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Alexander Ziedas

Joshua P. Castle

Varag Abed

Alexander Swantek

Sarah Chaides

See next page for additional authors

Authors

Alexander Ziedas, Joshua P. Castle, Varag Abed, Alexander Swantek, Sarah Chaides, Kareem Elhage, Johnathan Fife, Vasilios Moutzouros, and Eric C. Makhni

Associating Social Determinants of Health With PROMIS CAT Scores and Health Care Utilization After ACL Reconstruction

Alexander Ziedas,* MD, Joshua P. Castle,* MD, Varag Abed,* BS, Alexander Swantek,* MD, Sarah Chaides,* BS, Kareem Elhage,* BA, Johnathan Fife,* MS, Vasilios Moutzouros,* MD, and Eric C. Makhni,*† MD, MBA

Investigation performed at Henry Ford Hospital, Detroit, Michigan, USA.

Background: The term "social determinants of health" (SDOH) refers to social and economic factors that influence a patient's health status. The effect of SDOH on the Patient-Reported Outcomes Measurement Information System (PROMIS) computer adaptive test (CAT) scores and postoperative resource utilization in patients with anterior cruciate ligament reconstruction (ACLR) have yet to be thoroughly studied.

Purpose: To investigate the impact SDOH have on PROMIS CAT outcomes and postoperative resource utilization in patients with ACLR.

Study Design: Cohort study; Level of evidence, 3.

Methods: The electronic medical record was used to identify the SDOH for patients who underwent ACLR by 1 of 3 sports medicine fellowship–trained orthopaedic surgeons between July 2017 and April 2020. PROMIS CAT measures of Physical Function (PROMIS-PF), Pain Interference (PROMIS-PI), and Depression (PROMIS-D) were completed at the preoperative, 6-month postoperative, and 12-month postoperative time points. Postoperative health care utilization was recorded as well. Independent 2-group *t* tests and Wilcoxon rank-sum tests were used to analyze mean differences between patient groups based on SDOH.

Results: Two-hundred and thirty patients who underwent ACLR were included (mean age, 27 years; 59% male). Compared with White patients, Black patients were represented more frequently in the lowest median household income (MHI) quartile (63% vs 23%, respectively; $P < .001$). White patients were represented more frequently in the highest area deprivation index (ADI) quartile when compared with Black patients (67% vs 12%, respectively; $P = .006$). Significantly worse PROMIS-PF, PROMIS-PI, and PROMIS-D scores at all 3 time points were found among patients who were Black, female, smokers, and in the lower MHI quartiles, with higher ADI and public health care coverage. In terms of resource utilization, Black patients attended significantly fewer postoperative physical therapy visits when compared with their respective counterparts. Those in the lower MHI quartiles attended significantly fewer postoperative imaging encounters, and female patients attended significantly more postoperative virtual encounters than male patients.

Conclusion: Specific SDOH variables, particularly those that reflect racial and socioeconomic disparities, were associated with differences in postoperative health care utilization and ACLR outcomes as measured by PROMIS CAT domains.

Keywords: anterior cruciate ligament reconstruction; social determinants of health; Patient-Reported Outcomes Measurement Information System; health care utilization

The anterior cruciate ligament (ACL) is a commonly injured ligament in the knee[3] and is often managed with ACL reconstruction (ACLR) in active individuals.[44] A wealth of literature exists surrounding outcomes after ACLR[1,5,8,26,39,43,49]; however, little is known about the role of socioeconomic factors in clinical outcomes and resource utilization. The World Health Organization defines social determinants of health (SDOH) as the social environment in which people are born, work, live, learn, and age.[48] These variables include race, ethnicity, living situation, employment, income, health insurance status, education, and social support. Historically, these factors have been demonstrated to influence disease development, access to health care, and ultimately outcomes.[2,27,41] This drives population health disparities after common orthopaedic procedures,[48] including ACLR.[10]

Previous literature has suggested that certain SDOH parameters related to social deprivation, such as race or ethnicity, insurance status, sex, and socioeconomic status, are associated with differential access to orthopaedic care

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and health care utilization.[20] In addition, recent changes in US health care policy have altered the health insurance marketplace, affecting patient-borne costs, physician reimbursement, and demand for service, thereby limiting access to orthopaedic care.[31] Postoperative health care utilization, particularly physical therapy, has been shown to improve outcomes[25]; however, variables such as insurance status serve as a barrier to accessing postoperative physical therapy and portend worse clinical outcomes after ACLR.[40] Furthermore, SDOH factors, including ethnicity, Medicare insurance, and annual income, have been shown to be major contributors to costs of ACLR.[9]

Currently, there is a dearth of studies evaluating the impact that SDOH have on health care utilization and outcomes after ACLR. Investigating these associations may inform providers on how social and financial barriers hinder adherence to postoperative protocols and drive costs, while also identifying patients who are more vulnerable to inferior outcomes. Assessment instruments such as the Patient-Reported Outcomes Measurement Information System (PROMIS) can assist in measuring outcomes. Among patients with ACLR, the PROMIS computer adaptive testing (CAT) forms have demonstrated favorable psychometric profiles and shorter times required for administration compared with legacy patient-reported outcome measures.[4,6,7,30,33,36] Furthermore, PROMIS questionnaires are domain specific instead of disease specific, allowing them to be administered to a broader patient population. As patient-reported outcome measures and the PROMIS become more routine in orthopaedic practice, understanding how social and economic factors influence outcome scores will be crucial to identify those patients who may be more at risk for worse outcomes after surgery.

The purpose of this study was to investigate the impact of SDOH on PROMIS CAT outcomes and postoperative resource utilization in patients with ACLR. We hypothesized that certain SDOH variables will reflect patient socioeconomic status, while being associated with inferior PROMIS CAT scores and increased postoperative health care utilization after ACLR.

METHODS

Included were 230 patients who underwent ACLR by 2 sports medicine fellowship–trained orthopaedic surgeons (E.C.M. and V.M.) between July 2017 and April 2020. Patients completed the PROMIS CAT measures of Physical Function (PROMIS-PF), Pain Interference (PROMIS-PI), and Depression (PROMIS-D) at the preoperative, 6-month postoperative, and 12-month postoperative time points. All PROMIS forms were administered on a tablet (iPad; Apple) utilizing a secure web-based application (REDCap; Vanderbilt University) before the patients' respective office visits. These pre- and postoperative PROMIS CAT surveys were retrospectively analyzed. Exclusion criteria included those who have not undergone ACLR, were not able to read or write in English, or did not complete all PROMIS CAT forms at all 3 time points. Institutional review board approval was obtained before survey administration and data collection.

Multiple SDOH factors were retrospectively collected from the electronic medical record (EMR), including age, sex, race, ethnicity, body mass index, tobacco use, insurance status, marital status, estimated median household income (MHI), and area deprivation index (ADI). Race was self-reported and was categorized as White, Black, Asian, or other. Likewise, ethnicity was self-reported as either Hispanic (including Latino or Spanish) or non-Hispanic. Insurance status was categorized as having either private/commercial health insurance or public/government health care coverage (Medicare/Medicaid). Patients were stratified into MHI quartiles based on their ZIP code, which was cross-referenced with the US Census Bureau average household income database in 2020.[18] ADI values were calculated based on the methodology of Singh,[47] who measured the socioeconomic disadvantage of regions in the United States by a factor-based index using US Census data pertaining to poverty, education, housing, and employment.[24] Higher ADI scores indicate increased deprivation compared with lower scores. The ADI was obtained by entering each patient's unique home address into the University of Wisconsin School of Medicine and Public Health 2018 ADI (Version 3.0; https://www.neighborhoodatlas.medicine.wisc.edu); ADI values were stratified into 4 quartiles.

Postoperative health care utilization data, defined by the number of postoperative office visits, physical therapy visits, virtual encounters (video visits, EMR message encounters, telephone encounters), imaging encounters (radiograph, ultrasound, computed tomography, magnetic resonance imaging), and nonoperative procedures (steroid injections, electromyography), were retrospectively collected from the EMR as well.

Statistical Analysis

Variables were compared between groups using independent 2-group *t* tests for normally distributed continuous variables (PROMIS scores) and Wilcoxon rank-sum tests

†Address correspondence to Eric C. Makhni, MD, MBA, Henry Ford Health System, 2799 W Grand Boulevard, Detroit, MI 48202, USA (email: emakhni1@hfhs.org).

*Henry Ford Health System, Detroit, Michigan, USA.

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Ethical approval for this study was obtained from Henry Ford Health System (reference No. 13787).

TABLE 1
Patient and SDOH Characteristics (N = 230)[a]

Variable	Value	Variable	Value
Age, y	27.1 ± 10.7 (13.0-58.0)	Race	
BMI, kg/m^2	27.0 ± 5.8 (15.2-60.0)	White	140 (60.9)
MHI quartile[b]		Black	52 (22.6)
Q1 ($21-45k)	35 (15.2)	Asian	15 (6.5)
Q2 ($46-57k)	32 (13.9)	Arab American	23 (10.0)
Q3 ($58-79k)	56 (24.3)	Ethnicity	
Q4 ($80-157k)	107 (46.5)	Hispanic or Latino	19 (8.3)
ADI	51.2 ± 29.3 (1.0-100.0)	Non-Hispanic or Latino	211 (91.7)
ADI quartile		Insurance status	
Q1 (76-100)	63 (27.4)	Private/commercial	172 (74.8)
Q2 (51-75)	41 (17.8)	Public/government	51 (22.2)
Q3 (26-50)	74 (32.2)	None	3 (1.3)
Q4 (1-25)	52 (22.6)	Workers' compensation	1 (0.4)
Sex		Unknown	3 (1.3)
Male	136 (59.1)	Tobacco use	
Female	94 (40.9)	Current smoker	17 (7.4)
		Never smoker	191 (83.0)
		Former smoker	22 (9.6)

[a]Values are expressed as mean ± SD (range) or n (%). ADI, Area Deprivation Index; BMI, body mass index; MHI, median household income; Q, quartile; SDOH, social determinants of health.
[b]In 2020 US dollars.

for nonnormally distributed continuous variables (SDOH factors), and using chi-square tests or Fisher exact tests if expected cell counts were <5 for categorical variables. Statistical significance was set at $P \leq .05$. All analyses were performed using SAS Version 9.4 (SAS Institute).

RESULTS

Descriptive statistics for all variables are displayed in Table 1. The mean age of the cohort was 27 ± 11 years (range, 13-58 years), and 59% were male; 61% of patients were White, 23% Black, 7% Asian, and 10% Arab American. Patients with private health insurance made up 75% of the population while those with public insurance made up 22%; the remaining patients either had workers' compensation or were of unknown insurance status.

Black patients were represented more frequently in the lowest MHI quartile (Q1) compared with White patients (63% vs 23%, respectively; $P < .001$), whereas White patients were represented more frequently in the highest ADI quartile (Q4) when compared with Black patients (67% vs 12%, respectively; $P = .006$). Patients in the lowest ADI quartile (Q1) were represented significantly more in the lowest MHI quartile compared with patients in the highest ADI quartile (89% vs 0%, respectively; $P < .001$). Patients with public health care coverage were represented significantly more in the lowest ADI quartile when compared with the highest ADI quartile (51% vs 10%, respectively; $P = .002$). These results are depicted in Tables 2 and 3.

Black patients reported significantly higher preoperative PROMIS-D (50 vs 48, respectively; $P = .046$) and 6-month PROMIS-PI (54 vs 50, respectively; $P = .012$) compared with White patients. Patients in the lowest MHI quartile reported significantly higher preoperative PROMIS-PI (62 vs 59, respectively; $P = .029$) compared with those in the highest MHI quartile. Female patients reported significantly higher preoperative PROMIS-D (50 vs 46, respectively; $P < .001$), 6-month PROMIS-D (44 vs 42, respectively; $P = .023$), and 1-year PROMIS-D scores (44 vs 40, respectively; $P = .017$) compared with male patients. Current smokers reported significantly higher preoperative PROMIS-PI (64 vs 60, respectively; $P = .036$), lower 6-month PROMIS-PF (45 vs 49, respectively; $P = .007$), higher 6-month PROMIS-PI (57 vs 50, respectively; $P < .001$), and higher 6-month PROMIS-D scores (47 vs 42, respectively; $P = .049$) than nonsmokers.

Patients in the lower ADI quartile reported significantly higher preoperative PROMIS-D (51 vs 48, respectively; $P = .015$) and lower 1-year PROMIS-PF (53 vs 59, respectively; $P = .015$) scores than patients in the higher ADI quartile. Additionally, patients older than 18 years of age reported significantly lower 6-month PROMIS-PF (47 vs 52, respectively; $P < .001$), higher 6-month PROMIS-PI (52 vs 48, respectively; $P < .001$), and higher 1-year PROMIS-PI (49 vs 45, respectively; $P = .015$) scores than patients younger than 18 years.

Black patients attended fewer postoperative physical therapy visits compared with White patients (19 vs 28, respectively; $P < .001$). Patients in the highest MHI quartile had significantly more postoperative image encounters than those in the lowest MHI quartile (0.8 vs 0.6 encounters, respectively; $P = .002$). Male patients attended significantly fewer virtual encounters than female patients (2.7 vs 3.6 encounters, respectively; $P = .049$). Additionally, current smokers attended significantly fewer postoperative

TABLE 2
Univariate Associations Between Race and SDOH Factors[a]

Variable	White (n = 140)	Black (n = 52)	Asian (n = 15)	Arab American (n = 23)
Age, mean ± SD, y	27.7 ± 11.5	25.3 ± 9.7	27.5 ± 9.1	26.7 ± 9.0
BMI, mean ± SD, kg/m^2	26.1 ± 4.8[b]	29.7 ± 8.0[b]	24.1 ± 3.2[b]	28.0 ± 4.8[b]
MHI quartile				
Q1 ($21-45k)	8 (22.9)[b]	22 (62.9)[b]	0 (0.0)[b]	5 (14.3)[b]
Q2 ($46-57k)	20 (62.5)[b]	7 (21.9)[b]	1 (3.1)[b]	4 (12.5)[b]
Q3 ($58-79k)	37 (66.1)[b]	12 (21.4)[b]	3 (5.4)[b]	4 (7.1)[b]
Q4 ($80-157k)	75 (70.1)[b]	11 (10.3)[b]	11 (10.3)[b]	10 (9.3)[b]
ADI quartile				
Q1 (76-100)	28 (44.4)[b]	29 (46.0)[b]	0 (0.0)[b]	6 (9.5)[b]
Q2 (51-75)	24 (58.5)[b]	8 (19.5)[b]	4 (9.8)[b]	5 (12.2)[b]
Q3 (26-50)	53 (71.6)[b]	9 (12.2)[b]	5 (6.8)[b]	7 (9.5)[b]
Q4 (1-25)	35 (67.3)[b]	6 (11.5)[b]	6 (11.5)[b]	5 (9.6)[b]
Sex				
Male	73 (53.7)[b]	31 (22.8)[b]	13 (9.6)[b]	19 (14.0)[b]
Female	67 (71.3)[b]	21 (22.3)[b]	2 (2.1)[b]	4 (4.3)[b]
Insurance status				
Private/commercial	113 (65.7)	32 (18.6)	12 (7.0)	15 (8.7)
Public/government	24 (47.1)	17 (33.3)	2 (3.9)	8 (15.7)
None	2 (66.7)	1 (33.3)	0 (0.0)	0 (0.0)
Workers' compensation	0 (0.0)	1 (100.0)	0 (0.0)	0 (0.0)
Unknown	1 (33.3)	1 (33.3)	1 (33.3)	0 (0.0)
Tobacco use				
Current smoker	7 (41.2)	8 (47.1)	1 (5.9)	1 (5.9)
Never smoker	121 (63.4)	41 (21.5)	12 (6.3)	17 (8.9)
Former smoker	12 (54.5)	3 (13.6)	2 (9.1)	5 (22.7)

[a]Values are expressed as n (%) unless indicated otherwise. ADI, Area Deprivation Index; BMI, body mass index; MHI, median household income; Q, quartile; SDOH, social determinants of health.
[b]Denotes a statistically significant finding ($P \leq .05$).

office visits than nonsmokers (3.6 vs 5.1 encounters, respectively; $P = .005$). These results are displayed in Table 4.

DISCUSSION

The findings of this study indicate that specific SDOH, particularly those that reflect socioeconomic status and race, are associated with worse PROMIS CAT outcome scores and differential health care utilization after ACLR. Patients who were Black, female, in lower MHI quartiles, and in communities with higher ADIs, with public health care coverage, and smokers reported significantly worse PROMIS-PF, PROMIS-PI, and PROMIS-D scores at preoperative, 6-month, and 1-year postoperative time points when compared with their respective counterparts. Regarding postoperative health care resource utilization, Black patients attended significantly fewer postoperative physical therapy visits. Additionally, female patients attended significantly more postoperative virtual encounters than male patients.

Black patients reported significantly worse preoperative PROMIS-D and 6-month PROMIS-PI scores when compared with White, Asian, and Arab American patients. Preoperative depressive symptomatology could be attributed to the lack of function and increase in pain experienced after an ACL tear; however, these variables are not reflected by preoperative PROMIS-PF and PROMIS-PI metrics reported among Black patients. Perez et al[37] found that Black patients undergoing total knee arthroplasty (TKA) reported worse preoperative depression scores based on responses to the Geriatric Depression Scale. In orthopaedic surgery, racial disparities have also been shown to be a predictor of poorer clinical outcomes across a variety of procedures, including total hip arthroplasty (THA),[22,38] TKA,[19,38] trauma-related surgey,[12,29] shoulder arthroplasty,[15,52] and spine surgery.[21,45,46] However, additional socioeconomic factors may confound these conclusions. Two prior studies found no difference in Western Ontario and McMaster Universities Osteoarthritis Index pain and function scores among Black and White patients with TKA[16] and THA[20] living in areas with little poverty; however, Black patients fared far worse than White patients in areas of higher poverty. Since Black patients experience poverty disproportionately, which portends poorer outcomes after ACLR,[23,35] the origin of these observed disparities in ACLR outcomes remains obscure. Nevertheless, these results demonstrate that outcome disparities cannot be attributed to race alone but are rather multifactorial and must take into account multiple socioeconomic influences.

Within our study, Black patients with ACLR were highly represented in lower MHI quartiles, while also residing in communities with higher average ADIs compared with White, Asian, and Arab American patients. These patients

TABLE 3
Univariate Associations Between ADI Quartile and SDOH Factors[a]

Variable	ADI Q1 (n = 63)	ADI Q2 (n = 41)	ADI Q3 (n = 74)	ADI Q4 (n = 52)
Age, mean ± SD, y	26.5 ± 10.0	26.5 ± 10.9	27.4 ± 10.4	28.6 ± 11.6
BMI, mean ± SD, kg/m^2	28.4 ± 6.2	26.7 ± 4.4	25.9 ± 4.3	26.6 ± 5.4
MHI quartile				
Q1 ($21-45k)	31 (88.6)[b]	4 (11.4)[b]	0 (0.0)[b]	0 (0.0)[b]
Q2 ($46-57k)	19 (59.4)[b]	8 (25.0)[b]	4 (12.5)[b]	1 (3.1)[b]
Q3 ($58-79k)	12 (21.4)[b]	19 (33.9)[b]	23 (41.1)[b]	2 (3.6)[b]
Q4 ($80-157k)	1 (0.9)[b]	10 (9.3)[b]	47 (43.9)[b]	49 (45.8)[b]
Sex				
Male	37 (27.2)	26 (19.1)	46 (33.8)	27 (19.9)
Female	26 (27.7)	15 (16.0)	28 (29.8)	25 (26.6)
Race				
White	28 (20.0)[b]	24 (17.1)[b]	53 (37.9)[b]	35 (25.0)[b]
Black	29 (55.8)[b]	8 (15.4)[b]	9 (17.3)[b]	6 (11.5)[b]
Asian	0 (0.0)[b]	4 (26.7)[b]	5 (33.3)[b]	6 (40.0)[b]
Arab American	6 (26.1)[b]	5 (21.7)[b]	7 (30.4)[b]	5 (21.7)[b]
Insurance status				
Private/commercial	33 (19.2)[b]	30 (17.4)[b]	64 (37.2)[b]	45 (26.2)[b]
Public/government	26 (51.0)[b]	11 (21.6)[b]	9 (17.6)[b]	5 (9.8)[b]
None	1 (33.3)[b]	0 (0.0)[b]	1 (33.3)[b]	1 (33.3)[b]
Workers' compensation	1 (100.0)[b]	0 (0.0)[b]	0 (0.0)[b]	0 (0.0)[b]
Unknown	2 (66.7)[b]	0 (0.0)[b]	0 (0.0)[b]	1 (33.3)[b]
Tobacco use				
Current smoker	6 (35.3)	3 (17.6)	4 (23.5)	4 (23.5)
Never smoker	52 (27.2)	32 (16.8)	62 (32.5)	45 (23.6)
Former smoker	5 (22.7)	6 (27.3)	8 (36.4)	3 (13.6)

[a]Values are expressed as n (%) unless indicated otherwise. ADI, Area Deprivation Index; BMI, body mass index; MHI, median household income; Q, quartile; SDOH, social determinants of health.
[b]Denotes a statistically significant finding ($P \leq .05$).

with lower MHI harbored significantly worse preoperative outcomes, while patients with higher ADIs reported significantly worse preoperative and 1-year outcomes. The literature similarly demonstrates an association between lower socioeconomic status and inferior outcomes after ACLR. Jones et al[23] found that a lower neighborhood socioeconomic status was associated with worse International Knee Documentation Committee (IKDC) score, Knee injury and Osteoarthritis Outcome Score (KOOS), and Marx activity rating scale score for all measures completed by patients with ACLR. Patel et al[35] uncovered that pediatric patients with government-assisted insurance plans and from less affluent communities experienced delays in time to evaluation and treatment, higher rates of concomitant knee injuries on presentation, and increased postoperative complications. Similarly, we found that patients with ACLR with public health care coverage experienced worse preoperative PROMIS-PI, preoperative PROMIS-D, 1-year PROMIS-PF, and 1-year PROMIS-PI scores when compared with privately insured patients. When assessing public health care coverage or MHI as surrogates for socioeconomic status, our study confirms previous literature regarding the impact that socioeconomic status has on outcomes in orthopaedics. While these findings are multifactorial, these communities are deprived of financial resources and are significantly disadvantaged in the postoperative setting. Consideration of these variables may assist providers in identifying those with disadvantaged socioeconomic status and thereby increase focus and resource allocation to bring equity to these patients' outcomes. In the past, patients from lower socioeconomic communities have reported worse patient-reported outcome scores after TKA,[16,41] THA,[17,41] and primary shoulder arthroplasty.[50] Additionally, patients with lower household incomes experience poorer clinical outcomes after TKA[28] and spine surgery.[11]

In terms of postoperative resource utilization, Black patients attended significantly fewer physical therapy visits than their respective counterparts. These SDOH variables are intertwined with other barriers to adequate postoperative care, such as travel burden, fiscal obstacles, and social or familial support, all of which encompass a complex, multifactorial process.[42,51] Bram et al[10] found that Black and Hispanic pediatric patients attended fewer physical therapy visits after ACLR than White pediatric patients and, as a result, experienced significantly greater strength reductions 9 months postoperatively. These financial disadvantages create burdens that prevent patients from pursuing key postoperative elements such as therapy. Regaining strength and range of motion is especially important for athletes who want to return to competitive activity quickly.[25] Unfortunately, these socioeconomic disparities render it more difficult for patients to access postoperative resources beneficial to long-term outcomes. A lack of

TABLE 4
Impact of SDOH on Postoperative Resource Utilization[a]

Variable	Postoperative Office Visits	Postoperative PT Visits	Postoperative Virtual Encounters[c]	Postoperative Imaging Encounters[d]
MHI quartile				
Q1 ($21-45k)	4.4 ± 1.9	20.3 ± 9.4	3.6 ± 4.0	0.6 ± 0.9[b]
Q2 ($46-57k)	4.6 ± 1.4	27.4 ± 15.2	2.5 ± 2.8	0.3 ± 0.6[b]
Q3 ($58-79k)	5.1 ± 1.7	27.8 ± 13.3	2.7 ± 2.7	0.3 ± 0.7[b]
Q4 ($80-157k)	5.2 ± 2.0	25.7 ± 12.7	3.2 ± 3.5	0.8 ± 1.1[b]
ADI quartile				
Q1 (76-100)	4.8 ± 1.5	23.6 ± 12.8	2.8 ± 3.3	0.4 ± 0.8
Q2 (51-75)	4.7 ± 2.0	27.1 ± 14.2	2.7 ± 2.7	0.6 ± 1.0
Q3 (26-50)	5.1 ± 2.0	25.4 ± 10.4	3.2 ± 3.2	0.7 ± 1.1
Q4 (1-25)	5.1 ± 1.9	27.6 ± 14.1	3.3 ± 3.8	0.7 ± 0.9
Sex				
Male	4.8 ± 1.8	25.8 ± 12.0	2.7 ± 2.8[b]	0.6 ± 1.0
Female	5.2 ± 1.9	25.5 ± 13.8	3.6 ± 3.9[b]	0.6 ± 0.9
Race				
White	5.1 ± 1.9	27.9 ± 13.1[b]	2.9 ± 3.1	0.6 ± 0.9
Black	4.6 ± 1.8	19.1 ± 10.6[b]	3.9 ± 4.2	0.7 ± 1.0
Asian	5.1 ± 1.9	32.1 ± 12.9[b]	3.3 ± 2.7	0.7 ± 1.0
Arab American	4.8 ± 1.7	24.8 ± 9.9[b]	3.0 ± 3.3	0.3 ± 0.6
Insurance status				
Private/commercial	5.0 ± 1.9	26.4 ± 12.8	2.9 ± 3.2	0.6 ± 0.9
Public/government	5.0 ± 1.8	23.5 ± 12.1	3.6 ± 3.7	0.7 ± 1.0
None	4.3 ± 2.1	21.5 ± 29.0	1.3 ± 1.2	1.3 ± 0.6
Workers' compensation	2	—	1	0
Unknown	6.3 ± 1.5	26.0 ± 4.4	1.7 ± 2.1	0.3 ± 0.6
Tobacco use				
Current smoker	3.6 ± 1.2[b]	18.8 ± 12.4	2.5 ± 2.9	0.6 ± 0.9
Never smoker	5.1 ± 1.9[b]	26.4 ± 12.7	3.0 ± 3.2	0.6 ± 0.9
Former smoker	4.8 ± 1.5[b]	25.7 ± 12.7	4.1 ± 4.2	0.8 ± 1.2

[a]Values are expressed as mean ± SD. ADI, Area Deprivation Index; MHI, median household income; PT, physical therapy; Q, quartile; SDOH, social determinants of health. Dash indicates no data.
[b]Denotes a statistically significant finding ($P \leq .05$).
[c]Video visits, telephone encounters, and electronic medical record message encounters.
[d]Radiograph, ultrasound, computed tomography, and magnetic resonance imaging.

postoperative physical therapy may predispose patients with these SDOH to inferior functional and pain outcomes after ACLR.

Advancements in technology have led to an increase in virtual encounters and telemedicine as a means of communicating with orthopaedic patients.[13] Telemedicine offers streamlined communication between orthopaedic providers and their patients, while offering benefits with regard to patient convenience, costs, and maintenance of social distancing in light of the COVID-19 pandemic. As virtual care for postoperative monitoring becomes more prevalent in orthopaedics, it becomes important to understand how virtual resources are utilized and how they can improve care delivery for patients undergoing ACLR. The impact that SDOH have on the utilization of virtual clinic resources (video visits, telephone encounters, and EMR message encounters) has not been investigated in the field of orthopaedic surgery. The present study found that female patients utilized postoperative virtual encounters more than male patients. Other associations between SDOH and the utilization of postoperative virtual encounters, imaging encounters, and nonoperative procedures were not significant. These results are important, since the benefits of telemedicine may serve as an opportunity for equal access to postoperative orthopaedic care for patients with ACLR, regardless of socioeconomic background. Telemedicine has proven to be an efficient and cost-effective means of interacting with orthopaedic patients[32] while also reducing cost and travel burden for those in underserved communities.[18]

Early, appropriately timed surgical intervention is the preferred method for managing patients with deficient ACLs.[14] The goal of early intervention is to restore knee stability and limit the development of additional knee injuries. The findings of this study confirm that social and economic variables contribute to a complex, multifactorial process that drives function, pain, and depression outcomes as well as uptake of health care resources post-ACLR. It is important to consider the substantial burden placed on family members of the many diagnostic, operative, and postoperative appointments required during the treatment of an ACL tear. Several possible methods could be used to address the discrepancies shown in this paper, such as

increasing the use of telemedicine, improving physical therapy delivery methods, and implementing the aid of dedicated coordinators. The implementation of a care model in which dedicated coordinators aid patients with complex musculoskeletal disorders in navigating their pre- and postsurgical needs may be beneficial in helping patients at an increased risk for adverse ACLR outcomes to coordinate their medical appointments in a timely manner.

Limitations

The present study is not without limitations. The retrospective design of the study inherently relies on the accuracy and availability of previously reported variables. Certain variables, such as household income, were unavailable in the EMR and required estimation using patient ZIP codes, which may not accurately reflect all patients' incomes in a specific region. However, household income is not routinely reported in the EMR,[34] and therefore a narrowed geographic region such as ZIP code, as in this study, is often used to estimate income. Moreover, this study is limited by a large incompletion rate among its insurance status data. While these unknowns make it difficult to interpret these statistics, we feel that is still vital to examine and talk about these factors since they have been shown to affect ACL injury outcomes.[35]

Additionally, because of the limited reporting for each patient, the number of postoperative video visits, telephone encounters, and EMR message encounters were combined and reported collectively as postoperative virtual encounters. This generalized grouping may not accurately reflect the true effect that SDOH variables have on each form of postoperative encounter utilization. It is possible that certain groups may have more access to certain forms of communication than others. Furthermore, we cannot definitively ascertain why some patients were unable to use or had to cancel postoperative follow-up appointments. Therefore, further studies investigating the relationship between SDOH variables on specific forms of nonclinical visit follow-up after ACLR are required.

Moreover, only the English-language iteration of PROMIS CAT forms were distributed to patients with ACLR. English-only measures may preclude a significant group of people who may be adversely affected by these SDOH. Our study, however, included a broad and diverse spectrum of socioeconomic backgrounds that likely reflect underserved communities. To further generalize our results, future studies including multiple languages will be required. Finally, our study was performed at a single Midwestern multihospital tertiary care academic medical system, therefore limiting generalizability to the rest of the United States.

CONCLUSION

Specific SDOH variables, particularly those that reflect racial and socioeconomic disparities, are associated with differences in postoperative health care utilization and ACLR outcomes as measured by PROMIS CAT domains. Taking into account the SDOH of a patient with ACLR may help in improving outcomes and adherence to postoperative management.

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