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ASA Class Is a Stronger Predictor of Early Revision Risk Following Primary Total Knee Arthroplasty than BMI

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Background: Although there is a known correlation between obesity and revision risk following total knee arthroplasty (TKA), there is an ongoing debate regarding the appropriateness of denying TKA solely based on the body mass index (BMI) of a patient. Our aim was to determine whether a patient's American Society of Anesthesiologists (ASA) class predicts their risks of early all-cause revision and revision for periprosthetic joint infection (PJI) following primary TKA, independent of their BMI.

Methods: Data from the Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR) were obtained regarding all patients who underwent primary TKA for osteoarthritis in Australia from January 1, 2015, to December 31, 2022. Estimated hazard ratios of all-cause revision and revision for PJI, as well as predicted risks of revision within 3 months, 1 year, and 2 years, as a function of patient ASA class and BMI, were calculated with use of multivariable Cox proportional hazards models.

Results: A total of 274,786 primary TKAs (54.5% female; mean age, 68.3 years) were included in the study, of which 5,401 were revised during the study period. Compared with BMI, ASA class was a stronger predictor of the risks of all-cause revision and revision for PJI following primary TKA. Patients with an ASA class of 3 to 4 had higher risks of all-cause revision and revision for PJI at multiple time points after TKA compared with patients with an ASA class of 1 to 2, regardless of BMI.

Conclusions: Although ASA class and BMI are theoretically interrelated variables, we found that a patient's ASA class was more strongly associated with their risks of early all-cause revision and revision for PJI following primary TKA than their BMI. Employing a BMI threshold in isolation when assessing fitness for TKA may be inappropriate, and surgeons should give greater weight to the other medical comorbidities and general perioperative fitness of the patient. Patients with poorly controlled comorbidities should be referred for medical optimization prior to TKA.

Level of Evidence: Prognostic Level III. See Instructions for Authors for a complete description of levels of evidence.

Total knee arthroplasty (TKA) is a highly successful and cost-effective treatment option for patients who have advanced knee osteoarthritis[1,2] and for whom conservative therapy has failed[3]. In many countries, the demand for TKA is increasing[4-8], driven by population growth, population aging, and an increased prevalence of obesity[9]. Although the overall revision rate for TKA has decreased in recent years[10], periprosthetic joint infection (PJI) remains a major concern for arthroplasty surgeons. PJI is a devasting complication for patients and presents a substantial economic burden to the health-care system[11].

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Excessive body mass index (BMI) is known to increase the risks of all-cause revision and revision for PJI following TKA[12,13]. Despite this, restricting access to TKA in the setting of morbid obesity is controversial. A recent survey of arthroplasty surgeons in 9 different countries regarding their approaches to modifiable risk factors identified considerable variation in practice[14-19]. The proportion of surgeons who employed a BMI restriction in their arthroplasty practice varied from 29% in India to 97% in the U.S.[14].

Employing a BMI threshold to determine fitness for TKA may be overly simplistic, as it does not consider other comorbidities that could influence the risk of PJI. For example, a strong association has been found between morbid obesity and type-2 diabetes mellitus, and the latter is known to increase the risk of PJI following TKA, independent of BMI[20]. The American Society of Anesthesiologists (ASA) Physical Status Classification System is a widely utilized scoring system designed to assess a patient's fitness for surgery, and research has shown that ASA class is correlated with the risk of perioperative complications[21,22]. Although BMI theoretically influences ASA class[21], previous studies have demonstrated a lack of interrater agreement in ASA scoring for patients with obesity[23].

The 2 aims of this study were to investigate (1) whether ASA class was associated with the risks of early all-cause revision and revision for PJI following primary TKA performed for osteoarthritis in patients with different BMIs, and (2) whether BMI was associated with the risks of early all-cause revision and revision for PJI following primary TKA performed for osteoarthritis in patients with different ASA classes.

Materials and Methods

The Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR) was established in the late 1990s, and, since its national implementation in mid-2002, has collected data on 99.0% of TKAs performed in Australia[10]. To date, the AOANJRR has recorded data on >886,000 primary TKAs. The AOANJRR does not collect race or ethnicity data.

The AOANJRR commenced the collection of patient ASA class in 2012 and now has ASA data for >491,000 primary TKAs[10]. Patients undergoing elective surgery typically receive an ASA class between 1 and 4 (see Appendix Table A1)[21]. In 2015, the AOANJRR commenced the collection of patient BMI and now has BMI data for >405,000 TKAs[10]. Patient BMI is categorized according to the World Health Organization classification (see Appendix Table A2)[24].

Data from the AOANJRR were obtained regarding primary TKAs performed for osteoarthritis from January 1, 2015, to December 31, 2022. Patients who underwent a revision procedure during the study period were identified. A revision procedure was defined as a removal, a replacement, or an addition of any device component[10]. All-cause revision was defined as the primary outcome, with revision for PJI as a secondary outcome.

All TKAs performed with non-cross-linked polyethylene (NXLPE) were excluded from the study on the basis of a previous AOANJRR report that found that NXLPE is associated with a higher infection risk[25]. Procedures performed in patients with an ASA class of 5, an underweight BMI, or an age of <19 years at the time of TKA were also excluded. Procedures utilizing fully stabilized and hinged TKA implants were excluded because these implants are used in complex cases and the AOANJRR has previously reported that they have higher rates of revision[10].

Kaplan-Meier estimates of survivorship were utilized to report the time to first revision for each of the 2 revision outcomes, with right-censoring at the time of death and at the end of the study period on December 31, 2022. The unadjusted cumulative percent revision (CPR) is defined as the complement, in probability, of the Kaplan-Meier survivorship estimate, with 95% confidence intervals (CIs) calculated using unadjusted pointwise Greenwood estimates for the standard error. The combined association between revision rates and ASA class and BMI was examined with use of Cox proportional hazards models. For each revision outcome, a model was fitted that included patient age at the time of the primary procedure, sex (male or female), ASA class (1 to 2 or 3 to 4), and BMI. Patient age and BMI were modeled with use of natural cubic splines with 5 knots located at the 5th, 27.5th, 50th, 72.5th, and 95th percentiles of the sample distribution for each variable. In addition to the main effects for each variable, an interaction between ASA class and BMI was included. Wald tests were performed to test the hypothesis that there was no association between revision rates and ASA class or BMI, including possible nonlinear effects. The corresponding chi-square statistics were utilized to assess the importance of each variable. The assumption of proportional hazards was checked by examining the Schoenfeld residuals. When evidence of a violation of proportional hazards was found, a time-varying model was estimated, with coefficients assumed to be constant within selected time intervals. On the basis of the fitted models, predicted survival curves were calculated for selected values of the patient baseline characteristics in order to summarize the estimated predictor effects.

Approximately 95% of procedures recorded by the AOANJRR since 2015 have both the ASA class and BMI recorded. For the purposes of this study, it was assumed that missing ASA and BMI values were likely to be missing completely at random, and hence all analyses were restricted to procedures with complete data for these variables. No a priori power calculation was undertaken; the number of eligible procedures captured in the AOANJRR during the study period determined the available sample size. All tests were 2-tailed with a level of significance of 0.05. The statistical analysis was performed with use of SAS (version 9.4; SAS Institute) and R (version 4.2.2; R Foundation for Statistical Computing)[26].

Results

A total of 274,786 primary TKAs performed for osteoarthritis in 225,771 patients were included in the study. The

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mean age (and standard deviation [SD]) of the patients was 68.3 ± 8.9 years (range, 22 to 101 years), and 54.5% of patients were female. Overall, 58.5% of patients were obese (class I to III), and 10.3% were class-III obese. The majority of the cohort had an ASA class of 2 (53.7%) or 3 (40.3%). Further demographic data are provided in Table I. The mean follow-up was 3.4 ± 2.2 years (range, 0 to 8 years). A total of 5,401 procedures were revised during the study period, including 2,058 revisions for PJI.

ASA class was found to be independently associated with the rate of all-cause revision, with a time-varying effect, following primary TKA performed for osteoarthritis (Wald χ^2 [12 degrees of freedom (df)] = 157.7; $p < 0.001$), whereas BMI was very weakly associated with the all-cause revision rate (Wald χ^2 [8 df] = 15.5; $p = 0.050$), after adjusting for the effects of the other predictors included in the model. There was no strong evidence to suggest an interaction between ASA class and BMI (Wald χ^2 [4 df] = 5.2; $p = 0.264$).

Patients with an ASA class of 3 to 4 had a higher rate of all-cause revision than those with an ASA class of 1 to 2, regardless of BMI, at multiple time points after TKA (Fig. 1). The increased rate was particularly noticeable in the first 6 months postoperatively (Fig. 1; see also Appendix Table A3). Among patients with an ASA class of 1 to 2, there was no difference in the rate of all-cause revision when comparing a patient with any BMI between 18.5 and 45 kg/m^2 to a patient with a BMI of 31 kg/m^2, which was the median BMI in our cohort (Fig. 2; see also Appendix Table A4). Among patients with an ASA class of 3 to 4, the estimated all-cause revision rate for a patient with a BMI between 18.5 and 45 kg/m^2 was similar to that of a patient with a BMI of 31 kg/m^2, albeit with some evidence of an increased revision rate at lower BMI values (Fig. 2).

ASA class (Wald χ^2 [5 df] = 113.6; $p < 0.001$) and BMI (Wald χ^2 [8 df] = 68.5; $p < 0.001$) were each found to be independently associated with the rate of revision for PJI following primary TKA performed for osteoarthritis, after adjusting for the effects of the other predictors included in the model. ASA class was the more strongly associated of the 2 variables. There was no strong evidence to suggest an interaction between ASA class and BMI (Wald χ^2 [4 df] = 8.4; $p = 0.077$).

Patients with an ASA class of 3 to 4 had a higher rate of revision for PJI compared with patients with an ASA class of 1 to 2, regardless of BMI (Fig. 3; see also Appendix Table A5). Among patients with an ASA class of 1 to 2, there was no difference in the rate of revision for PJI when comparing a patient with any BMI between 18.5 and 45 kg/m^2 to a patient with a BMI of 31 kg/m^2 (Fig. 4; see also Appendix Table A6). However, among patients with an ASA class of 3 to 4, those with a BMI of ≥35 kg/m^2 had a significantly higher rate of revision for PJI than those with a BMI of 31 kg/m^2 (Fig. 4). There was also some evidence, albeit with greater uncertainty, of higher revision rates among patients with a lower BMI (Fig. 4).

Commensurate with the significantly higher rates of revision among patients with an ASA class of 3 to 4 compared to those with an ASA class of 1 to 2, the predicted risks of all-cause revision and revision for PJI at 3 months, 1 year, and 2 years were higher for 69-year-old male and female patients undergoing TKA (the median age of our cohort) with an ASA class of 3 to 4. This was demonstrated for all BMI measurements between 18.5 and 45 kg/m^2 (Figs. 5 and 6).

TABLE I Patient Demographics

Variable	No. (%) of TKAs
Sex	
Male	124,976 (45.5)
Female	149,810 (54.5)
Age group, in years	
<55	17,417 (6.3)
55-64	74,083 (27.0)
65-74	114,090 (41.5)
≥75	69,196 (25.2)
ASA class	
ASA 1	13,973 (5.1)
ASA 2	147,496 (53.7)
ASA 3	110,611 (40.3)
ASA 4	2,706 (1.0)
BMI category	
Normal weight	28,298 (10.3)
Pre-obese	85,657 (31.2)
Class-I obese	85,399 (31.1)
Class-II obese	47,023 (17.1)
Class-III obese	28,409 (10.3)
Total	274,786 (100)

Discussion

The results of our study demonstrated that the ASA class of a patient independently predicted their risk of early all-cause revision following primary TKA performed for osteoarthritis, whereas BMI was only very weakly associated with early all-cause revision risk, after adjusting for the effects of the other predictors included in the model. Both ASA class and BMI were independently associated with the risk of revision for PJI, after adjusting for the effects of the other predictors; however, ASA class was the stronger predictor of risk. These findings suggest that restricting access to TKA purely based on BMI may be inappropriate and that surgeons also need to consider the other medical comorbidities and general perioperative fitness of the patient when determining that patient's suitability for surgery.

As far as we are aware, this is the first study to specifically examine the interplay between ASA class and BMI with respect to the risk of revision following primary TKA. However, several previous studies have identified that these variables independently influence the risk of complications following TKA. Using a multivariable logistic regression analysis in a study of 56,216 TKAs from the Kaiser Permanente registry, Namba et al. found that severe obesity (a BMI of ≥35 kg/m^2) and an ASA class of ≥3

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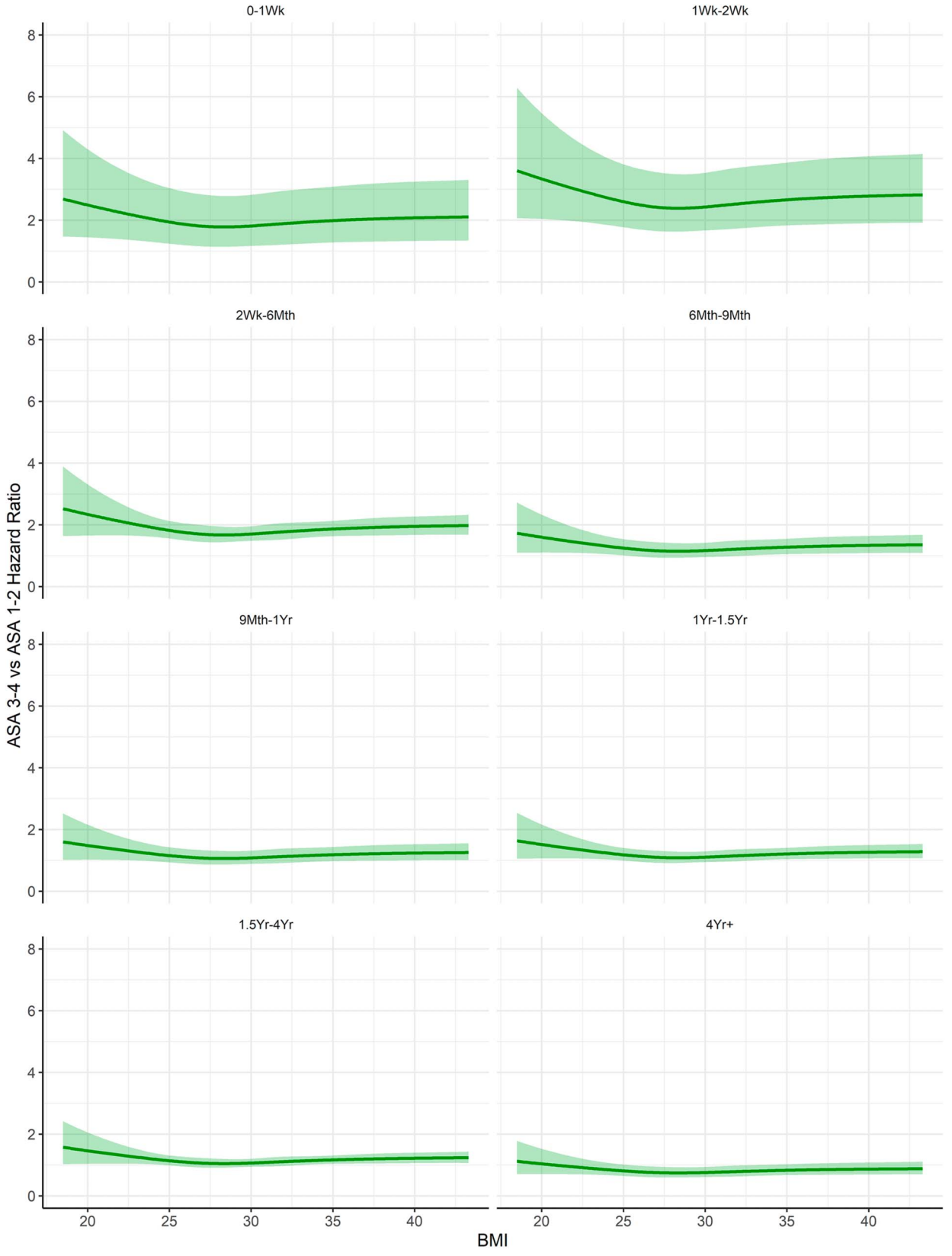

Fig. 1

Hazard ratios of all-cause revision in patients with an ASA class of 3 to 4 relative to that in patients with an ASA class of 1 to 2, by BMI, at different time intervals. The shading represents the 95% CI. Mth = month.

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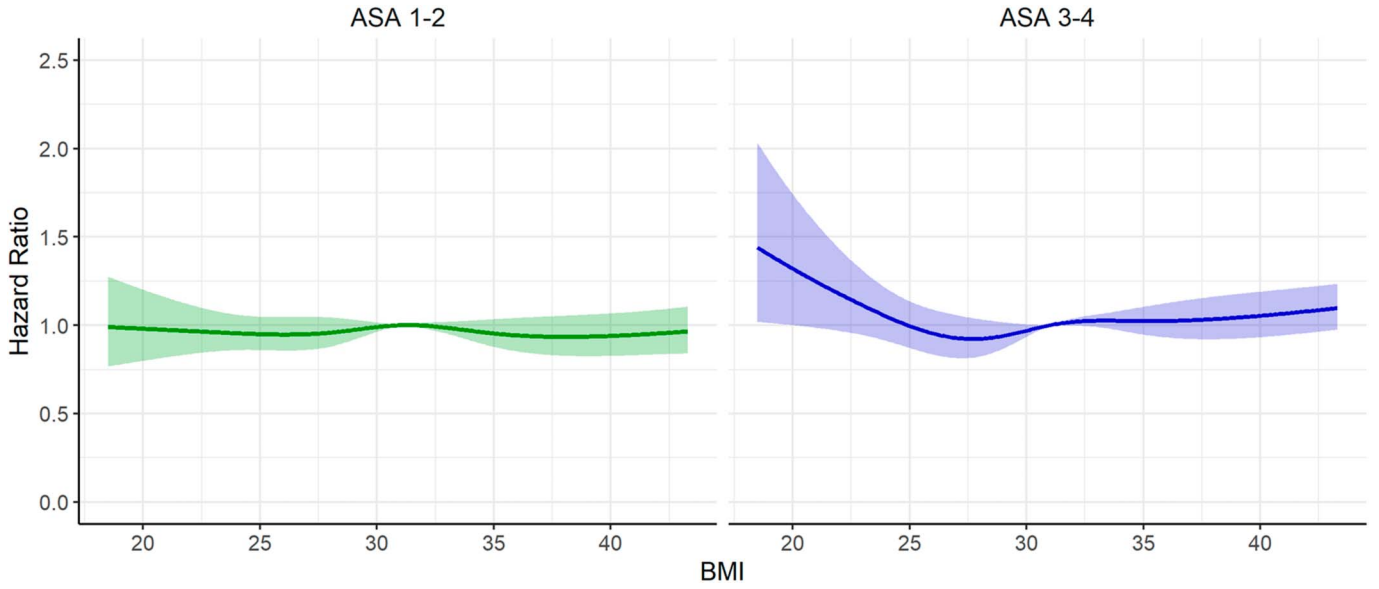

Fig. 2

Hazard ratios of all-cause revision in patients with a BMI of 18.5 to 45 kg/m^2 relative to that in patients with a BMI of 31 kg/m^2, by ASA class and BMI. The shading represents the 95% CI.

independently increased the risk of deep surgical site infections[27]. A similar study of 15,321 TKAs from the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) demonstrated that morbid obesity (a BMI of ≥40 kg/m^2) and an ASA class of ≥3 independently increased the risk of minor local complications, including superficial wound infection and wound dehiscence[28]. In that study, BMI and ASA class did not increase the risk of major local complications, including deep wound infection. Neither the Kaiser Permanente study nor the NSQIP study assessed revision risk[27,28].

The National Joint Registry (NJR) for England, Wales, Northern Ireland and the Isle of Man also records the ASA class and BMI of patients undergoing TKA[29]. A study of primary TKA data from the NJR found that 15.0% of the cohort had an ASA class of ≥3 and 54.4% had a BMI of ≥30 kg/m^2, indicating that the NJR cohort was healthier and less obese than the

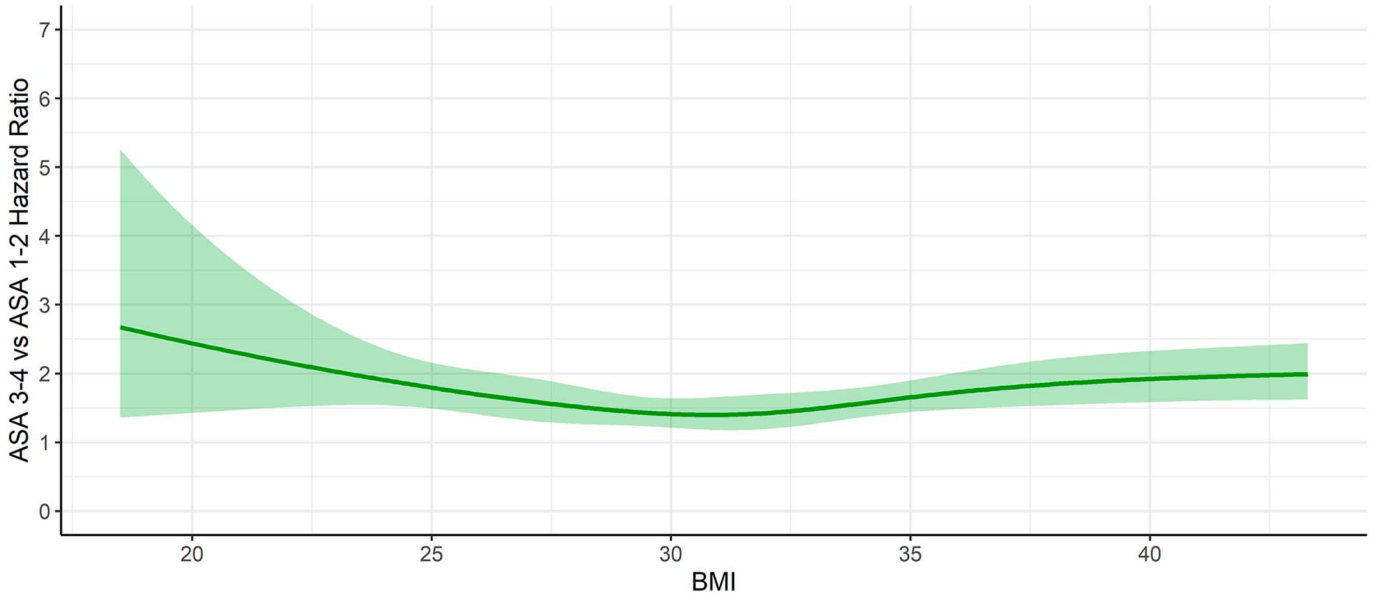

Fig. 3

Hazard ratios of revision for PJI in patients with an ASA class of 3 to 4 relative to that in patients with an ASA class of 1 to 2, by BMI. The shading represents the 95% CI.

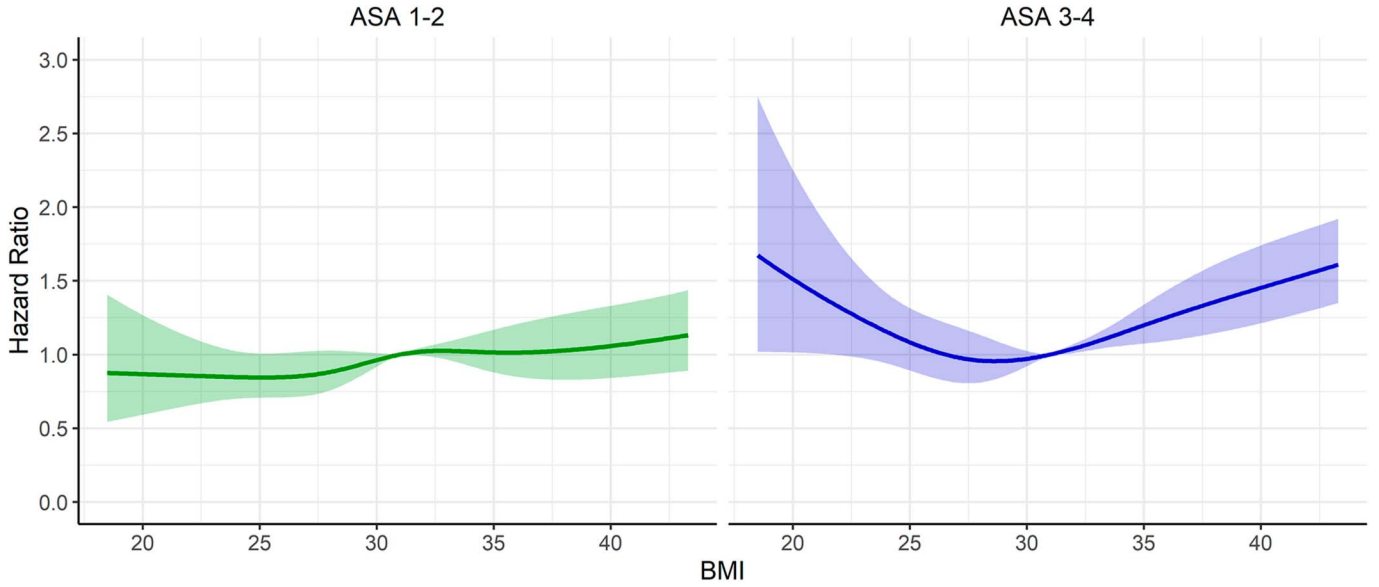

Fig. 4

Hazard ratios of revision for PJI in patients with a BMI of 18.5 to 45 kg/m^2 relative to that in patients with a BMI of 31 kg/m^2, by ASA class and BMI. The shading represents the 95% CI.

AOANJRR cohort utilized in the present study, for which the rates were 41.2% and 58.5%, respectively[30]. Although the NJR researchers demonstrated that both the ASA class and the BMI of a patient influenced the risk of revision for PJI following TKA, they did not assess whether there was any interaction between the 2 variables[30].

Although the ASA scoring system is widely utilized to assess perioperative fitness for surgery, it does have limitations[21]. Previous studies have demonstrated a lack of interrater reliability in ASA scoring among anesthetists[22]. In particular, obesity has been identified as an area of disagreement[23]. According to examples provided by the ASA, class-I or II obesity in an adult represents a mild systemic disease (ASA 2), and class-III obesity represents a severe systemic disease (ASA 3)[31]. Our results suggest that there is variability in the interpretation of ASA scoring for patients with obesity among Australian anesthetists. In our cohort, 3.3% of patients with class-I or II obesity were assigned an ASA class of 1 and 24.6% of patients with class-III obesity were assigned an ASA class of 1 or 2, in contrast to the examples provided by the ASA.

Obesity is a known risk factor for hypertension, type-2 diabetes mellitus, myocardial infarction, stroke, fatty liver disease, and certain malignancies[32], all of which may influence ASA scoring[31]. Bariatric surgery has been associated with maintained weight loss and remission of obesity-related comorbidities[33]. There is a lack of consensus regarding the role of bariatric surgery in patients awaiting arthroplasty[34-36], although a randomized controlled trial demonstrated that bariatric surgery reduced the need for TKA[37]. Recent advances in pharmacotherapy, in the form of glucagon-like peptide-1 (GLP-1) agonists, have demonstrated clinically meaningful weight loss and improvement in diabetic control, but further research is needed to determine whether these medications improve outcomes in patients with obesity who undergo TKA[38].

Our study has several strengths. The AOANJRR has an almost complete dataset of all TKAs performed in Australia since 2003, with ASA data from 2012 and BMI data from 2015. Because we utilized this large national database, we are confident in the accuracy of our findings. Patients undergoing TKA in Australia have high rates of obesity and associated comorbidity, providing an ideal population for this study. Arthroplasty surgeons around the world are cognizant of the importance of considering obesity when assessing fitness for TKA, and we believe that our results will prove beneficial for surgeons who provide care to patients with obesity and knee osteoarthritis.

We also acknowledge that our study has several limitations. Although we demonstrated statistically that ASA class and BMI independently influenced revision risk following primary TKA, they are theoretically interrelated variables[21]. Since the ASA class is, in principle, partly determined by the BMI of a patient, adjustment for ASA may partially control away the effect of BMI and hence lead to an underestimation of the association between BMI and revision rates. As mentioned above, 3.3% of patients with class-I or II obesity and 24.6% of patients with class-III obesity in our study population had their ASA class "incorrectly graded." We conducted a sensitivity analysis whereby patients were allocated to their "correct" ASA class on the basis of their BMI class and found that the results did not change with respect to the significant relationships identified. ASA class remained strongly associated with both all-cause revision and revision for PJI, whereas the evidence of an association between all-cause revision and BMI was somewhat reduced.

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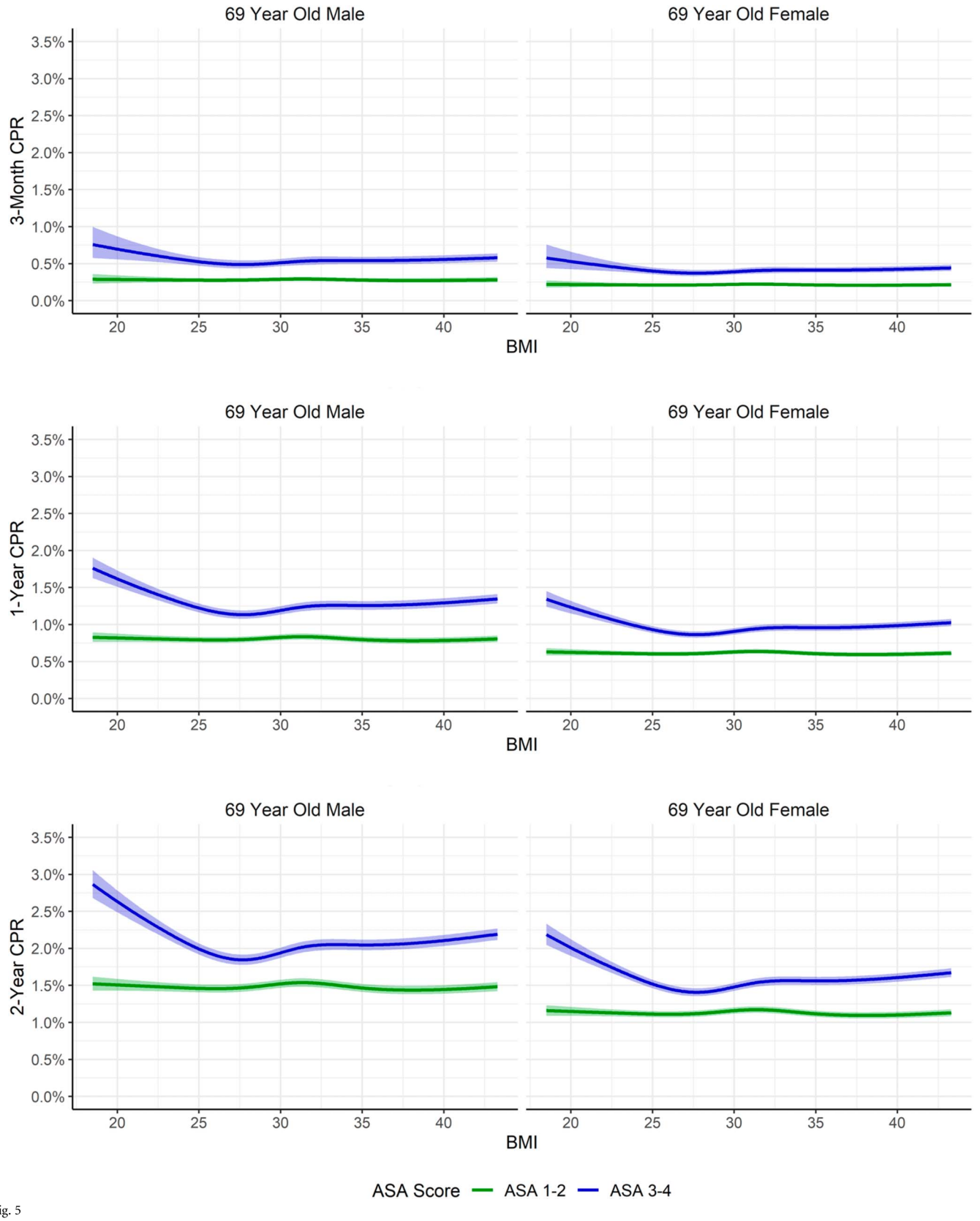

Fig. 5

Predicted CPRs for all-cause revision, by ASA class and BMI, in 69-year-old male and female patients at 3 months, 1 year, and 2 years after TKA. The shading represents the 95% CI.

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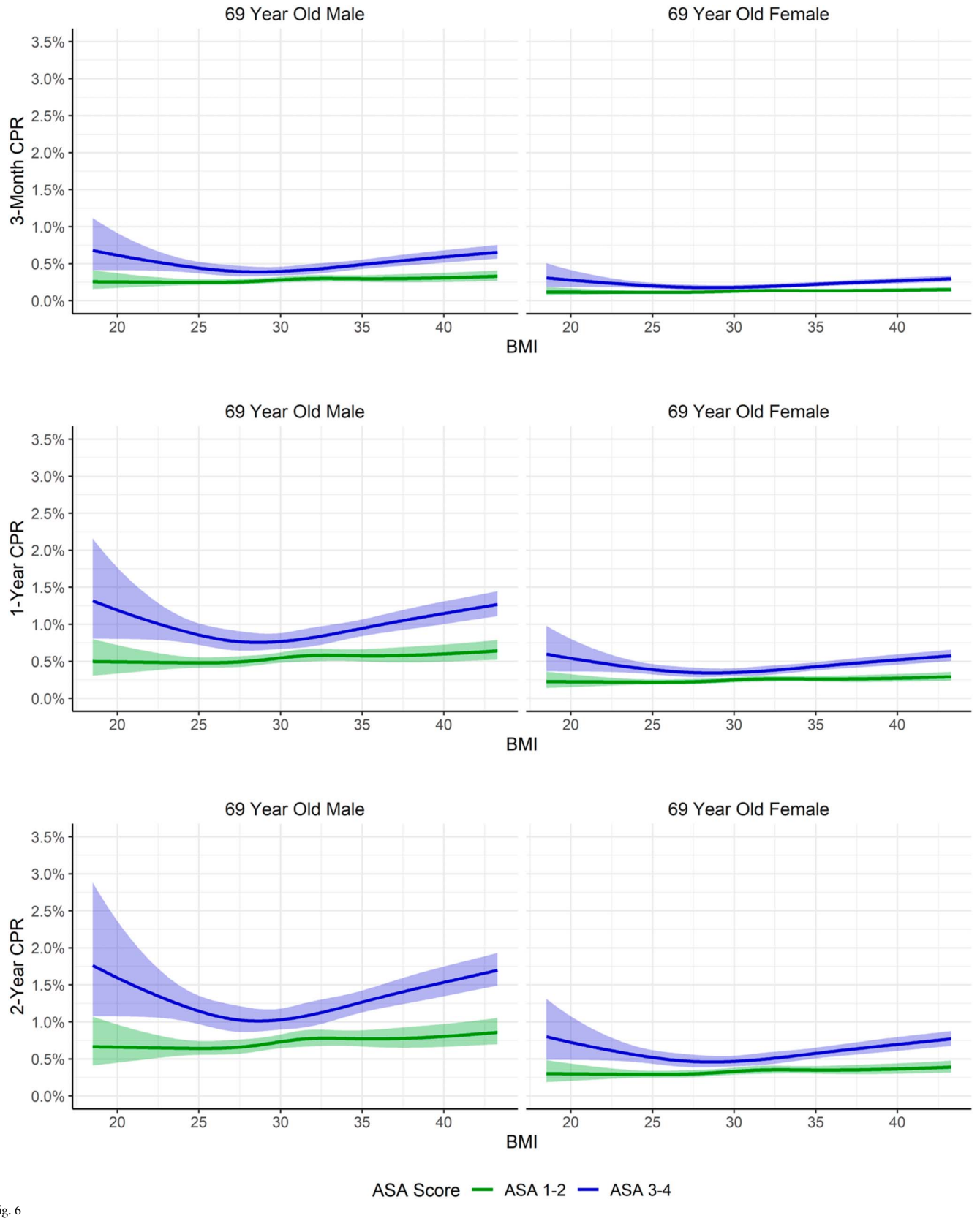

Fig. 6

Predicted CPRs for revision for PJI, by ASA class and BMI, in 69-year-old male and female patients at 3 months, 1 year, and 2 years after TKA. The shading represents the 95% CI.

The ASA class and BMI recorded by the AOANJRR are generated from data collection sheets completed at the time of surgery, and our results are dependent on the accuracy of the inputted measurements. The AOANJRR does not record patient comorbidity data, so we are unable to comment on the influence of specific comorbidities on revision risk. The primary outcome recorded by the AOANJRR is implant revision. We are unable to comment on the interplay between ASA class and BMI with respect to other postoperative complications, which are also important considerations for the patient, surgeon, and health-care system. The AOANJRR does not collect race or ethnicity data, which may affect the generalizability of the study. Finally, our results are based on population-level data, and surgeon discretion needs to be applied when considering individual patient care.

Although ASA class and BMI are theoretically interrelated variables, this study demonstrated that a patient's ASA class independently predicted their risk of early all-cause revision following primary TKA performed for osteoarthritis, whereas their BMI was only very weakly associated with early all-cause revision risk, after adjusting for the effects of the other predictors included in the model. Both the ASA class and BMI of a patient were independently associated with the risk of revision for PJI following primary TKA; however, the ASA class was the stronger predictor of risk. When considering a patient's suitability for TKA, employing a BMI threshold in isolation may be inappropriate, and surgeons should give greater weight to the other medical comorbidities and general perioperative fitness of the patient. Patients with poorly controlled comorbidities should be referred for medical optimization prior to TKA.

Appendix

eA Supporting material provided by the authors is posted with the online version of this article as a data supplement at jbjs.org (http://links.lww.com/JBJSOA/A735). ■

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