals with low BMI demonstrated higher odds (odds ratio = 1.45; 1.05–1.99) of achieving population average IKDC scores compared to participants with high BMI.

*Conclusions* There was a significant but negligible correlation between lower BMI and lesser disability in individuals with unilateral ACLR and individuals who are underweight or of normal BMI demonstrated higher odds of achieving population average IKDC scores compared to overweight or obese individuals. While an overall association was found between lower BMI and lesser disability, the magnitude of the association remains negligible; therefore, BMI was not a strong clinical predictor of successful ACLR outcomes in this cohort of patients with unilateral ACLR.

*Level of evidence* Cross-sectional prognostic study, Level II.

**Keywords** Obesity · Osteoarthritis · Knee · International Knee Documentation Committee Index

**Abbreviations**

| | |
|---|---|
| ACL | Anterior cruciate ligament |
| ACLR | Anterior cruciate ligament reconstruction |
| BMI | Body mass index |
| IKDC | International Knee Documentation Committee |
| KOA | Knee osteoarthritis |
| PT | Patellar tendon |
| PTOA | Post-traumatic osteoarthritis |

## Introduction

Higher body mass index (BMI) and knee injury history are two of the most predictive factors leading to the onset of KOA [20, 25, 26, 35]. Decreasing BMI in older patients with KOA will reduce the disability related to KOA [16], yet there is less evidence exploring the association between BMI and disability in younger individuals who have sustained a knee injury and are at high risk of developing post-traumatic osteoarthritis (PTOA). Anterior cruciate ligament (ACL) injury is one of the most common traumatic knee injuries among physically active individuals [13]. Individuals with an ACL injury often report decreased function that persists months to years following an ACL reconstruction (ACLR) [19] and approximately 50% of ACLR individuals developing PTOA within two decades of injury [21]. Persistent disability is coupled with an increased risk of undesirable weight gain following injury [27, 33]. Identifying factors, such as BMI, that can be modified to improve disability in individuals with ACLR are important for maintaining optimal long-term health following knee injury.

Previous longitudinal studies have reported that individuals with lower BMI demonstrated higher physical activity levels 2 years following ACLR [8] and better self-reported function 6 years following ACLR [6]. Furthermore, individuals with an ACLR who were obese or morbidly obese demonstrated lower odds of attaining patient-specific and gender-matched population average cut-offs for high self-reported function compared to individuals with an ACLR who were normal or underweight [18]. Conversely, Ballal et al. [2] reported that overweight and obese patients do not demonstrate worse outcomes within the first 2 years following primary hamstring autograft ACLR compared to patients who are normal or underweight. Discrepancies in the literature regarding the association between disability and BMI in individuals with an ACLR may be due to multiple factors including: (1) statistical comparisons that are only made between the most obese individuals and normal or underweight individuals, (2) differences in ACL patient inclusion criteria between studies that may influence self-reported function (i.e. history of multiple or bilateral ACL injuries, only single time points post-ACLR) and (3) variations in the methods used to collect height and weight, as self-reporting may underestimate the level of obesity in the population [12]. A more comprehensive analysis is needed in patients with a unilateral ACLR, using objectively measured height and weight data, to determine the nature of the association between BMI and self-reported disability following ACLR.

The purpose of this study was to determine the association between BMI and self-reported disability as continuous variables using the International Knee Documentation Committee (IKDC) Index in a cross section of individuals with a unilateral ACLR. Next, the association between BMI and self-reported disability for both genders, those with and without a concomitant meniscal injury, as well as individual ACLR graft types was determined. The differences in self-reported disability between BMI categories and the associations between BMI and self-reported disability within each BMI category were determined in a secondary analysis. Finally, odds ratios were used to determine whether individuals with low BMI (<25)

demonstrated different odds of achieving patient-specific age- and gender-matched healthy population average IKDC cut-off scores [1] compared to those with high BMI (≥25). It was hypothesized that lower BMI would associate with better self-reported function and that individuals with low to normal BMI will have better IKDC scores compared to those with high BMI.

## Materials and methods

The current study was a multi-site cross-sectional observational study at six different sites in the Midwest (Ohio, Michigan and Wisconsin) and Southeast regions (Virginia, North Carolina and South Carolina) of the USA. The principal investigators at all sites verified the accuracy of each data point and confirmed that all participants fit the inclusion criteria for the current study. All protected health information and any variables that could identify individual study participants were removed prior to data pooling. All de-identified data were electronically and securely transferred to approved database housed at University of Wisconsin—Madison (Approval Number 2013-1429) and then to the corresponding author of this study. The institutional review boards at each site individually approved the initial collection of these data and were consulted for approval of pooling de-identified data for the current study. All participants included in the current study provided informed written consent for data to be used for research purposes which were approved by the institutional review boards at each institution (University of Wisconsin—Madison 2013-1429; University of Toledo 107707, 106685; Michigan State University 15-971; University of Virginia HSR-17399, HSR-16997, HSR-15990, HSR-16849, HSR-17486; University of North Carolina at Chapel Hill 13-2385, 13-3228, 15-1003; Greenville Health System [South Carolina] Pro00041492).

### Participants

Participants were recruited from multiple sources including: university communities, private orthopaedic physician practices and university health system orthopaedic physician practices, as well as intercollegiate athletics. Methods for recruitment of participants varied across the collection sites and included by word of mouth, approved recruitment flyers, as well as referrals from participating physicians, physical therapists and athletic trainers. We included participants with a history of primary unilateral ACLR and who were currently participating in either unrestricted physical activity or functional activities supervised by a physical therapist or athletic trainer. All individuals in this study were allowed to participate in unsupervised sport activity or had been participating in supervised sport activity (by a healthcare professional) and were being evaluated to return to unsupervised sport activity at the time of testing. Therefore, included individuals were able to complete all questions on the IKDC, including questions regarding the capability to perform sport-related activities. We excluded individuals with an ACLR and a history of any other lower extremity orthopaedic surgery, ACLR revision surgery, multi-ligament reconstruction at the time of primary ACLR, bilateral ACLR, diagnosed KOA, balance or neuromuscular disorders, or a history of an orthopaedic injury in either limb, other than the ACL injury of interest, during the 6 months prior to testing. We did not exclude participants based on the amount of time since surgery in order to evaluate the associations between BMI and self-reported disability in a cohort of individuals with a diverse range of months since ACLR.

### Body mass index

Trained research personnel measured height and mass on the day of the testing session using stadiometers and calibrated scales, respectively. Height and mass were recorded to the nearest cm and 0.5 kg increment, respectively. BMI was calculated using standard equations (BMI = (kg/(m$^2$)) and delineated into categories (≤18.5 underweight, 18.5–24.99 normal range, 25–30 overweight, >30 obese) based on guidelines endorsed by the World Health Organization [4]. BMI was calculated to the hundredth decimal place.

### Measurement of self-reported function and patient-reported demographics

Participants completed a series of institution-specific forms, which included common data that were pertinent to the current study. All participants were asked to self-report age, sex, ACL graft type, the history of a concomitant surgical meniscal procedure (meniscectomy or meniscal repair) performed at the time of ACLR, as well as date of ACLR. If participants were unable to remember at the time of testing or determine this information from personal records, data were considered missing for the current study; Tegner activity levels were collected on the day of the testing session to determine the level of physical activity in which each participant was currently involved [3]. Tegner activity levels range from 0 to 10, with lower values indicative of a lower level of participation in physical activity and higher values indicative of participation in elite sports. All participants completed the subjective portion of the International Knee Documentation Committee (IKDC) Index on the day of the testing session, which is a valid and reliable measure of self-reported disability following knee injury [15]. The subjective IKDC questionnaire demonstrates acceptable test–retest reliability over a 1–2-week period (Intraclass

correlation coefficient and 95% confidence interval; 0.93, 0.89–0.96) [32]. IKDC scores were normalized to a total of 87 possible points and expressed as a percentage of 100 (rounded to hundredth decimal place). Scores for the IKDC range from 0 to 100 with higher scores indicative of better self-reported function or less disability. Trained study personnel provided directions for completing all self-reported questionnaires and were available during testing to answer questions from the participants.

### Statistical analysis

The primary analyses were conducted using Pearson product–moment correlations ($r$) to assess the simple bivariate associations between BMI and IKDC. Additionally, we performed separate bivariate Pearson product–moment correlations to determine associations between main outcome measures (BMI and IKDC) and potential covariates (Tegner activity level, age at the time of testing and months since ACLR surgery). We utilized multiple linear regression models to determine how relevant covariates influenced the association between IKDC and BMI. Covariates that were found to significantly associate with IKDC or BMI were first entered into a multiple linear regression model prior to BMI. The covariates were entered into the regression model in a hierarchal order based on the strength of the associations between the covariates and main outcome measures. Next, we assessed the $R^2$ of the entire model (covariates + BMI) for predicting IKDC, as well as the unique variance that BMI contributed to the IKDC prediction model by evaluating the change ($\Delta$) in $R^2$ after entering BMI. We performed similar bivariate associations in separate subsections of the sample based on gender, concomitant meniscal injury and graft type. Multiple regression analyses that included potential covariates were only conducted if a significant simple bivariate association was initially detected between BMI and IKDC within a given subsample (e.g. females).

Next, we dichotomized participants into low BMI (underweight and normal) and high BMI (overweight and obese) groups and separated participants that were able to achieve age- and gender-matched normative IKDC scores [1]. Odds ratios were calculated with corresponding 95% confidence intervals to determine whether high or low BMI was associated with the odds of achieving age- and gender-matched normative IKDC cut-off scores.

A post hoc analysis was conducted to assess the association between BMI and IKDC in subgroups of our cohort based on clinically relevant timeframes durations following ACLR. Subgroups were categorized as: <6, 6–12, 12–24 and >24 months. The same analyses as described above in the a priori primary analyses were conducted for each subgroup. The magnitude of all bivariate associations were classified as negligible (0.0–0.3), low (0.31–0.5) moderate (0.51–0.7), high (0.71–0.9) and very high (0.9–1.0) [24]. We considered correlations to be statistically significant if alpha levels were $\leq$0.05 and non-statistically significant findings were indicated as n.s. Statistical Package for the Social Sciences software (SPSS, version 19.0, IBM Corp., Somers, NY) was used to perform all analyses.

## Results

There were no significant differences for BMI ($F_{5, 667} = 0.61$, n.s.) or IKDC ($F_{5, 667} = 1.03$, n.s.) between data collection sites in the 668 individuals who fulfilled inclusion criteria (Table 1).

For the entire sample, there was a significant but negligible association indicating that lower BMI associated with higher IKDC (Fig. 1). Higher Tegner activity levels greater number of months since ACLR and a younger age were associated with higher IKDC scores, while an older age and lower Tegner activity levels were associated with higher BMI (Table 2). Together, Tegner activity level, months since ACLR and age accounted for 19.1% of the variance in IKDC ($n = 636$, $R^2 = 0.193$, $P < 0.001$). Subsequently, including BMI accounted for a small and non-significant increase of >0.1% ($\Delta R^2 > 0.001$, n.s.) to the total predicted variance in IKDC with Tegner activity level, months since ACLR, age and BMI included in the multiple linear regression model ($n = 636$, $R^2 = 0.193$, $P < 0.001$).

### Gender

Females with lower BMI demonstrated significantly higher IKDC scores ($r = -0.13$, $P = 0.009$). After accounting for Tegner activity level, months since ACLR and age (Table 3), BMI did not significantly improve the ability to predict IKDC score ($\Delta R^2 = 0.006$, n.s.) from the entire model of females including covariates and BMI ($n = 400$, $R^2 = 0.24$, $P < 0.001$). There was no significant bivariate association between BMI and IKDC scores for males ($r = -0.07$, n.s.).

### History of a concomitant meniscal injury and graft types

BMI was not significantly associated with IKDC in individuals with ($n = 273$; $r = -0.04$, n.s.) or without ($n = 259$; $r = -0.09$, n.s.) a history of a concomitant meniscal injury. Tegner activity level, months since ACLR and age associated with IKDC score and age were associated with BMI regardless of meniscal injury history (Table 4). There were no significant associations between BMI and IKDC

**Table 1** Demographics, outcome measures and potential covariates

| | |
|---|---|
| Participants | 421 (63%) Women |
| | 247 (37%) Men |
| Age | 21.73 ± 6.17 years |
| Height | 1.71 ± 0.1 m |
| Mass | 72.0 ± 15.0 kg |
| Body mass index | 24.39 ± 3.71 |
| Months post-ACLR | 30.51 ± 35.45 |
| | Missing = 25 (3.7%) |
| International Knee Documentation Committee Scale | 84.68 ± 11.91% |
| Tegner score median (range) | 6 (1–10) |
| | Missing = 7 (1.0%) |
| ACLR graft type | 38 (5.7%) Allograft |
| | 286 (42.8%) Patellar tendon autograft |
| | 224 (33.5%) Semitendinosus/gracilis autografts |
| | 4 (0.5%) Other |
| | 116 (17.4%) Missing |
| History of concomitant meniscal repair or meniscectomy with ACLR | 273 (40.9%) Yes |
| | 259 (38.8%) No |
| | 136 (20.4%) Missing |

*ACLR* anterior cruciate ligament reconstruction

in individuals with an allograft ($n = 38$, $r = -0.14$, n.s.) or a semitendinosus/gracilis autograft ($n = 224$, $r = -0.03$, n.s.); yet, those with a patellar tendon (PT) autograft and lower BMI demonstrated better self-reported function ($n = 286$, $r = -0.16$, $P = 0.01$). Higher Tegner activity levels and a greater number of months since ACLR were associated with higher IKDC scores, and greater BMI was found to be significantly associated with older individuals with PT autografts (Table 5). In individuals with a PT autograft, BMI ($\Delta R^2 = 0.015$, $P = 0.02$) significantly improved the capability of Tegner activity level, months since ACLR surgery and age to collectively predict IKDC, with the total model, accounting for 19.4% of the variance in IKDC ($n = 279$ $R^2 = 0.194$, $P > 0.001$). Due to an inadequate sample size ($n = 4$), we choose not to perform analyses on the subgroup of patients that reported a graft type other than semitendinosus/gracilis autograft, PT autograft or allograft.

### BMI categories and self-reported disability

When separated into low and high BMI categories, participants with a low BMI (underweight and normal) demonstrated higher odds of achieving patient-specific age- and gender-matched population average IKDC cut-off scores (odds ratio = 1.45; 95% confidence interval 1.05–1.99) compared to participants with high BMI (overweight and obese).

### Post hoc analysis: groups based on months post-ACLR

When separated into groups based on months post-ACLR, no group demonstrated a significant association between BMI and IKDC (Table 6). Tegner was significantly associated with IKDC in every group based on months post-ACLR (Table 6). BMI did not significantly improve the capability of Tegner activity level, months since ACLR surgery and age to collectively predict IKDC of individuals in any of the groups based on months post-ACLR (Table 6). The 95% confidence intervals for all of the odds ratios crossed 1.00.

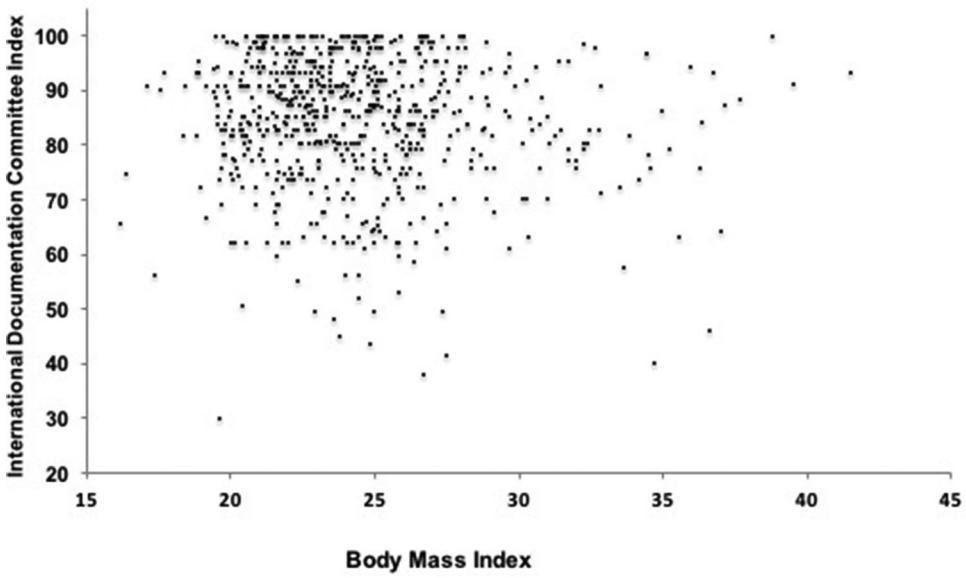


**Fig. 1** Association between body mass index and self-reported disability in those with unilateral anterior cruciate ligament reconstruction: For the entire sample, there was a significant but negligible association indicating that lower body mass index associated with higher scores on the International Knee Documentation Committee Index ($r = -0.08$, $P = 0.04$)

**Table 2** Associations between main outcome measures and covariates for entire sample

| | International Knee Documentation Committee Index | | Body mass index |
|---|---|---|---|
| | *n* | | |
| Age | 668 | −0.09* | 0.23* |
| Tegner activity level | 661 | 0.41** | −0.08* |
| Months since surgery | 643 | 0.23** | −0.05 |

* $P \leq 0.05$; ** $P \leq 0.001$

## Discussion

The most important finding of the present study was that there was a significant but negligible association between higher BMI and lower IKDC scores across the entire sample ($r = -0.08$, $P = 0.04$). The odds of achieving patient-specific age- and gender-matched healthy population average IKDC scores [1] are 1.45x higher in participants with low BMI [underweight and normal BMI (< 25)] compared to those with high BMI [overweight or obese (≥25)]. Younger individuals with higher Tegner activity levels, who reported greater months since ACLR, reported lesser disability (Table 3). After accounting for the variance associated with Tegner activity levels, months since ACLR and age, we found that BMI did not improve the capability of predicting IKDC scores in the entire sample of patients with an ACLR. Additionally, the association between BMI and IKDC remained negligible after separately evaluating the associations in individuals who were within specific timeframes post-ACLR (<6, 6–12, 12 – 24, >24 months).

In the general population, higher BMI has been found to associate with lower quality of life after accounting for other health-related comorbidities [29] and sociodemographic factors [17]. Obesity is a known risk factor for the development of chronic lower extremity joint pathology [9, 11] and has been linked to the incidence [5, 9, 11] and progression [31] of radiographic KOA. Greater body weight can negatively influence the load exerted on different tissues (i.e. cartilage, meniscus, bone) in the knee that are associated with KOA [10, 22].

**Table 3** Associations between main outcome measures and covariates for male and female SUBSETS

| | International Knee Documentation Committee Index | | | | Body mass index | | | |
|---|---|---|---|---|---|---|---|---|
| | *n* | Males | *n* | Females | *n* | Males | n | Females |
| Age | 247 | −0.06 | 417 | 0.20 | 247 | 0.29** | 421 | 0.03 |
| Tegner activity level | 244 | 0.37** | 417 | 0.40** | 244 | −0.13 | 417 | −0.01 |
| Months since surgery | 238 | 0.26** | 405 | 0.28** | 238 | 0.10 | 405 | −0.10 |

* $P \leq 0.05$; ** $P \leq 0.001$

**Table 4** Associations between main outcome measures and covariates for history of concomitant meniscal surgery (CMS)

| | International Knee Documentation Committee Index | | | | Body mass index | | | |
|---|---|---|---|---|---|---|---|---|
| | *n* | CMS (*r*) | *n* | No CMS (*r*) | *n* | CMS (*r*) | *n* | No CMS (*r*) |
| Age | 273 | −0.15* | 259 | 0.10* | 273 | 0.16* | 259 | 0.32** |
| Tegner activity level | 269 | 0.39** | 256 | 0.42** | 269 | −0.08 | 256 | −0.03 |
| Months since surgery | 271 | 0.16** | 236 | 0.23** | 271 | −0.04 | 236 | −0.08 |

* $P \leq 0.05$; ** $P \leq 0.001$

**Table 5** Associations between main outcome measures and covariates for anterior cruciate ligament reconstruction graft type

| | International Knee Documentation Committee Index | | | | | | Body mass index | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *n* | Allograft (*ρ*) | n | PT autograft (ρ) | *n* | ST/G autograft (ρ) | *n* | Allograft (*ρ*) | *n* | PT autograft (*ρ*) | *n* | ST/G autograft (*ρ*) |
| Age | 38 | −0.03 | 286 | 0.04 | 224 | −0.12 | 38 | 0.03 | 259 | 0.24* | 224 | 0.27* |
| Tegner activity level | 38 | 0.06 | 282 | 0.32* | 221 | 0.47* | 38 | 0.06 | 256 | −0.01 | 221 | 0.04 |
| Months since surgery | 38 | 0.14 | 283 | 0.25* | 223 | 0.21* | 38 | 0.11 | 236 | −0.11 | 223 | 0.02 |

**Table 6** Associations between IKDC and BMI based on time post-ACLR

| | <6 months | 6–12 months | 12–24 months | >24 months |
|---|---|---|---|---|
| BMI | −0.05 | −0.09 | 0.01 | −0.05 |
| | $n = 75$ | $n = 185$ | $n = 128$ | $n = 255$ |
| Age | −0.05 | −0.21** | 0.01 | 0.03 |
| | $n = 75$ | $n = 185$ | $n = 128$ | $n = 255$ |
| Tegner | 0.37** | 0.44** | 0.33** | 0.31** |
| | $n = 73$ | $n = 181$ | $n = 127$ | $n = 255$ |
| Months post-ACLR | 0.09 | 0.06 | 0.16 | 0.19** |
| | $n = 75$ | $n = 185$ | $n = 128$ | $n = 255$ |
| BMI contribution to the $\Delta R^2$ of IKDC after accounting for significant covariates | <0.001 | 0.003 | 0.001 | 0.001 |
| | $n = 73$ | $n = 181$ | $n = 127$ | $n = 255$ |
| Odds ratio (95% CI) | 2.61 (0.84–8.11) | 1.48 (0.82–2.68) | 1.10 (0.53–2.30) | 1.21 (0.71–2.06) |

*BMI* body mass index; *ACLR* anterior cruciate ligament reconstruction; *IKDC* International Knee Documentation Committee; *CI* confidence interval

* Amount of variance in IKDC predicted by BMI after accounting for all significant covariates (potential covariates include age, Tegner and months post-ACLR)

** Significant at $p \leq 0.05$

Additionally, a high percentage of adipose tissue may increase the level of circulating adipocytokines, which may influence systemic inflammation and local joint inflammation that could accelerate joint breakdown [7]. While our data are consistent with previous studies [6, 8, 14] that have reported a significant association between BMI and self-reported disability in individuals with an ACLR, our data found the magnitude of the association to be negligible. We found that individuals with a BMI <25 are more likely to achieve self-reported knee function equal to population averages [1] than participants with BMI ≥25; however, we did not identify any other subsamples of individuals in our cohort that demonstrated notable associations between BMI and IKDC.

Lower BMI associated with higher IKDC scores in those with a PT autograph; however, BMI only predicted 1.5% of the variance in IKDC after accounting for Tegner activity level and months since ACLR. While previous studies [23, 34] have reported no difference in self-reported disability for individuals with PT autografts compared to those with semitendinosus/gracilis autografts, there is evidence to suggest a higher prevalence of PTOA in individuals with a PT autograph [21]. Therefore, higher BMI in patients with PT autografts may increase chronic symptoms differently than those with other graft types. The negligible association between higher BMI and lower IKDC may be complicated by the percentage of lean body mass for each individual. BMI is limited by the inability to distinguish the type of tissue associated with mass of the individual [30]. High BMI is commonly associated with higher fat mass; yet, individuals with higher BMI and increased lower extremity muscle mass report less disability following ACLR [28]. Both muscle mass and fat mass can contribute to higher BMI, yet both affect tibiofemoral joint space narrowing differently. Increased fat mass can act to increase tibiofemoral joint narrowing [34], while increased muscle mass may act to maintain proper tibiofemoral joint space [30]. Therefore, clinicians and patients may need to focus on improving lower extremity muscle mass rather than decreasing BMI following ACLR. Overall, these data suggest that clinicians should encourage maintenance of normal body weight in patients with a unilateral ACLR but realize that BMI may not be a strong clinical predictor of which patients will demonstrate acceptable outcomes following surgery.

There are limitations to the current study, which may inform the development of future research in this area. The participants in the current study were generally young (21.73 ± 6.17 years old), exhibited healthy BMI (24.39 ± 3.71 kg/m$^2$), participated in moderate levels of physical activity (6.51±1.81) and demonstrated a level of self-reported disability (IKDC = 84.68 ± 11.91%) that is consistent with what is commonly reported following ACLR [19]. Only 1 and 8% of our cohort were underweight or obese, respectively, and we caution overgeneralizing the results to severely underweight or morbidly obese ACLR populations. Our study was cross-sectional and did not evaluate how a change in BMI over time may impact later outcomes of self-reported disability following ACLR. While our sample ranged from 3.9 to 301.2 months since ACLR surgery, the average time since ACLR was just over 2 years (30.51 ± 35.45 months since ACLR surgery); therefore, the participants in the current study may not have had sufficient time since ACLR to develop symptoms of KOA that were hypothesized to be associated with high BMI and chronic disability. It should be noted that the level of sport-related

activity performed by individuals only 4 months following ACLR may have differed significantly from the level of sport activities performed by individuals who had undergone ACLR greater than 12 or 24 months before testing, yet our post hoc analyses indicated that the magnitude of the association between BMI and IKDC is not more than negligible throughout different time periods that we assessed (<6, 6–12, 12–24, >24 months). Each participant reported Tegner activity level, ACLR graft type, months since ACLR and history of a concomitant injury, which introduced the opportunity for accuracy of these data to be influenced by reporting bias. Future research should objectively measure outcomes of ACL injury and ACLR surgical history when determining the association between BMI or body composition and self-reported disability.

## Conclusions

There was a significant but negligible association between higher BMI and lower IKDC scores, and the odds of achieving patient-specific age- and gender-matched healthy population average IKDC scores were higher in individuals with underweight and normal BMI compared to those with overweight and obese BMI. While an overall association was found between lower BMI and lesser disability, the magnitude of the association remains negligible; therefore, BMI alone was not a strong clinical predictor of successful ACLR outcomes in this cohort of patients with unilateral ACLR.

#### Compliance with ethical standards

**Conflict of interest** Authors declare that they have no conflict of interest.

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