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The effect of BMI and other factors on post-operative length of stay: a multivariable regression analysis of 860 patients undergoing total knee arthroplasty

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Abstract

Background

There is a trend towards minimising length of stay (LOS) after total knee arthroplasty (TKA), as greater LOS is associated with poorer outcomes and higher costs. Patient factors known to influence LOS post-TKA include age and ASA grade.

Evidence regarding the effect of body mass index (BMI) in particular is conflicting, with some studies finding that increased BMI predicts increased LOS, while others have found no relationship. Few previous studies, which have mostly been conducted outside the UK, have examined the effect of living alone or socioeconomic deprivation, which may be confounders.

Methods

We conducted a retrospective cohort study of 1031 consecutive primary TKAs performed 01-04-2021 to 31-12-2021 in a single high-volume arthroplasty centre. A multivariable negative binomial regression model was performed for the 860 patients with complete data, using pre-operative (BMI, age, gender, ASA grade, smoking, ethnicity, socioeconomic deprivation, living arrangement, EQ5D quality of life score, and indication for surgery) and peri-operative variables (surgeon, surgical approach, tourniquet use, AM/PM operation, operation side, duration, and day of the week).

Results

Mean LOS was 2.6 days. BMI and socioeconomic deprivation had no effect on LOS ($p>0.05$). Increased LOS was associated with living alone, lower EQ5D, age and ASA grade (all $p<0.001$), PM operation ($p<0.01$), female gender and duration of surgery ($p<0.05$).

Conclusion

BMI and socioeconomic status were not correlated with LOS after TKA. Living alone, which has not been previously reported and lower pre-operative EQ5D status were significant risk factors, which merit consideration in pre-operative planning and counselling.

1. Introduction

Demand for hip and knee arthroplasty has increased year on year (1), and this trend is predicted to continue due to unmet need, increasing obesity, and longer life expectancy (2). There is a trend towards minimising length of stay (LOS) after total knee arthroplasty (TKA), as increased LOS is associated with increased complication and readmission rates, worse 1-year PROMS scores, and higher costs (3–6). In some studies, day case arthroplasty has been shown to be beneficial compared to inpatient arthroplasty for both the hip and knee (7–9). Diverse patient factors are known to influence LOS after TKA, such as age, gender, and ASA grade (4,10).

The evidence on the effect of body mass index (BMI) in particular has been inconsistent. A systematic review on the effect of pre-operative factors on LOS by Shah et al (19) discussed 29 relevant studies, some of which reported a significant positive correlation between BMI and LOS, and some of which reported no effect. The meta-analysis combined fifteen of these studies, comparing patients with BMI above vs below 30, and found that the lower BMI group had shorter LOS. However, this result was driven by only six studies which reported a significant effect. Of these, one did not adjust for variables other than BMI (20), and of the other five, four did not include smoking, living arrangements, or any peri-operative variables (other than duration of surgery and grade of surgeon in one study) (21–24), two did not include socioeconomic status **(21, 22)**, and two did not include ethnicity (22,23). All of these may be important confounding variables.

Our own literature search identified further studies on this topic, which were again mixed. The most robust study in favour of a positive correlation **(10)** was performed in the USA, included 4509 TKAs across 4 sites, and used a multivariable regression model which took into account numerous preoperative and perioperative variables including age, BMI, comorbidities, mental health score, smoking status, operation day of week and time of day. Other supporting studies included a UK cohort **(6)** of 1001 arthroplasties (566 TKAs, remainder hip arthroplasties) which studied only pre-

operative variables, and a Pakistani cohort of 577 TKAs **(11)**. None of these studies included socioeconomic status, whether patients lived alone, or ethnicity in their statistical models.

Studies which found no relationship between BMI and LOS were generally mixed cohorts of approximately equal numbers of hip and knee arthroplasties, e.g. one French cohort with 725 TKAs **(12),** one US cohort with 62 TKAs **(13)**, and another US cohort with 420 TKAs **(14)**, all of which examined only pre-operative factors, and did not include socioeconomic status or living arrangements. Most did not include ethnicity, with the exception of **(14)**, which modelled ethnicity as a binary "Black" or "Non-Black" variable.

The existing evidence, then, has often omitted potentially important confounders, and generally originated outside the UK. It has also originated entirely prior to the Covid-19 pandemic, which has changed patients' pre-operative health, social context, and the provision of care. The current study presents an updated post-Covid cohort of 100% TKAs in the UK, and takes into account commonly omitted variables such as socioeconomic status, living alone, and ethnicity.

2. Methods

Data were retrospectively sought from medical records for all primary TKAs performed between 01-04-2021 and 31-12-2021, following the resumption of elective surgery in a single high-volume centre. Exclusion criteria were: revision surgery, removal of metalwork, unicompartmental arthroplasty, isolated patellar resurfacing, and simultaneous bilateral total knee arthroplasty.

Socioeconomic deprivation was measured by the Index of Multiple Deprivation Rank assigned by the UK Ministry of Housing, Communities, and Local Government to each patient's home postcode (Rank 1 being the most deprived) (16).

A multivariable count data regression model was performed using a range of relevant covariates, including pre-operative (BMI, age, gender, ASA grade, index of multiple deprivation rank, ethnicity, smoking status, living alone vs not, EQ5D quality of life score, and diagnosis) and peri-operative variables (surgical approach, tourniquet use, use of navigation-assisted surgery, AM/PM operation start, operation side, operation duration, and day of the week). Surgeon-level effects were modelled as fixed-effects. A Poisson model was initially tested but a negative binomial model which allows overdispersion was used for the final result. Potential non-linear effects of covariates were modelled using fractional polynomial terms (17). In addition, a link test was performed to explore any model specification issues. Given the missing data for some covariates, a complete-case analysis was employed, and its appropriateness was checked by a logistic regression model to see if the missingness was due to the outcome variable (18).

3. Results

After applying the inclusion and exclusion criteria, 1031 consecutive patients undergoing total knee arthroplasty were included (Table 1). The mean age was 70 years (std. dev. 8.9 yrs, range 41-94 yrs), the mean BMI was 31.2 (std. dev. 5.9, range 18.4-55.1), and 61% of patients were female, 58% had never smoked, 25% lived alone, and 79% were Caucasian.

The TKAs were performed by a total of 48 surgeons. 100% were via a medial parapatellar approach. The diagnosis (indication for TKR) was primary knee osteoarthritis in 994 patients (96%), inflammatory arthropathy in 21 patients (2%), and miscellaneous others including post-traumatic arthritis and septic arthritis in 16 patients (2%). A tourniquet was used in 708 cases (69%) and navigation-assisted surgery was used in 74 cases (7%).

The mean LOS was 2.6 days (range 0-25 days), and day cases accounted for 5% of all patients. The distribution of LOS was skewed towards a shorter stay (Figure 1).

A univariate analysis of all 1031 patients showed no significant correlation between BMI and LOS (Figure 2) (Kendall's rank correlation -0.024, $p = 0.29$).

860 patients were included in the regression model, and the remainder were not included because data was missing for one or more of the variables. The results of the model are summarised in Table 2. The model coefficients were exponentiated to indicate a factor change (similar to relative risk), such that all else being equal, ASA 4 patients stay 2.3 times as long as ASA 1 patients, and for each unit (1 kg/m^2) increase in BMI, the LOS changes by a factor of 0.993.

The effect of BMI on LOS was not statistically significant (Table 2). Increased LOS was experienced by older patients ($p < 0.001$), female patients ($p < 0.05$), patients with ASA grade = 4 ($p < 0.001$), patients of non-Caucasian ethnicity ($p < 0.05$) and patients who lived alone ($p < 0.001$). Increased LOS was also associated with surgery starting in the afternoon ($p < 0.01$) rather than the morning, and operations which lasted longer ($p < 0.05$).

Pre-operative EQ5D (quality of life) score was negatively associated with LOS, i.e. better quality of life before TKA is associated with shorter LOS ($p < 0.001$).

There was no statistically significant effect of index of multiple deprivation rank, smoking status, side of operation, day of the week, tourniquet use, or use of navigation-assisted surgery (all $p > 0.05$).

4. Discussion

BMI had no statistically significant effect on LOS in the current cohort. Previous evidence has been conflicting with regards to whether or not BMI affects length of stay after TKA. The current results suggest that the positive correlation found by some previous studies may have been driven by commonly omitted confounders, particularly ethnicity. There was a significant association in the current cohort between ethnicity and BMI (one-way ANOVA, $F = 5.3751$, $p = 0.0003$).

Living arrangement had a highly statistically significant effect in the current cohort, with living alone associated strongly with increased LOS. To our knowledge, this association has not previously been reported in the literature. Most of the pre-existing studies have not included living arrangements, and those which did were small cohorts in which the effect of living arrangements did not rise to statistical significance in multivariable analysis **(19)**.

A higher pre-operative EQ5D score was significantly correlated with shorter LOS. The EQ5D is a holistic quality of life assessment which asks patients about mobility, self-care, impairment of usual activities, pain/discomfort and anxiety/depression. While previous studies on LOS have included individual components of this e.g. mental health, mobility, and range of motion, few have used a holistic assessment tool such as the EQ5D **(10, 19)**. Pre-operative quality of life is likely to affect post-operative recovery in multiple ways, including functional reserve and motivation to engage with physiotherapy.

Other statistically significant findings in the current cohort were consistent with those of previous studies, showing an association between increased LOS and increasing age, ASA grade, female gender, non-Caucasian ethnicity, afternoon operations, and operative duration (10,19,25).

No statistically significant relationship was found in the current study between socioeconomic deprivation and LOS. In contrast, three previous studies have shown a strong positive relationship. Courtney et al (26) studied a US population, using income data by zip code, while Hollowell et al (27) and Jonas et al (23) studied patients in the UK and used the index of multiple deprivation by postcode (US zip codes cover a much larger area than UK postcodes). Jonas et al found that the association was strongly significant only in their univariate analysis and not the multivariate one, suggesting that the effect may be driven by confounding variables. The other two studies adjusted for age and gender, with Courtney et al also adjusting for some comorbidities. All three studies divided patients into quartiles or quintiles of deprivation and compared those groups, rather than using multiple deprivation rank which is much higher-resolution data, and these methodological

choices may account for the differing results. Another plausible explanation is that there are regional differences in social care and support at home post-operatively, which may compensate for socioeconomic deprivation in the current cohort.

Day of the week of surgery had no statistically significant effect on LOS in the current study. The previous literature on this is mixed, with some centres finding no effect (28) and others finding longer stay on various different days of the week e.g. Fridays longer (10,29), Fridays shorter (30), or Thursdays longer (31). This is likely to reflect differences in staff availability or standard practices in different centres, with some centres emphasising day case arthroplasty where possible, and some being able to discharge patients over the weekend, with greater access to physiotherapy and rehabilitation.

4.1. Limitations

The current study includes fewer patients than some previous literature (19). Some studies have achieved greater patient numbers by spanning multiple years and/or combining data from multiple hospitals in a large region. These methods improve statistical power but introduce heterogeneity, as practice and patient pathways vary over time and between institutions.

A further limitation of the current study is that the data was retrospectively reviewed. Finally, pre-operative health status was measured using ASA grade and EQ5D, which give little insight into which comorbidities are the most important.

Conclusion

BMI and social deprivation had no statistically significant effect on LOS. Living alone predicted longer inpatient stay, which has not been previously reported, and higher EQ5D scores predicted shorter LOS. Both should be taken into account when planning the patient care, and specific pre-operative counselling may be considered for patients living alone or with poor pre-operative quality of life. The current results confirm previous reports that greater LOS should also be expected in patients who are older, female, have greater comorbidities, are non-Caucasian, and have afternoon or longer surgeries.

References

1. National Joint Registry Editorial Board and Contributors. 18th Annual Report 2021 [Internet]. National Joint Registry of England, Wales, Northern Ireland, the Isle of Man, and Guernsey; [cited 2021 Dec 1]. Available from: https://reports.njrcentre.org.uk/Portals/0/PDFdownloads/NJR%2018th%20Annual%20Report%202021.pdf

2. Culliford D, Maskell J, Judge A, Cooper C, Prieto-Alhambra D, Arden NK. Future projections of total hip and knee arthroplasty in the UK: results from the UK Clinical Practice Research Datalink. Osteoarthritis and Cartilage. 2015 Apr;23(4):594–600.

3. Nassar I, Fahey J, Mitchell D. Rapid recovery following hip and knee arthroplasty using local infiltration analgesia: length of stay, rehabilitation protocol and cost savings. ANZ J Surg. 2020 Mar;90(3):355–9.

4. Williams J, Kester BS, Bosco JA, Slover JD, Iorio R, Schwarzkopf R. The Association Between Hospital Length of Stay and 90-Day Readmission Risk Within a Total Joint Arthroplasty Bundled Payment Initiative. J Arthroplasty. 2017 Mar;32(3):714–8.

5. Sutton JC, Antoniou J, Epure LM, Huk OL, Zukor DJ, Bergeron SG. Hospital Discharge within 2 Days Following Total Hip or Knee Arthroplasty Does Not Increase Major-Complication and Readmission Rates. J Bone Joint Surg Am. 2016 Sep 7;98(17):1419–28.

6. Brock TM, Baker PN, Rushton S, Bardgett M, Deehan D. Length of stay and its impact upon functional outcomes following lower limb arthroplasty. Knee Surg Sports Traumatol Arthrosc. 2017 Sep;25(9):2676–81.

7. Dey S, Gadde R, Sobti A, Macdonald N, Jacob J, Unnithan A. The safety and efficacy of day-case total joint arthroplasty. annals. 2021 Apr 14;rcsann.2021.0066.

8. Saunders P, Smith N, Syed F, Selvaraj T, Waite J, Young S. Introducing a day-case arthroplasty pathway significantly reduces overall length of stay. Bone & Joint Open. 2021 Nov 1;2(11):900–8.

9. Lazic S, Boughton O, Kellett CF, Kader DF, Villet L, Rivière C. Day-case surgery for total hip and knee replacement: How safe and effective is it? EFORT Open Rev. 2018 Apr;3(4):130–5.

10. Cleveland Clinic Orthopaedic Arthroplasty Group. The Main Predictors of Length of Stay After Total Knee Arthroplasty: Patient-Related or Procedure-Related Risk Factors. J Bone Joint Surg Am. 2019 Jun 19;101(12):1093–101.

11. Malik AT, Mufarrih SH, Ali A, Noordin S. Predictors of an increased length of stay following Total Knee Arthroplasty - Survey Report. J Pak Med Assoc. 2019 Aug;69(8):1159–63.

12. Roger C, Debuyzer E, Dehl M, Bulaïd Y, Lamrani A, Havet E, et al. Factors associated with hospital stay length, discharge destination, and 30-day readmission rate after primary hip or knee arthroplasty: Retrospective Cohort Study. Orthop Traumatol Surg Res. 2019 Sep;105(5):949–55.

13. Forrest G, Fuchs M, Gutierrez A, Girardy J. Factors affecting length of stay and need for rehabilitation after hip and knee arthroplasty. J Arthroplasty. 1998 Feb;13(2):186–90.

14. Lin JJ, Kaplan RJ. Multivariate analysis of the factors affecting duration of acute inpatient rehabilitation after hip and knee arthroplasty. Am J Phys Med Rehabil. 2004 May;83(5):344–52.

15. Petis SM, Howard JL, Lanting BA, Somerville LE, Vasarhelyi EM. Perioperative Predictors of Length of Stay After Total Hip Arthroplasty. J Arthroplasty. 2016 Jul;31(7):1427–30.

16. Ministry of Housing, Communities, and Local Development. English Indices of Deprivation 2019 [Internet]. English Indices of Deprivation 2019. Available from: https://imd-by-postcode.opendatacommunities.org/imd/2019

17. Sauerbrei W, Meier-Hirmer C, Benner A, Royston P. Multivariable regression model building by using fractional polynomials: Description of SAS, STATA and R programs. Computational Statistics & Data Analysis. 2006 Aug;50(12):3464–85.

18. Carpenter JR, Smuk M. Missing data: A statistical framework for practice. Biometrical Journal. 2021 Jun;63(5):915–47.

19. Shah A, Memon M, Kay J, Wood TJ, Tushinski DM, Khanna V, et al. Preoperative Patient Factors Affecting Length of Stay following Total Knee Arthroplasty: A Systematic Review and Meta-Analysis. J Arthroplasty. 2019 Sep;34(9):2124-2165.e1.

20. Batsis JA, Naessens JM, Keegan MT, Huddleston PM, Wagie AE, Huddleston JM. Body Mass Index and the Impact on Hospital Resource Use in Patients Undergoing Total Knee Arthroplasty. The Journal of Arthroplasty. 2010 Dec;25(8):1250-1257.e1.

21. Abdel MP, Ast MP, Lee Y yu, Lyman S, González Della Valle A. All-Cause In-Hospital Complications and Urinary Tract Infections Increased in Obese Patients Undergoing Total Knee Arthroplasty. The Journal of Arthroplasty. 2014 Jul;29(7):1430–4.

22. D'Apuzzo MR, Novicoff WM, Browne JA. The John Insall Award: Morbid Obesity Independently Impacts Complications, Mortality, and Resource Use After TKA. Clinical Orthopaedics & Related Research. 2015 Jan;473(1):57–63.

23. Jonas SC, Smith HK, Blair PS, Dacombe P, Weale AE. Factors influencing length of stay following primary total knee replacement in a UK specialist orthopaedic centre. The Knee. 2013 Oct;20(5):310–5.

24. Pugely AJ, Martin CT, Gao Y, Belatti DA, Callaghan JJ. Comorbidities in Patients Undergoing Total Knee Arthroplasty: Do They Influence Hospital Costs and Length of Stay? Clin Orthop Relat Res. 2014 Dec;472(12):3943–50.

25. Chen AZ, Gu A, Wei C, Nguyen KT, Fassihi SC, Malahias MA, et al. Increase in Operative Time Is Associated With Postoperative Complications in Revision Total Knee Arthroplasty. Orthopedics. 2021 Jan 1;44(1):18–22.

26. Courtney PM, Ashley BS, Hume EL, Kamath AF. Are Bundled Payments a Viable Reimbursement Model for Revision Total Joint Arthroplasty? Clin Orthop Relat Res. 2016 Dec;474(12):2714–21.

27. Hollowell J, Grocott MPW, Hardy R, Haddad FS, Mythen MG, Raine R. Major elective joint replacement surgery: socioeconomic variations in surgical risk, postoperative morbidity and length of stay. Journal of Evaluation in Clinical Practice [Internet]. 2010 Mar [cited 2022 May 12]; Available from: https://onlinelibrary.wiley.com/doi/10.1111/j.1365-2753.2009.01154.x

28. Edwards PK, Hadden KB, Connelly JO, Barnes CL. Effect of Total Joint Arthroplasty Surgical Day of the Week on Length of Stay and Readmissions: A Clinical Pathway Approach. J Arthroplasty. 2016 Dec;31(12):2726–9.

29. Newman JM, Szubski CR, Barsoum WK, Higuera CA, Molloy RM, Murray TG. Day of Surgery Affects Length of Stay and Charges in Primary Total Hip and Knee Arthroplasty. J Arthroplasty. 2017 Jan;32(1):11–5.

30. Martino J, Peterson B, Thompson S, Cook JL, Aggarwal A. Day of Week and Surgery Location Effects on Stay Length and Cost for Total Joint Arthroplasty: Academic versus Orthopaedic-Specific Hospital. J Knee Surg. 2018 Oct;31(9):815–21.

31. Lilly R, Siljander M, Koueiter DM, Verner J. Day of Surgery Affects Length of Hospitalization for Patients Undergoing Total Joint Arthroplasty Discharged to Extended Care Facilities. Orthopedics. 2018 Mar 1;41(2):82–6.

283 32. Rajaee SS, Debbi EM, Paiement GD, Spitzer AI. Increased Prevalence, Complications, and
284 Costs of Smokers Undergoing Total Knee Arthroplasty. J Knee Surg. 2022 Jan;35(1):91–5.

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Tables

Table 1: Descriptive statistics (n=1031)

	Mean/Prop.	SD	Freq.	Median	Min.	Max.	n
Length of stay (days)	2.61	2.05		2.00	.00	25.00	1031
Age	70.49	8.93		71.00	41.00	94.00	1031
Gender							1031
Female	.61		634				
Male	.39		397				
BMI	31.17	5.91		30.62	18.36	55.11	1031
EQ5D quality of life score	.37	.34		.52	-.59	1.00	939
Operation duration (min)	86.80	28.28		83.00	2.00	585.00	1031
Operation side							1031
Left	.48		493				
Right	.52		538				
ASA							1031
1	.04		43				
2	.63		647				
3	.32		332				
4	.01		9				
Op started am vs pm							1031
AM	.53		548				
PM	.47		483				
Day of week							1031
1	.14		142				
2	.10		102				
3	.24		250				

4	.16	169					
5	.15	156					
6	.21	212					
Index of Multiple Deprivation Rank	22219.52	7804.98		23880.00	1096.00	32789.00	1031
Living arrangements							954
Alone	.25	236					
Nursing Home, hospital or care home	.00	2					
Other	.00	3					
Partner / family / Spouse / Friends	.75	713					
Ethnicity							945
Afro-Caribbean	.07	63					
Asian	.10	99					
Caucasian	.79	751					
Mixed	.01	9					
Other minority ethnic group	.02	23					
Smoking status							1028
Never	.56	574					
Ex	.34	345					
Current	.06	66					
Unknown	.04	43					
Tourniquet use							1031
No	.31	323					
Yes	.69	708					
Navigation							1031
No	.93	957					
Yes	.07	74					

Table 2: Modelling results

	Factor change	95% confidence interval
BMI	0.993	[0.983,1.004]
Gender (Female)	ref.	
Male	0.908*	[0.826,0.997]
Age	1.019***	[1.013,1.026]
Operation side (Left)	ref.	
Right	1.091	[0.993,1.199]
ASA (=1)	ref.	
2	0.887	[0.721,1.092]
3	1.080	[0.853,1.366]
4	2.295***	[1.509,3.491]
Index of Multiple Deprivation Rank (per 1000)	1.000	[0.994,1.006]
Op started am vs pm (AM)	ref.	
PM	1.153**	[1.055,1.259]
Day of week (=1)	ref.	
2	0.857	[0.698,1.053]
3	0.991	[0.845,1.162]
4	0.904	[0.750,1.089]
5	1.121	[0.915,1.373]
6	1.002	[0.831,1.209]
Operation duration (min)	1.002*	[1.000,1.004]
Living Alone	1.202***	[1.078,1.340]
Ethnicity (Caucasian)	ref.	
Afro-Caribbean	1.357*	[1.055,1.744]
Asian	1.078	[0.929,1.252]
Mixed	1.642**	[1.202,2.242]
Other minority ethnic group	1.408**	[1.116,1.777]
Smoking status (Never)	ref.	
Ex	1.047	[0.955,1.147]
Current	0.775	[0.594,1.011]
EQ5D quality of life score	0.670***	[0.574,0.783]
Tourniquet use (No)	ref.	
Yes	0.872	[0.756,1.005]
Navigation (No)	ref.	
Yes	0.972	[0.728,1.297]
Constant	0.773	[0.371,1.607]
Observations	860	
Pseudo R^2	0.108	

Exponentiated coefficients; 95% confidence intervals in brackets

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; Surgeon-level effects modelled as fixed-effects.

Figures

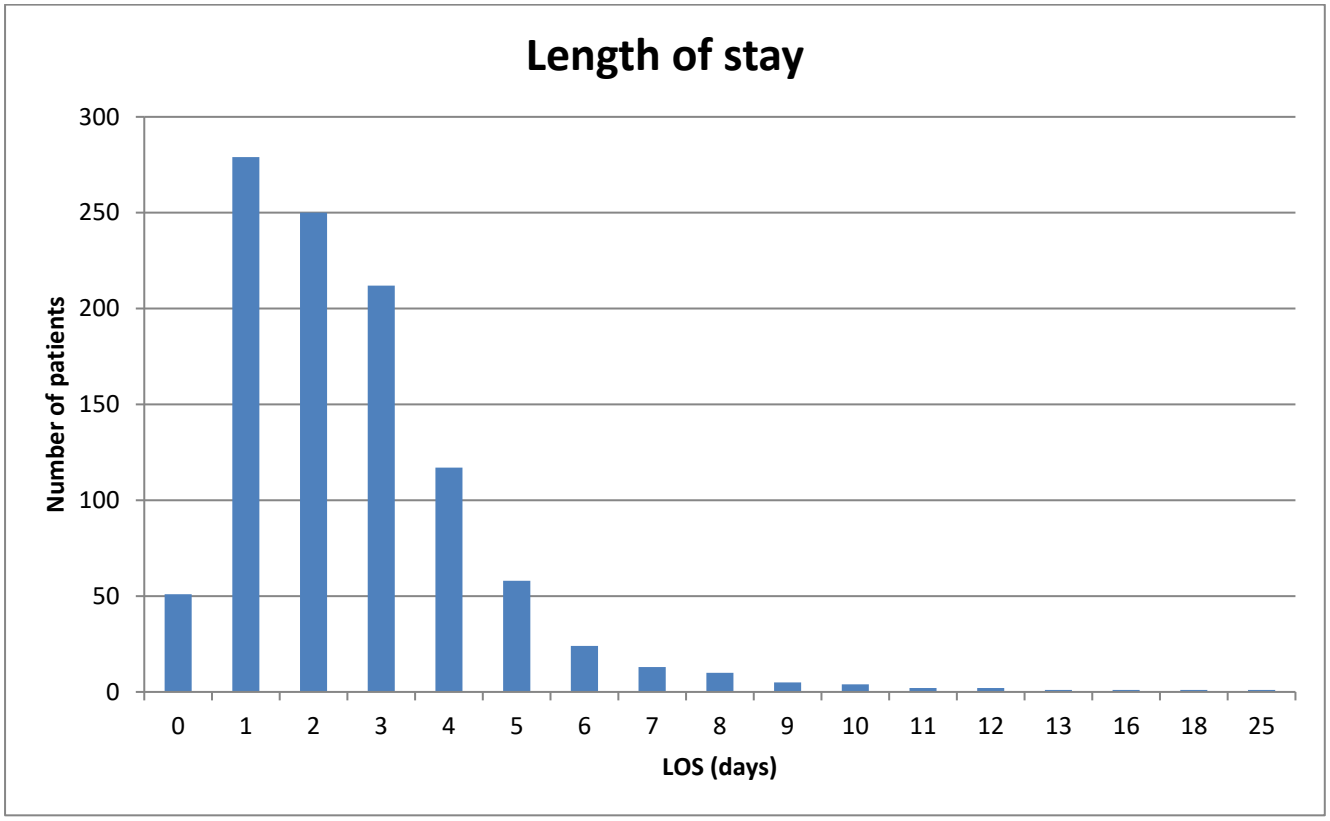

Figure 1: distribution of length of stay.

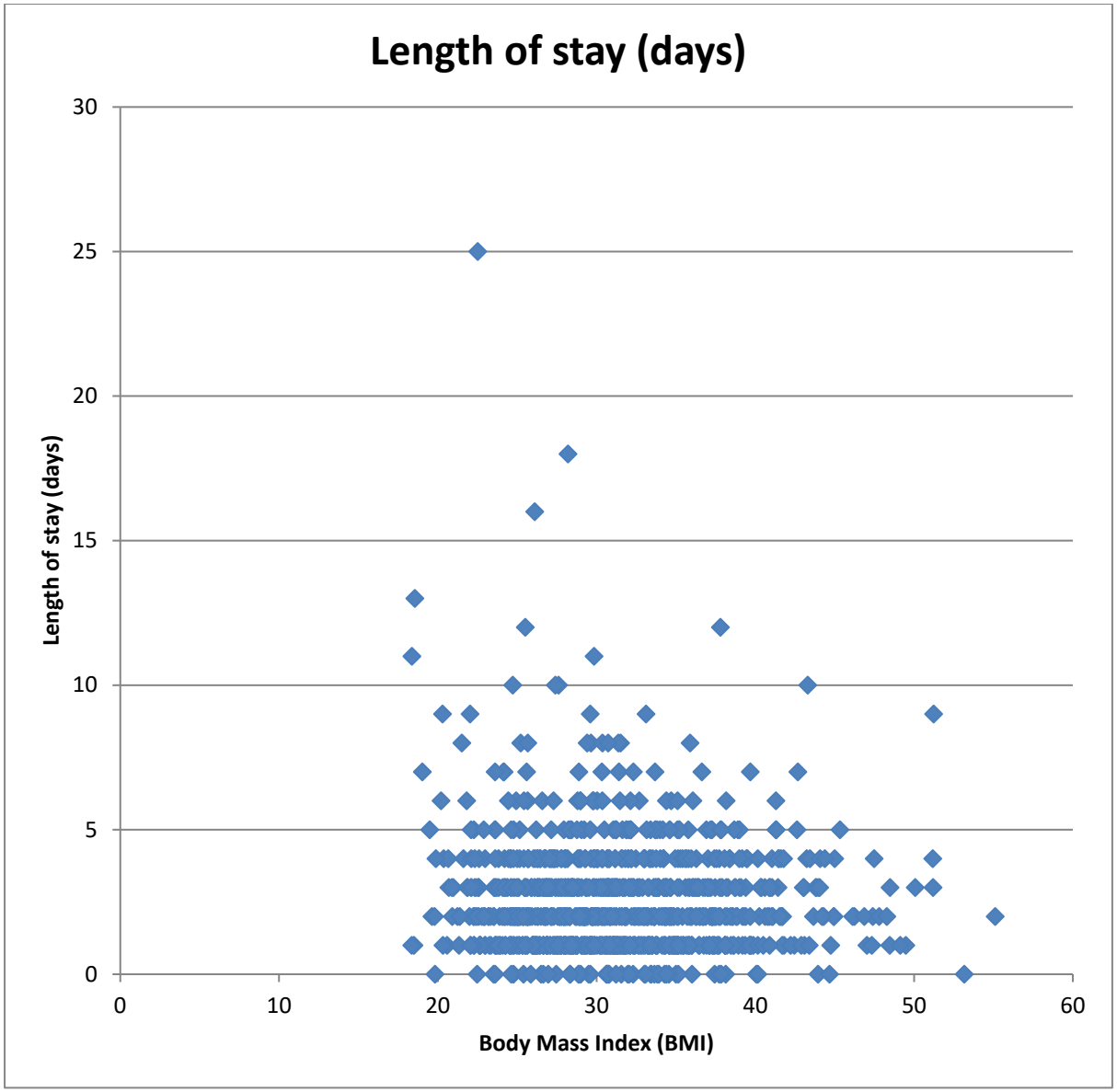

Figure 2: relationship between Body Mass Index and length of stay.

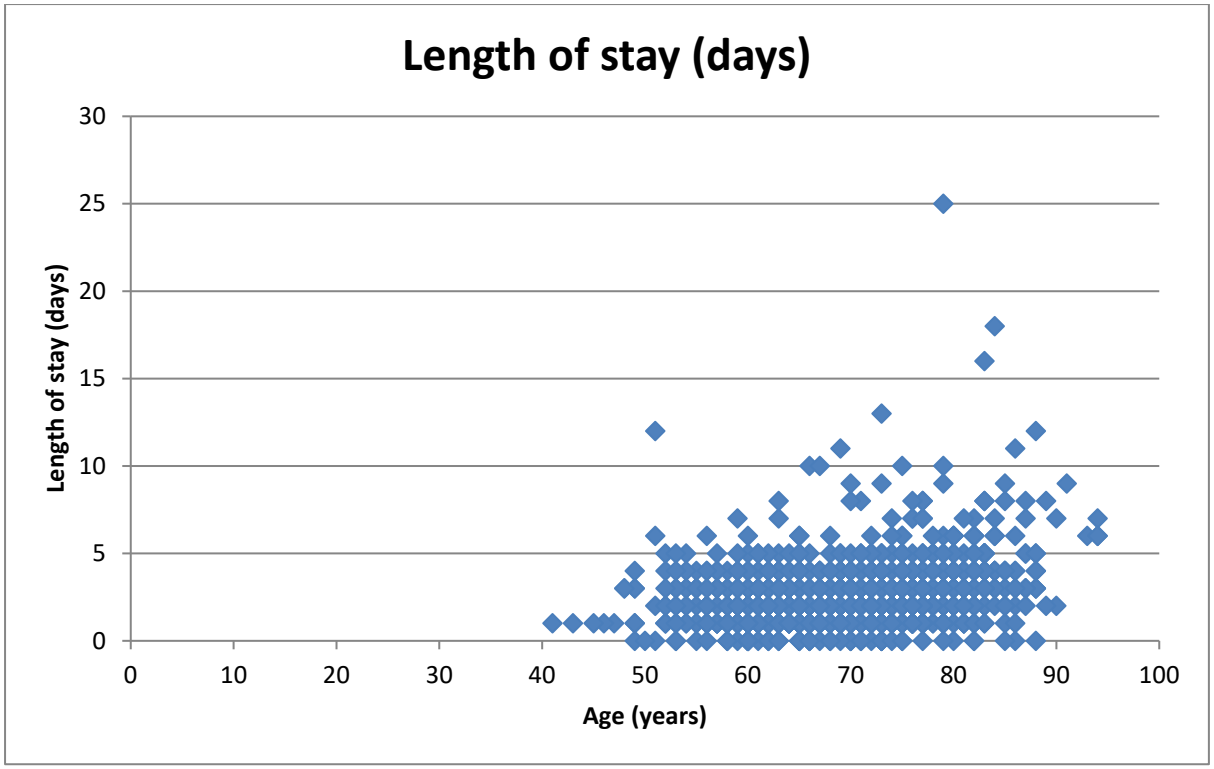

Figure 3: relationship between age and length of stay.