The Natural History of Genu Valgum in the Pediatric Obese Patient

Mark Mandel[1†], Brandi Woo[1†], Benjamin Wheatley[2], Amanda Young[2], Peter Fabricant[3], and Mark Seeley[2]
[1]Geisinger Commonwealth School of Medicine, Scranton, PA 18509
[2]Geisinger Medical Center, Danville, PA 17822
[3]Hospital for Special Surgery, New York, NY 10065
[†]Doctor of Medicine Program
Correspondence: mmandel@som.geisinger.edu

Abstract

Background: Pediatric obesity is a growing epidemic in the United States. There is little information on the impact this increasing incidence of obesity in the younger population has on the developing musculoskeletal system. Genu valgum is a common lower extremity malalignment that is thought to remodel as a child grows. Our hypothesis is that obesity may hinder the natural remodeling potential of these patients, which will lead to a greater clinical impact and cost of care.

Methods: A retrospective chart review of patients with genu valgum diagnoses over a span of 19 years was performed in a pediatric population. Inclusion criteria was diagnosis before age 18. Exclusion criteria was misdiagnosis, deceased before 18, or not evaluated by our institution's physicians. Demographic information was collected, and the clinical impact of the disease was estimated by using surrogate markers. Comparisons were analyzed using Fisher's exact or chi-square tests for categorical data and the Wilcoxon test for non-parametric continuous data.

Results: Out of 604 charts reviewed, 554 children met inclusion criteria for the study. Thirty-nine patients required surgical intervention. A majority of the patients who had surgery were obese (63.6%). A comparison of body mass index (BMI) categories showed a higher number of visits in the overweight/obese categories as compared to the normal weight group (11.6% vs. 2.4% of patients with greater than five visits, $p = 0.0068$). The number of surgeries was higher in the overweight/obese group compared to the healthy weight group ($p = 0.0268$), and a higher number of patients had surgery in the overweight/obese categories than the healthy weight category (6.9% vs. 1.9%, $p = 0.0188$).

Conclusion: Historically, pediatric genu valgum runs an indolent course without requiring surgical intervention. Our findings suggest that the clinical impact of this disease changes with increased bodyweight. The relationship between obesity and the severity of genu valgum in the pediatric population appears to be a prognostic indicator of a more challenging disease course complicated by an increased likelihood for surgical intervention.

Level of Evidence: Level II – Prognostic Studies – Investigating the Effect of a Patient Characteristic on the Outcome of Disease, Retrospective Study

Introduction

The increased incidence of obesity in the pediatric population is accompanied by an increase in incidence of lower extremity pathology and decreased physical activity levels, all of which predispose to musculoskeletal pain and bone/joint dysfunction later in life (1–3). Recent studies have examined the relationship between increased body weight and musculoskeletal pathology in children; however, there is currently a dearth of research that investigates the relationship between obesity and the trajectory of genu valgum in children. Genu valgum, also called "knock-knee" deformity, is a common lower extremity abnormality seen in children that makes the knees appear like they are touching while the ankles are apart (4). For children ages 2 to 7 years old, genu valgum is a physiologic process and most cases spontaneously resolve. If the genu valgum persists beyond age 8 or is extreme, surgical intervention may be required to allow for normal growth and alignment of the legs (4, 5).

While most idiopathic cases of genu valgum follow a mild course, our clinical observations suggest that genu valgum in an overweight or obese child may present a more challenging trajectory for the patient. A study by Jankowicz-Szymanska and Mikaloajczyzk reported a higher prevalence of genu valgum in obese children compared to non-obese children (6). Another study by Walker et al. found direct correlations between obesity and genu valgum by examining radiographs and calculating intermalleolar distances (7). This study aimed to gain a deeper understanding of the relationship between obesity and genu valgum in the pediatric population. We hypothesized that children with increased bodyweight, as reflected in their body mass index (BMI), and genu valgum are more likely to experience long-term sequalae and the need for surgical intervention.

Methods

Upon Institutional Review Board (IRB) approval, we performed a retrospective chart review of genu valgum diagnoses over a span of 19 years. Patients with a genu valgum diagnosis were determined by using the Epic WebI database searching for the ICD-9 code 736.41 (Genu valgum, acquired) and the ICD-10 codes M21.069 (Valgus deformity, not elsewhere classified) and Q74.1 (Congenital malformation of the knee). Patients were eligible for inclusion if the diagnosis of genu valgum was made before age 18. Exclusion criteria included patients who were either misdiagnosed, not seen within the hospital system, or deceased before age 18.

Charts were reviewed for relevant demographic and clinical information. The initial date and age of when a patient was seen for knee concerns/complaints were determined from the patients' charts. The date of initial diagnosis was documented, what the diagnosis/cause of the knee complaint was (e.g., congenital or acquired genu valgum, any preceding

	All patients N = 554
Age, years	
Mean (SD)	6.14 (4.43)
Median (IQR)	4.0 (2.0, 9.0)
Min, Max	1.06, 18.0
Age at Initial Surgery, years	
Mean (SD)	12.50 (2.89)
Median (IQR)	12.9 (10.8, 14.1)
Min, Max	3.75, 18.92
Knee Surgery to correct Genu Valgum, n (%)	
Yes	39 (7.0)
No	30 (5.4)
No Surgery	485 (87.6)
Type of Surgery for Genu Valgum, n (%) (N=39)	
ACL/OCD/MPFL/Loose Body	6 (15.4)
Osteotomy	4 (10.3)
Hemiepiphyseiodesis	29 (74.4)
Follow up, years	
Mean (SD)	5.51 (4.38)
Median (IQR)	4.62 (1.69, 8.19)
Min, Max	0.02, 20.01
Diagnosis Cause, n (%)	
non-traumatic/congenital deformity/acquired	436 (78.7)
traumatic/MVA/secondary to fracture/iatrogenic, etc.	18 (3.2)
n/a or missing	100 (18.1)
X-rays, n (%)	
No	305 (55.1)
Yes	246 (44.4)
n/a	3 (0.54)
Number of visits for knee complaints, n (%)	
0	133 (24.0)
1	213 (38.5)
2	72 (13.0)
3	32 (5.6)
4	26 (4.7)
5+	75 (13.5)
missing	3 (0.54)
Number of knee surgeries, n (%)	
0	485 (87.6)
1	30 (5.4)
2	25 (4.5)
3+	14 (2.5)

Table 1. Summary table for all patients with genu valgum diagnosis.

trauma injury), and who diagnosed the knee problem (PCP or orthopaedics). Additional data collected included how many orthopaedic visits were made for knee complaints, whether knee X-rays were taken, how many knee surgeries were performed, the patient's age at initial surgery, type of surgery, the date of the last orthopaedic visit for a knee complaint, and length of follow-up.

All demographic and clinical characteristics are fully described by reoperation status. Continuous variables are summarized using means and standard deviations for normally distributed data or median and interquartile range (IQR) for non-normally distributed data. Categorical variables are summarized using frequency and percentages. Demographic and clinical characteristics are compared using Fisher's exact or chi-square tests for categorical data and the Wilcoxon test for non-parametric continuous data. Logistic regression techniques were used to calculate the area under the curve (AUC) for the receiver operating characteristics (ROC) curve. All analyses were performed using SAS v9.4 (SAS Institute Inc., Cary, NC, USA).

	Surgery for Genu Valgum N = 39	No Surgery for Genu Valgum N=515	P-value
Race, %			
White	82.0	85	0.8467
Non-white	15.4	12.2	
Unable to obtain/Missing	2.6	2.5	
Age at Initial Surgery, years (N=69)			
Mean (SD)	12.14 (2.95)	12.96 (2.78)	0.0890
Median (IQR)	11.58 (10.46, 13.58)	13.38 (11.75, 14.50)	
Min, Max	3.75, 18.92	6.75, 18.56	
Follow up, years			
Mean (SD)	4.89 (3.88)	5.56 (4.42)	
Median (IQR)	3.82 (2.22, 7.82)	4.68 (1.61, 8.31)	0.4874
Min, Max	0.35, 15.11	0.02, 20.01	
Diagnosis Cause, n (%)			
non-traumatic/congenital deformity/acquired	32 (82.0)	404 (78.5)	0.0197
traumatic/MVA/secondary to fracture/iatrogenic, etc.	4 (10.3)	14 (2.7)	
n/a or missing	3 (7.7)	97 (18.8)	
X-rays, n (%)			
No	1 (2.6)	304 (59.4)	<0.0001
Yes	38 (97.4)	208 (40.6)	
n/a		3	
Diagnosed by n (%)			
Primary Care Provider	4 (10.3)	272 (52.8)	<0.0001
Orthopaedic Surgeon	34 (87.2)	227 (44.1)	
unknown	1 (2.5)	16 (3.1)	
Number of initial visits for knee complaints, n (%)			
0	1 (2.6)	132 (25.8)	<0.0001
1	0 (0)	213 (41.6)	
2	0 (0)	72 (14.1)	
3	2 (5.1)	30 (5.9)	
4	3 (7.7)	23 (4.5)	
5+	33 (84.6)	42 (8.2)	
missing	0	3	
Number of knee surgeries, n (%)			
0	0 (0)	485 (87.6)	N/A
1	19 (48.7)	11 (2.1)	
2	14 (35.9)	11 (2.1)	
3+	6 (15.4)	8 (1.6)	

Table 2. Comparing demographic and clinical characteristics for those that had surgery specifically to correct their genu valgum to those who did not.

Results

Our study reviewed 604 charts from pediatric patients covering visits from March 1999 to December 2018. Of the 604 charts, 554 children met inclusion criteria for the study. A total of 50 patients (8.2%) were excluded due to misdiagnosis, not being seen by an OMITTED physician, or deceased before age 18.

Demographic and clinical characteristics are described for all patients with genu valgum (Table 1). The mean age at initial encounter for all patients diagnosed with genu valgum is 6.14 years with a standard deviation of 4.43. The sample was 49.8% female and 85% white. The BMI percentile categories were a combined underweight and healthy weight category (48.6%), an overweight category (15%), and an obese category (36.4%). A total of 69 (12.4%) of these patients had knee surgeries, of which 39 (7.0%) patients had surgery specifically to correct their valgus deformity and 30 (5.4%) patients had knee surgeries for other reasons with their valgus being a significant contributor. Of the patients who had surgery for their genu valgum, 63.6% of them were obese. The mean age at initial surgery was 12.50 years with a standard deviation of 2.89. The majority of those who had surgery for genu valgum had hemiepiphysiodesis surgery (74.4%).

Results are reported in Table 2, which is a comparison of those who had surgery for genu valgum versus those who did not have surgery for genu valgum. Those who had surgery had significantly more X-rays (97.4% v. 40.6%, P < 0.0001) and significantly more visits for knee complaints (>5 visits for knee complaints, 84.6% v. 8.2%. p <0 .0001).

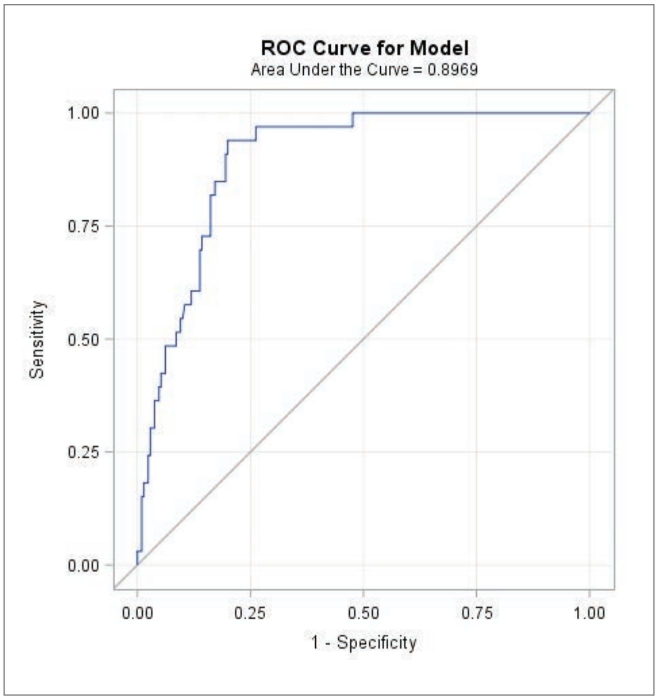

Figure 1. This receiver operating characteristic (ROC) curve was designed to assess how well age at initial encounter for genu valgum can independently predict the outcome of whether or not surgery is required. Area under the curve = 0.792 (95% CI 0.7429 – 0.8516)

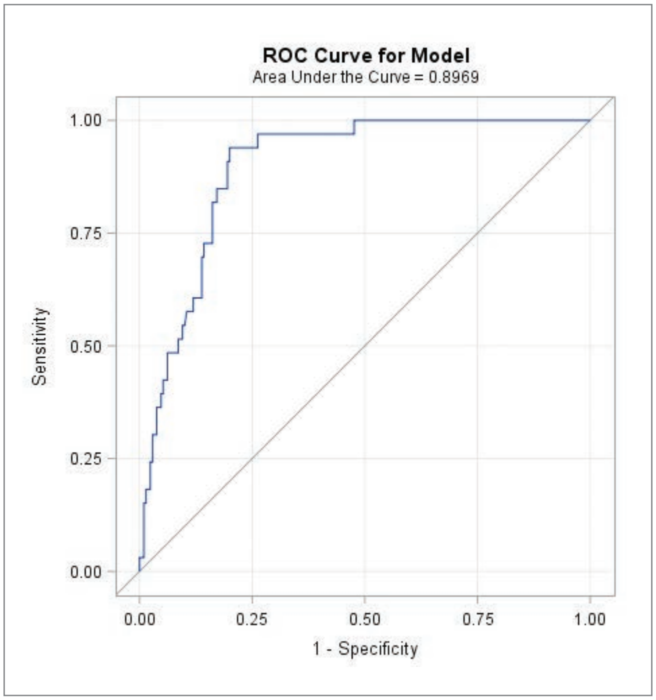

Figure 2. This receiver operating characteristic (ROC) curve was designed to assess how well BMI can predict whether the outcome of surgical intervention was required. Area under the curve = 0.8969 (95% CI 0.8532 – 0.9406)

The BMI percentiles were divided into two groups, an underweight/healthy weight group and an overweight/obese group. A comparison of the two groups shows a higher number of visits for knee complaints in the overweight/obese as compared to the healthy weight group (over 5 visits, 11.6% v. 2.4%, p=0.0068). The number of knee surgeries is significantly higher in the overweight and obese categories compared to healthy weight (p=0.0268). There was not a significant difference in cause of diagnosis between the two groups. The prevalence of surgery for correction of genu valgum was significantly higher in the overweight/obese group (p=0.019).

The ROC curves were designed to assess how well age and BMI separately predict the outcome of whether or not surgery is required for genu valgum in these children (Figure 1). The area under the curve (AUC) for age at initial encounter is 0.7972 (95%CI: 0.7429-0.8516). In Figure 2, the ROC curve for BMI is displayed, and the AUC is 0.8969 (95%CI: 0.8532-0.9406).

Discussion

While the negative effects of excess body weight on the musculoskeletal system are well known, to our knowledge the burden of disease and clinical impact of genu valgum in overweight and obese children has not yet been rigorously studied. Our study utilized historical chart and anthropometric data to better understand the epidemiology and clinical trajectory of genu valgum in overweight and obese children compared to their normal weight counterparts. A review of previous studies was helpful in establishing original associations between obesity and genu valgum.

Several studies have reported that obesity can cause deformities in the lower limbs which specifically include genu valgum (2, 8, 9). A paper published by Wearing et al. helped to detail the biomechanical basis of the pathology, making note that children have a larger amount of collagen during their growth phase, which is susceptible to remodeling in response to higher load and therefore susceptible to plastic deformation (10). The chronically increased load due to their obesity can exacerbate this process, causing significant deformation and excess angulation leading to genu valgum. In addition to this potential cause, Espandar et al. suggest that ligamentous laxity may also be the cause of genu valgum, and this is congruent with the soft-tissue deformation theory of the disease (9). Combined with our findings, these investigations suggest that obesity may exacerbate genu valgum in pediatric patients and therefore increase the need for corrective surgery as well as increase the burden of disease. However, a more detailed investigation into the timing and progression of genu valgum as it relates to the onset of obesity in these children would be helpful in determining possible causality.

The median age of genu valgum diagnosis in our study was 4 with IQR of 2-9 which is consistent with the known epidemiology of genu valgum, as it is a physiologic process in children between the ages of 2 and 7 years old (5). Pathologic genu valgum is more common in older children, as the physiologic valgum may persist or worsen and this is similarly reflected in our data as the median age for those who required surgery was 12.9 years old (IQR 10.8:14.1) (9,11).

The increased median age of those who required surgery was consistent with our ROC curve, which showed that age could be used to predict whether a child would require surgery.

In our study, we used the number of visits for knee complaints and/or pain, the number of X-rays taken, and the requirement for surgical intervention as the surrogate markers to track the severity and burden of the disease course in these patients. We did not use radiographic images to track intermalleolar distances, as the purpose of the study was to investigate how the trajectory of the disease differs between the overweight and obese children compared to healthy weight children. Due to the mild course of genu valgum and relatively rare need for corrective surgery, it is easy to observe deviations from this path. It is important to make note of the cause of the diagnosis and compare these among weight groups, as a traumatic cause of genu valgum could potentially lead to a more severe genu valgum presentation than an idiopathic cause and thus be a confounder. The cause of diagnosis was recorded as either non-traumatic/congenital deformity, acquired, or traumatic secondary to motor vehicle accident, fractures, iatrogenic, or missing. Our findings indicated that there was no difference among the three BMI percentile categories for cause of diagnosis.

As was expected due to the naturally mild course of genu valgum, most patients in our sample did not require surgery. However, 39 of the 554 patients required surgery specifically to correct their valgus deformity while 30 other patients had knee surgery where their valgum was a contributing factor. The group that received surgery also had a significantly higher percentage of having X-rays taken, which is evidence of both the greater direct cost of care due to medical bills and the greater indirect cost of care such as time off work for the parent to take the child for the imaging. The percentage of surgical patients who were obese was nearly double that of the percentage of obese patients in the sample. This is an interesting finding and agrees with Wearing et al. finding that obesity in their sample of genu valgum patients was twice the rate of obesity in the general pediatric population (10). Once again, this further helps us understand the association between obesity and an increase in the severity of the disease and likelihood of surgery.

Our ROC curves for BMI and surgery also showed that BMI can be used to predict surgical intervention for these patients. The interrelatedness between genu valgum and obesity is apparent, but the causal directionality is still slightly unclear.

The increased burden of disease in overweight children with genu valgum was additionally evidenced by the higher number of visits and longer length of follow-up. This data helps estimate the clinical impact of the disease on these patients and secondarily the direct and indirect costs of health care. Although we did not measure and compare radiographic data, our study findings are able to serve as a link between prior quantitative genu valgum research findings and the clinical consequences and outcomes experienced by these pediatric patients. The single most important finding of the study is that the overweight and obese group had a significantly higher number of patients undergoing surgery for their genu valgum than the underweight and healthy weight group. This is a potentially actionable finding and should help guide treatment via early weight-loss intervention programs, which may help these pediatric patients decrease the likelihood of requiring surgery. In addition to the increased burden of disease for the patient undergoing surgery and postoperative rehabilitation, their parents/guardians must undergo additional financial burden in the form of missing work to accompany the patient at these visits.

Our study has several limitations, which include the retrospective nature of the study, the reliance on ICD coding and EMR data input, and that the study was not designed with power or sample size considerations. We believe that the effect of the chart review based on ICD diagnosis likely underrepresents the number of visits and severity of genu valgum in the overweight and obese patients, as musculoskeletal problems in this group tend to involve multiple joint locations. Along these lines, if a child presented with shoulder pain, it may not have been recorded that they also had knee complaints. This theory is backed by several papers previously published on musculoskeletal health and musculoskeletal pain in overweight and obese children that show high rates of simultaneous joint pain complaints (1, 3).

With prevention being the best medicine, our study findings reinforce the previous research on the association of genu valgum and obesity and underscore the necessity of early weight-loss intervention in children to prevent the development of more severe musculoskeletal pathology. Our findings also suggest that although genu valgum appears likely to resolve in healthy weight patients, we should attempt to identify lower extremity issues earlier and consider being more aggressive with treatment and surveillance of the deformity in overweight and obese patients. Additionally, our study bolsters the importance of our colleagues' prior findings on the anatomic and measurement-based relationship between genu valgum and obesity in children, but adds the additional dimension of clinical impact. Furthermore, we demonstrated that genu valgum in an obese child is associated with an increased risk for more clinic visits, more imaging studies, and the potential need for surgery. This increase in clinical impact and burden of disease further increases the cost of care for the patient and on the health care system. Further research is needed within this area, and we hope that our findings can facilitate a multicenter and multidisciplinary approach to better understand the effect of obesity on the prognosis of children with genu valgum diagnoses, with the ultimate goal of improving outcomes in these children and preventing the progression of disease into adulthood and its associated long-term comorbidities.

References

1. Smith SM, Sumar B, Dixon KA. Musculoskeletal pain in overweight and obese children. *Int J Obes*. 2014 Jan;38(1):11–5.
2. Taylor ED, Theim KR, Mirch MC, Ghorbani S, Tanofsky-Kraff M, Adler-Wailes DC, et al. Orthopedic complications of overweight in children and adolescents. *Pediatrics*. 2006 Jun;117(6):2167–74.
3. Bell LM, Curran JA, Byrne S, Roby H, Suriano K, Jones TW, et al. High incidence of obesity co-morbidities in young children: A cross-sectional study: Obesity co-morbidities in young children. *Journal of Paediatrics and Child Health*. 2011 Dec;47(12):911–7.

4. Kids Health. Available from: https://m.kidshealth.org/Nemours/en/parents/az-genu-valgum.html
5. Hatch, Daniel. *OrthoBullets*. Available from: https://www.orthobullets.com/pediatrics/4052/genu-valgum-knocked-knees
6. Jankowicz-Szymanska A, Mikolajczyk E. Genu Valgum and Flat Feet in Children With Healthy and Excessive Body Weight: *Pediatric Physical Therapy*. 2016;28(2):200–6.
7. Walker JL, Hosseinzadeh P, White H, Murr K, Milbrandt TA, Talwalkar VJ, et al. Idiopathic Genu Valgum and Its Association With Obesity in Children and Adolescents: *Journal of Pediatric Orthopaedics*. 2019 Aug;39(7):347–52.
8. Jannini SN, Dória-Filho U, Damiani D, Silva CAA. Musculoskeletal pain in obese adolescents. *J Pediatr (Rio J)*. 2011 Aug;87(4):329–35.
9. Espandar R, Mortazavi SM-J, Baghdadi T. Angular deformities of the lower limb in children. *Asian J Sports Med*. 2010 Mar;1(1):46–53.
10. Wearing SC, Hennig EM, Byrne NM, Steele JR, Hills AP. Musculoskeletal disorders associated with obesity: a biomechanical perspective. *Obesity Reviews*. 2006 Aug;7(3):239–50.
11. Ciaccia MCC, Pinto CN, Golfieri F da C, Machado TF, Lozano LL, Silva JMS, et al. Prevalence of genu valgum in public elementary schools in the city of Santos (SP), Brazil. *Rev Paul Pediatr*. 2017 Dec;35(4):443–7.