The variation of arthroplasty procedures in the OECD Countries: analysis of possible influencing factors by linear regression

Jamie Lee Günsche,[1,2] Veronika Pilz,[2] Tim Hanstein,[2,3] Ralf Skripitz[3,4]

[1]Bavarian State Office for Statistics, Schweinfurt Office, Schweinfurt; [2]Heraeus Medical GmbH, Health Economics, Wehrheim; [3]Rostock University Medical Center, Orthopedic Clinic and Policlinic; Rostock; [4]Roland-Klinik, Centre forArthroplasty, Foot Surgery, Paediatric and General Orthopaedics, Bremen, Germany

Abstract

Total hip and knee replacements (THR, TKR) are among the most common surgeries but incidence rates vary between OECD countries. Previous studies suggested economic factors to be most influential but did not take into account health care system related factors. Hence we analysed the possible influence of healthcare system related factors on the operation rate. We used OECD data for 27 countries and calculated Age-Standardized Incidence Rates (ASIR). In order to determine possible explanatory variables on the ASIRs we performed a stepwise blockwise linear regression. The ASIR of hip and knee replacement varies widely. We identified statistically significant determinants which influence the ASIR of THR in a positive manner: incidence and length of stay of coxarthrosis, ASIR of knee replacement, health expenditures, number of nurses and an etatistic social insurance. Diabetes prevalence, gross domestic product and number of doctor consultations, however, have a negative influence on the ASIR. TKR rate is positively influenced by health expenditures and incidence rate of gonarthrosis, negatively by the number of primary practitioners. We observed strong geographic disparities in the frequency of THR and THR that cannot be explained by age structure of the countries. Economic factors seem to play a secondary role while healthcare related factors have a greater influence.

Introduction

Knee and hip arthroplasties are among the most frequently performed surgical operations worldwide,[1] thus evolving be a significant cost factor on inpatient health expenditures.[2] The high frequency of joint arthroplasties is therefore subject to ongoing discussions, often being a major focus of health policy debates. Data from the Organization for Economic Co-operation and Development (OECD) show a strong geographical variation in the frequency of joint replacement surgeries.[3,4] This discrepancy is especially apparent in Western European countries where operation rates are particularly high. One possible explanation could be that the risk structures vary between the different countries. Since arthroplasty procedures are commonly indicated for degenerative joint diseases, risk factors for osteoarthritis - like older age, female gender and a high body mass index - might influence the operation rate.[5,6] On the other hand, socioeconomic factors such as ethnic origin or income play an important role and influence the rate of arthroplasty surgeries.[4,7-11] Previous publications studying the international variation of the frequency of joint replacement surgeries concluded that the variation is mainly due to economic factors such as the Gross Domestic Product (GDP) and health expenditures of the respective country.[3,4,12,13] But besides that, factors like infrastructure and the financing of the healthcare system should also be considered.[14,15] In this study, we wanted to address the question, which factors influence the frequency of operations in hip and knee arthroplasty in order to explain the variation present between countries.

Tim Hanstein, Heraeus Medical GmbH, Philipp-Reis-Str. 8/13, 61273 Wehrheim, Germany.
Tel.: +49 6181/35-2910
E-mail: tim.hanstein@heraeus.com

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Materials and Methods

We used data from the OECD including the rates of primary arthroplasty surgeries, the number of discharges with the main diagnosis of cox- and gonarthrosis, as well as their average length of stay. Data on economics and health expenditures as well as the number of beds or staffing resources and demographic information of the OECD countries were also included in the study. The prevalence of diabetes was taken from the International Diabetes Federation.

In order to understand the impact of the design and organization of the different healthcare systems, we classified the OECD countries into five categories according to Böhm *et al.*[16,17] Böhm *et al.*, who take into account the different responsibilities in the dimensions of funding, provision, and regulation of health services. Additionally, we included factors proposed by Wendt, classifying healthcare systems according to the access to health services as well as the funding and reimbursement system.[14]

For a comparison between the countries, regardless of the age distribution, we calculated the Age-Standardized Incidence Rate (ASIR) of hip or knee replacements. An indirect standardization based on population data of the United Nations with Germany as a reference country was undertaken. Germany was used as a reference since age-specific case numbers are available in the nationwide inpatient statistics (DRG statistics) of its Federal Bureau of Statistics (Statistisches Bundesamt). Furthermore, Germany is one of the largest OECD countries with a population of around 82 million. We used indirect standardization because of incomplete data availability although we are aware of its disadvantage that it primarily serves as a pairwise comparison between two countries.[3,18]

We used a linear regression model separately for hip and knee arthroplasty to investigate the different influencing factors. The model selection is based on a block-

wise stepwise forward selection. Various factors mentioned in Wendt[14] were included in the regression model whereas the classification from Böhm *et al.*[16,17] is estimated in a separate model. We classified the variables into thematic blocks and added them stepwise to the model according to the assumed explanatory content derived from previous research. First, control variables such as the incidence of osteoarthritis and health determinants were added, followed by an economic and resource-related variable group. Variables with an F-value above 0.1 were kept in the model.

The models were tested for multicollinearity or misspecification and the information criteria of the different model specifications were compared. For this analysis, we used the software Stata 13 (Stata Corp., College Station, TX, USA) and a significance level of $p<0.05$ was defined.

Results

In total, 27 OECD countries with a combined population of 936.2 million were included in our analysis. In 2015, a total of 1.69 million hip and 1.53 million knee endoprostheses were implanted. On average, 224 hip and 169 knee operations per 100,000 inhabitants were performed in 2015. In contrast, only around 208 hip and 153 knee operations per 100,000 were performed in 2010, which shows a significant increase in the operation rate.

After age standardization, there were still large variations in incidence rates between the countries. In hip arthroplasty, the highest ASIR per 100,000 inhabitants was found for Switzerland [356.5 (352.1, 360.9)] whereas South Korea had the lowest ASIR being 4.5-fold lower [78.5 (77.6, 79, 5)] (Table 1). While, for knee arthroplasty, the highest ASIR per 100,000 inhabitants was found for the U.S. [292.1 (291.4, 292.8)] whereas Poland had the lowest ASIR being 6-fold lower [48.5 (47.8; 49.3)] (Table 1). The standardized incidence rates (SIR) and the ASIR are shown with Confidence Intervals (CI) in Table 1.

The final regression models of hip arthroplasty built by stepwise block selection are shown in Table 2.

Model 1 includes financial, staff-related and medical factors and it accounts for 93.39% of the variation in the data. All included variables have a significant impact on the ASIR. The variables GDP, doctor consultations and prevalence of diabetes showed a negative effect. The highest positive effect estimates were seen for inpatient hospital stays with the main diagnosis of coxarthrosis and the number of nurses. Model 2 included the variables of the classification according to Böhm *et al.*[17] with Bismarck's social insurance system as a reference. *Ceteris paribus*, approximately 70 more operations per 100,000 inhabitants were performed in a country with an etatistic social insurance system compared with a Bismarck's social insurance system (Figure 1). Table 3 shows the final model selection

Table 1. ASIR in hip and knee arthroplasty, year 2015 or earlier.

	Hip arthroplasty				Knee arthroplasty			
Country	SIR	CI	ASIR	CI	SIR	CI	ASIR	CI
Australia[1]	96,4	(95,5; 97,3)	248,2	(245,8; 250,5)	124,5	(123,4; 125,6)	264,1	(261,7; 266,5)
Austria	116,7	(115,2; 118,2)	300,4	(296,6; 304,3)	113,2	(111,6; 114,8)	240,1	(236,7; 243,6)
Belgium[1]	112,8	(111,5; 114,1)	290,4	(287,0; 293,8)	110,8	(109,3; 112,2)	234,9	(231,9; 238,0)
Canada	71,6	(71,0; 72,2)	184,3	(182,7; 185,9)	102,5	(101,7; 103,3)	217,5	(215,8; 219,2)
Czech Republik	82,9	(81,7; 84,0)	213,3	(210,3; 216,4)	67,4	(66,3; 68,6)	143	(140,6; 145,4)
Denmark	104,8	(103,0; 106,6)	269,8	(265,2; 274,5)	85,9	(84,2; 87,7)	182,3	(178,6; 186,1)
Finland	103,5	(101,7; 105,2)	266,4	(261,9; 270,9)	93,5	(91,7; 95,3)	198,3	(194,4; 202,2)
France	107,8	(107,3; 108,4)	277,7	(276,3; 279,1)	90,2	(89,7; 90,8)	191,4	(190,3; 192,6)
Germany	116,2	(115,7; 116,6)	299,1	(298,0; 300,3)	97	(96,6; 97,5)	205,8	(204,8; 206,8)
Great Britain	83,3	(82,8; 83,7)	214,4	(213,1; 215,6)	83	(82,4; 83,5)	176	(174,9; 177,1)
Hungary	63,4	(62,3; 64,5)	163,2	(160,5; 166,0)	46,1	(45,2; 47,1)	97,9	(95,8; 100,0)
Iceland[2]	83,3	(76,0; 91,0)	214,4	(195,7; 234,3)	85,8	(77,7; 94,4)	181,9	(164,9; 200,1)
Ireland	77,3	(75,4; 79,3)	199,2	(194,2; 204,2)	35,8	(34,4; 37,3)	76	(73,0; 79,0)
Israel	45,3	(44,1; 46,5)	116,6	(113,4; 119,8)	48,2	(46,9; 49,6)	102,3	(99,4; 105,3)
Italy	65,8	(65,4; 66,2)	169,3	(168,3; 170,4)	53,3	(52,9; 53,7)	113	(112,2; 113,9)
Latvia	59,9	(57,7; 62,2)	154,3	(148,6; 160,1)	40,9	(39,0; 43,0)	86,8	(82,6; 91,2)
Luxemburg	104,6	(98,4; 111,0)	269,2	(253,5; 285,7)	115,5	(108,4; 122,9)	244,9	(229,9; 260,6)
Netherlands[3]	103,4	(102,4; 104,5)	266,3	(263,6; 269,0)	74	(73,1; 75,0)	157	(155,0; 159,0)
New Zealand	85,3	(83,3; 87,3)	219,6	(214,5; 224,7)	69,5	(67,6; 71,5)	147,5	(143,4; 151,6)
Norway	122	(119,8; 124,1)	314	(308,6; 319,5)	60,8	(59,1; 62,5)	128,9	(125,4; 132,5)
Poland	55,2	(54,6; 55,7)	142	(140,7; 143,4)	22,9	(22,5; 23,3)	48,5	(47,8; 49,3)
Slovenia	75,2	(72,7; 77,7)	193,6	(187,3; 200,0)	55,6	(53,3; 58,0)	117,9	(113,1; 122,9)
South Korea	30,5	(30,1; 30,9)	78,5	(77,6; 79,5)	78	(77,3; 78,6)	165,3	(164,0; 166,7)
Sweden	102,1	(100,7; 103,4)	262,8	(259,4; 266,2)	66,1	(64,9; 67,3)	140,1	(137,6; 142,6)
Switzerland	138,4	(136,7; 140,2)	356,5	(352,1; 360,9)	132	(130,2; 133,9)	280	(276,1; 283,9)
Turkey[3]	38,6	(38,2; 39,0)	99,4	(98,3; 100,5)	66,1	(65,5; 66,6)	140,1	(138,9; 141,3)
USA[4]	104,7	(104,5; 105,0)	269,7	(269,0; 270,4)	137,7	(137,4; 138,0)	292,1	(291,4; 292,8)

[1]2014 last available year; [2]2009 last available year; [3]2012 last available year; [4]2010 last available year.

in knee arthroplasty.

Model 1 accounted for a total of 67.44 % of the variation in the data. The number of discharges with main diagnosis gonarthrosis and the per capita health expenditure were significant effect estimates. The number of general practitioners showed a high negative effect estimate but did not reach significance. Model 2 including the classifications according to Böhm *et al.*[17] provided no additional explanatory content. The Akaike and Bayesian information criteria supported the prior model (Figure 2).

Discussion

The number of discharges with a diagnosis of cox- or gonarthrosis showed a significant effect on operation incidence in all models. Since osteoarthritis is the most common indication of arthroplasty surgery[19,20] it seems to be comprehensible that a higher incidence of osteoarthritis also results in a higher number of arthroplasties. However, in our study, the discharges with a diagnosis of cox- or gonarthrosis also include the patients who already received an artificial joint. Thus, mutual correlation cannot be ruled out here, as is the case with the variable average length of stay with the main diagnosis of osteoarthritis. However, it can be assumed that the incidence of osteoarthritis on basis of inpatient discharges is underestimated, as many patients

Table 2. Regression models for hip arthroplasty.

	Modell 1	P-value	Modell 2	P-value
Discharges of coxarthrosis	0,1852329*	*0,028*	0,3665807*	*0,002*
Length of stay of coxarthrosis	3,748767*	*0,049*	3,775541	*0,052*
ASIR knee arthroplasty	0,1811044*	*0,045*	0,2351*	*0,006*
GDP	-0,001151*	*0,015*	-0,0002966	*0,565*
Public healthcare spending per capita	0,0197395*	*0,001*	0,0203184*	*0,01*
Public healthcare expenditures in %	1,613574*	*0,003*	0,909011	*0,087*
Number of doctor consultations per capita/year	-7,121921*	*0,006*	-8,989724*	*0,001*
Number of nurses per 1000	4,128888*	*0,014*	3,017817	*0,092*
Diabetes prevalence	-5,578409*	*0,025*	-2,340144	*0,456*
National Health Service			49,24259	*0,11*
National Health Insurance			50,17092	*0,084*
Private Health Insurance			0,7367958	*0,985*
Etaistic Social Insurance			69,67244*	*0,017*
Constant	28,03311	0,49	-41,7228	*0,453*
N	27		27	
R^2	0,9568		0,9779	
R^2 adjusted	0,9339		0,9558	
Akaike s information criterion (AIC)	239,963		229,841	
Bayesian information criterion (BIC)	252,9214		247,9827	
Significance	0,0000		0,0000	

*P<0,05.

Table 3. Regression models for knee arthroplasty.

	Model 1	P-value	Model 2	P-value
Discharges of gonarthrosis	0,5041663*	*0,001*	0,6397671*	*0,001*
Length of stay of gonarthrosis	-3,794929	*0,153*	-3,498578	*0,303*
Healthcare spending per capita	0,0140297*	*0,013*	0,0195441*	*0,02*
Number of general practitioners per 1000	-18,148	*0,087*	-19,74818	*0,158*
National Health Service			48,41117	*0,295*
National Health Insurance			50,63932	*0,276*
Private Health Insurance			1,838027	*0,974*
Etaistic Social Insurance			56,6302	*0,211*
Constant	111,977*	0,012	24,39835	0,772
N	27		27	
R^2	0,7245		0,7487	
R^2 adjusted	0,6744		0,637	
Akaiks's information criterion (AIC)	275,477		280,9951	
Bayesian information criterion (BIC)	281,9562		292,6576	
Significance	0,0000		0,0004	

*P<0,05.

diagnosed with osteoarthritis receive outpatient treatment.

In contrast to prior publications, our analysis showed a comparatively small correlation between economic factors and ASIR in hip and knee arthroplasty.[12,13] Only the share of public health expenditure showed a significant effect on hip arthroplasty. It can be assumed, that there is a positive association between public health expenditures and resource availability in respect to hospital beds and staff. From a patient perspective, it can be concluded that higher public healthcare expenditure result in a lower personal share of direct health expenditure for the patient. Consequently, patients would rather choose being operated on than conservative treatment since own budgets will not be affected. Depending on the healthcare system, the type of funding differs significantly. In the case of Bismarck's social insurance, there is only a governmental framework, which leaves actors free and autonomous whereas in an etatistic social insurance, the government's influence is higher.[16,17] Governmental control of healthcare is even higher in the National Health Service. However, in all these systems with the exception of the private system, high public expenditures are observed.

Hip arthroplasty

The positive effect hypothesizing that the number of nurses is associated with the number of hip arthroplasties might be a spurious correlation in regard to the levels of health expenditures. Moreover, the type of nursing qualification might be an explanatory factor. Nursing qualifications mainly pertain to tertiary education, with Germany and Luxembourg being an exception where it is mainly pertained to secondary education.[21,22] This might lead to differing levels of competence resulting in a greater staff need. It may be possible that in countries where a higher educational level is required for nursing qualifications, more staffing will be needed to cover additional work. However, no publications were available investigating this research question.

A negative effect on the number of hip arthroplasties is shown for the doctor consultations, including the outpatient and inpatient area, and the prevalence of diabetes. It should be noted that in many countries outpatient care predominantly takes place in hospitals rather than in outpatient practices, as is the case in Germany. A correlation between the number of doctor consultations and medical services might support the gatekeeping theory where a general practitioner acts as a key figure and gatekeeper to medical services. It has been proven that when the number of specialist consultations is decreasing the number of general practitioner consultations increases.[23,24] However, a causal relationship cannot be inferred from our data as detailed information is lacking.

We were not expecting the negative effect of diabetes prevalence on the hip arthroplasty rate. Diabetes has been defined as a risk factor for the development of osteoarthritis.[25] However, it might be possible that arthroplasty surgery of diabetic patients is avoided since the disease also poses a risk for an infection after prosthesis implantation.[26,27]

Regarding the healthcare system classifications included in Model 2, there is a positive effect of the etatistic social insurance system on the ASIR. There is a higher governmental influence compared to Bismarck's social insurance system model. This result contradicts the observation that in German-speaking countries - which have predominantly Bismarck's social insurance systems - the operation rate is comparatively high (Figure 1). However, the influence of other variables not examined herein cannot be excluded. Furthermore, mulitcollinearity cannot be ruled out in Model 2, which hinders clear interpretations.

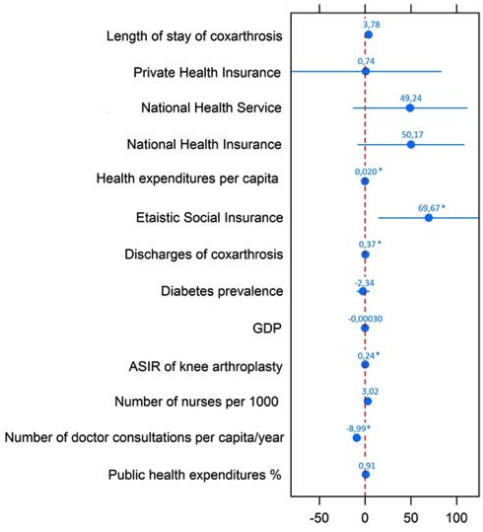

Figure 1. Factors influencing the frequency of operations in total hip arthroplasty (Model 2).

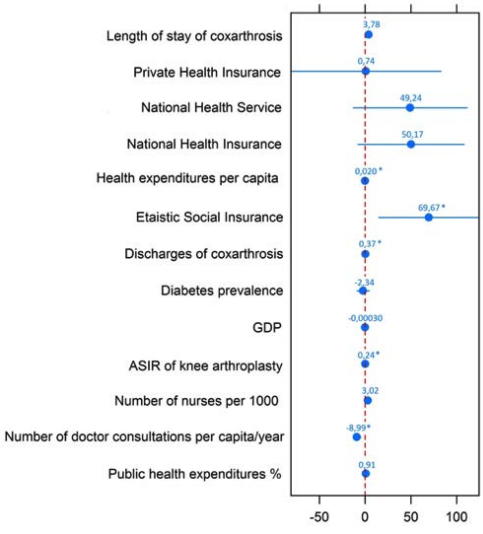

Figure 2. Factors influencing the frequency of operations in total knee arthroplasty (Model 2).

Knee arthroplasty

In our final model for knee arthroplasty, only the incidence of gonarthrosis and the per capita health expenditure showed positive significant effects. These findings are analogous to the findings in hip arthroplasty. Moreover, we did not see an influence of the different classifications of healthcare systems on the ASIR of knee arthroplasty. However, our model showed a high negative effect estimate of the number of general practitioners. A reduction in the rate of surgery in association with more primary care practitioners is in line with the gatekeeping theory. When access to health care is overseen by a general practitioner, a reduction in the use of health services and cost savings have been demonstrated (Figure 2).[28]

However, our data covers only the number of general practitioners per 1,000 inhabitants rather than the actual consultations but an association between the number of primary care practitioners and the frequency of doctor consultations can be assumed.[29]

Limitations

Our cross-sectional analysis might be limited as documentation of arthroplasty surgeries differs between the individual countries. The OECD obtains the data from national statistical offices as well as from national patient or registry data. Therefore, uniform documentation or calculation of case numbers cannot be guaranteed because of each country having a different documentation and billing system. Furthermore, in some countries, it is not possible to differentiate between primary and revision arthroplasty, which is why this study only focuses on primary surgery.

The classification of the different healthcare systems is another limitation. There are many different classification systems focusing on different influencing factors. The approach of Böhm *et al.*[16] was chosen because it equally covers the three dimensions of funding, provision, and regulation of health services, which allows for a detailed distinction. We covered Wendt's proposals for the classification of health systems by the OECD data.

Conclusions

Data from the OECD show strong geographical variations in the frequency of joint replacement surgery.[3,4] Previous publications studying the international variation of the frequency of joint replacement surgery concluded that the variation is mainly due to economic factors.[3,4,12,13] But besides that, additional factors like healthcare infrastructure and the financing of the health system should be considered.[14,15]

In our analysis, we showed, that the differences in the frequency of hip and knee arthroplasty are not limited to demographic and medical factors. Compared to previous research, the current analysis shows only a minor association between surgical incidence and the economic situation as well as the overall health expenditure of a country. Rather, we observed the effects of health resources and the nature of the healthcare system, especially in hip arthroplasty. The association between the number of doctor consultations and the arthroplasty rate needs to be emphasized as a negative effect and could be detected herein. It can be assumed that the high number of arthroplasty surgeries - especially in developed countries - could be influenced by primary care gatekeepers (general practitioners). However, further research is needed to confirm our results and thus derive political implications.

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