UNIVERSITY OF CALIFORNIA SAN DIEGO

Racial and Ethnic Disparities in Total Knee Arthroplasty Utilization and Outcomes among Older Women

A dissertation submitted in partial satisfaction of the
requirements for the degree Doctor of Philosophy

in

Epidemiology

by

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The Dissertation of Alyson Marie Cavanaugh is approved, and it is acceptable in quality and form for publication on microfilm and electronically:

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TABLE OF CONTENTS

LIST OF ABBREVIATIONS

CMS-HCC	Centers for Medicare & Medicaid Services Hierarchical Condition Category
CPT	Current procedural terminology
FFS	fee-for-service
HHPT	home health physical therapy
ICD-9	International Classification of Diseases, Ninth Revision
IRF	inpatient rehabilitation facility
MVPA	moderate to vigorous physical activity
OA	osteoarthritis
OPPT	outpatient physical therapy
PF	physical function
PT	physical therapy
RA	Rheumatoid arthritis
SNF	skilled nursing facility
TKA	total knee arthroplasty

LIST OF TABLES

LIST OF FIGURES

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ABSTRACT OF THE DISSERTATION

Racial and Ethnic Disparities in Total Knee Arthroplasty Utilization and Functional Outcomes among Older Women

by

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Doctor of Philosophy in Public Health (Epidemiology)

University of California San Diego, 2019
San Diego State University, 2019

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Background: Black and Hispanic older adults with arthritis are less likely to receive total knee arthroplasty (TKA) than non-Hispanic Whites despite the effectiveness of the procedure. Disparities in functional outcomes after TKA have also been recognized. The mechanisms for disparities in utilization and functional outcomes remain unknown.

Methods: Data from 102,767 women enrolled in the Women's Health Initiative who had linked Medicare claims data were used to evaluate racial/ethnic disparities in TKA utilization and outcomes. Chapter 1 evaluated utilization rates after adjusting for need for TKA and medical access factors. Chapter 2 assessed physical function in the decades pre- and post-TKA by race/ethnicity. Chapter 3 evaluated racial disparities in post-TKA rehabilitation.

Results: Chapter 1: Black and Hispanic women were significantly less likely to receive TKA than non-Hispanic White women after accounting for need [Black: HR (95%CI)=0.70 (0.63-0.79); Hispanic=0.58 (0.44-0.77)]. Medical access factors had a modest effect on mediating disparities in utilization [Black: HR (95%CI)=0.75 (0.67-0.88); Hispanic=0.65 (0.47-0.89)]. Chapter 2: Among women who underwent TKA, Black women had significantly worse physical function for the entire decade pre-operatively compared with White women (mean difference=5.8 points, p-value<0.01) and had delayed surgery from the time of onset of mobility limitations. Poorer function pre-operatively largely explained racial disparities in functional outcomes post-TKA. Chapter 3: Black women, who had poorer function pre-operatively than White women, received more intensive rehabilitation services postoperatively. After accounting for differences in need for PT services, Black and White women appear to be equally as likely to continue rehabilitation after discharge home, through receipt of either home health or outpatient services.

Discussion: Neither need nor medical access explained why Black and Hispanic women underutilized TKA procedures compared with White women. Delays in receiving TKAs among Black women contribute to poorer functional improvement postoperatively. A better understanding of the decision-making process among surgical candidates is needed to ensure that women of minority race/ethnicity with arthritis receive appropriate treatment and in a timely

manner. Efforts to reduce postoperative functional outcomes should be focused pre-operatively at optimizing physical function for Black and Hispanic women with arthritis and improving timely receipt of TKA once need arises.

INTRODUCTION

Twenty years ago, the United States Congress commissioned a comprehensive evaluation of racial and ethnic disparities in healthcare. The evaluation culminated in a landmark report titled "Unequal Treatment: Confronting Ethnic and Racial Disparities in Health Care."[1] The report concluded that racial and ethnic minority groups in the United States receive a lower standard of healthcare and called attention to a need for more data and research to create a thorough and comprehensive approach for eliminating disparities.

While research of racial and ethnic disparities is greatly needed, theoretical and methodological challenges in evaluating disparities can complicate research efforts. The non-uniformity of the definition of disparities within scientific literature can contribute to varying measurement practices. For example, Healthy People 2010 defined disparities as: "all differences among populations in measures of health and health care are considered evidence of disparities,"[2] a definition subsequently adopted by the Agency for Healthcare Research and Quality (AHRQ).[3] The Institute of Medicine (IOM) offered a different interpretation, defining disparities as differences in health care that are not due to health needs or patient preferences(Figure I.1).[4] For this IOM definition, health indicators representing need and appropriateness for treatment must be accounted for, as a means to determine whether the healthcare system is equitably providing appropriate services among those with need. Other researchers argue that it is important to separate the effects of race/ethnicity from socioeconomic status (SES), as racial/ethnic disparities should not be a direct reflection of poverty or limited resources, which are disproportionately experienced by minorities. The complex relationship of race with social and economic determinants of healthcare utilization can create complications when attempting to separate the effects of medical access from the relationship of race and

healthcare utilization. There is a growing recognition that social and economic disadvantages, which might affect health and access to health care, can occur throughout the lifetime, and at multiple levels and throughout multiple domains.[5] The best methodology for handling determinants of medical access and healthcare utilization when measuring disparities has been highly debated.[6] However, a central theme has emerged that a carefully designed conceptual framework of the relationship of such factors of healthcare access and utilization must be developed to improve our understanding of the mechanisms and pathways that lead to racial/ethnic disparities.[7]

Racial/Ethnic Disparities in Total Knee Arthroplasty

In "Unequal Treatment: Confronting Ethnic and Racial Disparities in Health Care," substantial evidence was presented that patients of minority race and ethnic groups were less likely to receive recommended evidence-based diagnostic and treatment procedures.[1] Total knee arthroplasty (TKA) is one such evidence-based treatment procedure where significant racial and ethnic disparities in utilization have been documented.[8–10] Considered an effective treatment for end-stage knee arthritis, TKA can provide considerable improvements in pain, mobility, and quality of life, but has been underutilized in Black and Hispanic populations.[11–13] While the use of the procedure has exponentially increased among the American population over the last few years,[14] the racial/ethnic gap in TKA utilization has not only failed to narrow but instead has widened over time.[15,16] This failure to close the gap has occurred in spite of the fact that several prominent groups and agencies, including the Institute of Medicine, the U.S. Department of Health and Human Services, and the American Academy of Orthopedic Surgeons, have issued agendas and plans to reduce the disparities.[2,17–19] In recent years, rising attention to patient-reported outcomes has brought recognition that, in addition to disparities in utilization,

racial/ethnic disparities in outcomes after TKA exist.[20] While racial/ethnic disparities in post-arthroplasty outcomes are less studied than utilization, available evidence suggests non-White populations have higher rates of complications and poorer function following surgery.[16,21–26]

Understanding the Mechanisms for Disparities in TKA utilization

Healthcare administration claims data have been used to measure disparities and to track progress over time.[15,16,27] Many studies using administrative claims data have compared crude and/or age-adjusted differences in utilization rates between racial/ethnic groups (See Table I.1). Several landmark publications using this approach have been instrumental in bringing awareness to the widening gap in TKA utilization.[15,16] The use of crude or age-adjusted incidence rates to measure disparities is in accordance with the definition by Healthy People/AHRQ, which considers any differences between racial/ethnic groups as evidence of disparities. This methodology is useful in providing an absolute measure of differences between racial/ethnic groups, yet it is important to recognize these measurements do not account for intergroup differences in need for the procedure. While this methodology can be used to monitor progress over time, a more intricate methodology is needed to improve our understanding of the mechanisms and reasons underlying such disparities.

Need and Appropriateness for TKA

The IOM definition of disparities may arguably be better suited to assess disparities in TKA utilization due to inequity of healthcare system. In accordance with the IOM definition, need and appropriateness to receive TKA must be accounted for when measuring disparities in TKA utilization (Figure I.1). While healthcare administration claims are valuable data sources for evaluating disparities in TKA utilization due to their large sample size and generalizability to

a greater population, these data sources present challenges when attempting to identify need/appropriateness for TKA. Relying on medical diagnosis and procedure coding available within administrative claims may be confounded by intergroup differences in healthcare-seeking behaviors.[28] Thus, determining need through administrative claims can be problematic, as some minority groups may be less likely to seek medical care and receive a diagnosis of arthritis. In addition, while diagnostic codes can be used to identify arthritis, the severity of joint disease or symptoms cannot be easily determined through claims data. Despite these drawbacks, some researchers have tried to use a combination of diagnostic and procedure codes in attempts to identify need within healthcare claims data. For example, Jones et al.[29] used diagnostic codes for osteoarthritis (OA) in combination with rheumatology and orthopedic specialist visit code to serve to indicate need when measuring TKA utilization rates in Veterans Administration claims data. This methodology to determine need was not without limitations. The anatomic location of arthritic disease was not able to be determined through the International Classification of Diseases, Ninth Revision (ICD-9) code that was used to identify subjects with osteoarthritis (OA), and the specialist visit served as a crude proxy for severity of OA. Nevertheless, the researchers used the available data to improve our understanding of how need affected disparities in utilization. The study found that African American VA beneficiaries were less likely to undergo TKA than Whites, with no changes in the measured relative disparities when restricting the sample of VA beneficiaries to the subsample of beneficiaries with need.[29]

Cohort data can offer some advantages when attempting to identify need and appropriateness for TKA. Yet, to date, few cohort data sources have been used to evaluate racial/ethnic disparities in TKA utilization. The Health and Retirement Study (HRS) and the Asset and Health Dynamics among the Oldest Old (AHEAD) cohort, nationally-representative

panel surveys of older adults aged 50 years and older (HRS) and adults 70 and older (AHEAD), have been used by several researchers in evaluating disparities in joint surgeries.[30–33] Using these data sources, a more precise indication of need is possible due to the availability of data on self-reported joint pain, use of medicine or treatment for arthritis, functional mobility limitations, and diagnoses of arthritis.[30–33] In the studies published to date using the HRS/AHEAD data, consistent findings have been presented that Black men and women were significantly less likely than their White counterparts to undergo TKA, after accounting for health factors representing need.[30–32] The studies have offered conflicting findings on comparisons of Hispanics and non-Hispanic whites. Hanchate et al.[32] reported significantly lower utilization of knee surgeries in Hispanic women compared with non-Hispanic whites, whereas Dunlop et al.[31] failed to find a significant difference in utilization when comparing the composite outcome of knee and hip joint surgeries between Hispanic and White adults. Some limitations were encountered because of the relatively smaller sample size of HRS/AHEAD, particularly in the Hispanic population, which may have affected power to detect differences.[32] Categorizations of race/ethnicity that combined multiple race/ethnicities were used in two of the studies. Steel et al.[33] used comparisons of White versus Other, and Dunlop et al.[30] used a composite comparison group of Black and Hispanic adults versus White adults. Because the need for and the utilization of TKA likely varies between minority racial groups, combining multiple groups may mask true differences in TKA utilization between various minority groups and Whites. Additionally, in two out the four studies published to date using HRS/AHEAD data, surgeries of the hip and knee were combined for the outcome of interest.[30,31] However, disparity measurements may differ between the two joints,[16] thus biasing the findings. While the use of this nationally representative sample allowed for a more precise mechanism for determining need, the smaller size of the sample has presented challenges

in an ability to specifically evaluate the topic of disparities in TKA utilization between Black, Hispanic, and White older adults.

The Osteoarthritis Initiative (OAI), an observational study of adults with OA or at risk for OA, has also been used as a data source in evaluating disparities in TKA utilization. Data from radiographs, clinical examination, and subjective symptom reporting are available within the OAI study and have been used to classify need for TKA when evaluating disparities.[34] In a study by Collins et al.,[34] non-White older adults were significantly less likely than Whites to undergo TKA, after accounting for severity of TKA and appropriateness of TKA, based on radiographic evidence of joint damage, pain reporting, body mass index (BMI), and comorbidities. While to date, the OAI data source has provided the most detailed and accurate indication for need for TKA, the aforementioned study categorized race/ethnicity into White and non-White groups, thus preventing specific racial/ethnic group comparisons. In addition, it is important to recognize the potential of selection bias within this longitudinal study focused on arthritis, as participants participating in such a study may not represent the general population of older adults with arthritis.

Identifying need and appropriateness for TKA for the purpose of measuring disparities according to the IOM definition poses challenges. When the specificity of classification improves, the generalizability of the population may decrease. Larger data sets, while offering more generalizability, often require crude approximations for determining need.

Patient Preference

TKA is an elective surgical procedure, and thus patient preference for surgery has an obvious impact on utilization. According to the IOM definition, differences in patient preference

for TKA must be accounted for, as these differences should not contribute to the actual measurement of disparities. Identifying variables of patient preference for TKA can be problematic, as no such variables are routinely collected in healthcare administrative data or national cohort studies. The majority of research on patient preference to date has relied on interviews, focus groups, or survey studies, which focus on reported willingness to undergo TKA, knowledge of the procedure, and perceived risks/benefits.[35–37] Complicating the ability to understand the role of patient preference with observed disparities is the question whether willingness to undergo TKA is truly a preference, arising from cultural beliefs or values, or instead is a failure of the healthcare system to adequately educate and inform. For example, while Black patients are more likely than Whites to report unwillingness to undergo TKA, they are also less likely to understand the details of the operation and are less likely to know a friend or family member who has undergone joint arthroplasty.[35,36] Black adults report higher perceived risks of surgery, have lower expectations of benefit, and expect longer hospitalization after TKA.[35,38] Hispanic patients have similarly been found to have lower scores on knowledge of arthroplasty procedures and reported lower expectations from surgery.[39] While research to date demonstrates differences in willingness to undergo TKA by race/ethnicity, the extent that this is due to health literacy, misinformation, or unfamiliarity with the procedure is not clear.

Medical Access to TKA

Minorities are more likely to experience socioeconomic disadvantage than Whites, which may contribute to differences in healthcare utilization.[40] Understanding the relation of medical access and disparities in utilization is necessary to develop strategies to reduce such disparities. Similar to complications with identifying need, challenges exist in the identification of medical access factors. For example, healthcare administration data, commonly used in researching this

topic, is void of individual-level SES information, with the exception of identifying dual-eligibility of Medicare-Medicaid. Some researchers have attempted to investigate the role of SES with disparities using healthcare administration data by using regional income information linked to the beneficiary's zip code.[27,41] Skinner et al.[41] adjusted for census-level median regional income when investigating Medicare data claims and reported that Hispanic men, Black men, and Black women remained significantly less likely than their White counterparts to undergo TKA. Bang et al.[27] using the National Inpatient Sample reported similar findings that Black and Hispanics were less likely to receive TKA after accounting for medical regional income.

Use of cohort data offers certain advantages in the ability to more thoroughly measure and therefore decompose the effects of medical access factors on racial/ethnic disparities in TKA utilization. HRS/AHEAD data has collected detailed individual-level economic data that has been used by various researchers to strengthen our understanding of how medical access factors affect disparities.[30–33] Comparison of measurements of income, wealth, education, working status, comprehensiveness of insurance coverage revealed that Black and Hispanic older adults overall possessed fewer resource than Whites.[30–32] However, studies using HRS/AHEAD data have offered some conflicting findings of how lower socioeconomic position impacts disparities. Steel et al.[33] found disparities in racial utilization of hip and knee surgeries persisted after adjustment for differences in SES, using Black versus White comparisons. Dunlop et al.[31] similarly found that disparities persisted with Black-White comparisons after adjustment for medical access, but failed to find significant differences in utilization when comparing Hispanic and non-Hispanic whites, with or without adjustment of medical access. A study by Hanchate et al.[32] found sex-specific effects of medical access on disparities, reporting that differences in TKA utilization were attenuated and no longer significantly different between Black, Hispanic,

and White women after adjustment for medical access factors. However, disparities between Black and White men persisted.[32]

Current Gaps in Knowledge

While racial/ethnic disparities in TKA utilization have been recognized for several decades, there are still gaps in our understanding of the topic. Because of the complexity in measuring disparities and decomposing the reasons for such disparities, there is still much to learn about how health, function, and medical access to the procedure affects disparities in TKA utilization. From available evidence to date, it appears that need for TKA does not explain underutilization of the procedure by Black adults.[29,31,32] However, only two studies to date have evaluated utilization of joint surgeries specifically in Hispanic populations offering conflicting results of whether disparities in utilization persist after accounting for need.[31,32] The impact of SES on racial disparities may have sex-specific effects. Medical access factors may have a larger impact on underutilization of TKA in minority women than it does it minority men, but the effect of medical access on disparities by sex and race/ethnic groups have only been addressed in one study to date.[32] Furthering our understanding of how need and SES impacts utilization requires an approach that accounts for potential differences in mechanisms for disparities that vary by sex and racial/ethnic group.

Understanding Disparities in Functional Outcomes after TKA

Compared to utilization, far less information is available to guide our understanding of the reasons for racial disparities in functional outcomes. Several hypotheses to explain the existence of disparities in functional outcomes can be postulated, but limited evidence to support them currently exists. One proposed rationale for disparities in functional outcomes involves

differences in physical function prior to surgery. Pre-operative physical function is known to be one of the strongest predictors of outcomes postoperatively,[42,43] and, on average, Blacks and Hispanics have poorer pre-operative function compared to non-Hispanic whites.[25,44] It has been theorized that Black and Hispanic populations delay TKA utilization from the time of onset of mobility limitations, thus presenting with worse physical function at the time of surgery.[45] However, limited information exists that quantifies delays to surgical intervention. The majority of research in functional outcomes of TKA is conducted using single institution studies or retrospective medical records analyses, thus restricting the ability to determine the time from actual onset of pain/disability until surgical intervention. One study by Kamath et al.[46] estimated delays to orthopedic surgeon visit for patients who eventually received TKA by relying on patient recall. The study found that Black men had reported waiting nine months longer until orthopedist visit and Black women 21 months longer than White men and women respectively.[45] The authors concluded that poorer range of motion and function in Black women after TKA was likely attributable to the delayed presentation to the orthopedist specialist.[46]

Another plausible rationale for disparities in functional outcomes is that minority patients have a higher likelihood of receiving TKAs from low-volume surgeons and institutions.[47,48] The use of low-volume surgeons/hospitals can result in a higher complication rate and worse medical outcomes.[49,50] The relationship of low-volume surgeons/institutions with racial and ethnic disparities in functional outcomes has not yet been thoroughly evaluated, but emerging evidence suggesting worse functional outcomes may result from TKAs received at low-volume surgeons/hospitals.[51]

A third conceivable reason for disparities in postoperative function includes differences in receipt of post-surgical rehabilitation care. Race has been shown to be a significant predictor

of post-acute discharge destination (inpatient rehabilitation facility, skilled nursing facility, or home) following TKA.[52–54] Evaluations of racial disparities in post-acute discharge destination have not linked rehabilitation setting with function, and, thus, the relationship of post-acute discharge setting with disparities in functional outcomes remains unknown. While post-acute destination setting is one component of patient recovery, rehabilitation after TKA is a continuum that can include multiple pathways and additional services. Receipt of home health and outpatient rehabilitation services are also important to consider. Rehabilitation care may influence a patient's motion, strength, and mobility, thus playing a major role in functional outcomes, yet limited knowledge regarding racial/ethnic utilization of rehabilitation care currently exists.

Current Gaps in Knowledge

The mechanisms for racial disparities in functional outcomes after TKA are unknown, and the topic has been relatively understudied. While several reasons for these disparities can be hypothesized, limited evidence exists to support these suppositions. Further research into the effects of delayed surgical intervention, level of expertise of surgeon and medical center, and intensity of postoperative rehabilitation care on disparities in functional outcomes is needed.

Purpose and General Methods

This dissertation aims to further explore the reasons why racial/ethnic disparities in utilization and functional outcomes of TKA exist among older adult women. Because the mechanisms for disparities in TKA utilization appear to differ by sex, restricting the focus to women allows for a better understanding of the factors that affect utilization and outcomes specific to this group. Older women are the demographic most likely to need and receive a

TKA.[55] Because women are likely to outlive their spouse and live alone with advanced age,[56] the optimization of function for those suffering from end-stage arthritis may be an important consideration for independence and quality of life with aging.

Prospectively collected data from the diverse population of the Women's Health Initiative (WHI) with linked Medicare claims data provide a unique opportunity to explore individual-level demographic, socioeconomic status, health, and medical characteristics when investigating racial/ethnic disparities in use and outcomes after TKA. WHI is an ongoing prospective study that recruited 161,808 post-menopausal women from 40 clinical centers throughout the United States from 1993-1998.[57,58] Women representing minority racial and ethnic groups were recruited to proportionately represent the US population of 50-79-year-old women and include 17% of the total WHI sample. The WHI data source includes prospectively collected information on the presence and magnitude of joint pain, as well as self-reported physical function with specific questions on independence with daily mobility measures. Medicare claims data are linked to consenting WHI participants and allow for investigation of health conditions, TKA procedures, medical complications, and rehabilitation utilization. While past studies on the topic have largely used either health administrative claims or cohort data, the linked data source used in this dissertation research provides rich data for the investigation of characteristics influencing racial/ethnic gaps in use or benefit from the TKA procedure.

This dissertation aims to build on existing evidence regarding racial/ethnic disparities in TKA use and functional outcomes and hopes to fill knowledge gaps that have persisted despite the long-standing recognition of the problem. The purpose of this dissertation is to improve understanding of the mechanisms of racial/ethnic disparities in TKA utilization and functional

outcomes, with an ultimate goal of developing and implementing effective strategies to eliminate such disparities.

Chapter 1 of this dissertation examines racial and ethnic disparities in TKA utilization among older women with relation to demographic, health, and socioeconomic status characteristics. Because the majority of research to date on disparities in TKA utilization has relied on healthcare administrative data alone, gaps exist in our understanding of how characteristics including social and economic resources and severity of arthritic symptoms affect the measurements of disparities. A conceptual model adapted from the IOM definition of disparities provided the framework for the measurement of disparities within this chapter (Figure I.1). Utilization rates between racial/ethnic groups were compared within a population of women with need and appropriateness for TKA in accordance with the IOM definition. Individual-level SES data were used to understand the mediating effects of medical access on disparities in utilization. This chapter adds to our understanding of how the severity of pain and mobility restriction, as well as SES impacts disparities in utilization.

Chapters 2 and 3 focus on explanations for why disparities in functional outcomes occur after TKA. In Chapter 2, physical function trajectories during the decade prior to and following TKA by race are presented, derived from prospectively collected data on physical function and activity limitations. Figure I.2 presents the conceptual framework of the hypothesis under evaluation that pre-operative function contributes to differences in postoperative function. While it has been speculated that poorer pre-operative function resulting from delayed surgical intervention among minorities may contribute to poorer functional performance after TKA,[45] the use of single-institution joint registry studies or retrospective medical records analyses limits the

ability to quantify delays or determine the duration of mobility limitations. The use of prospectively collected information from this community-dwelling population affords a more complete representation of pre-operative function, offering insight into physical function well before an individual might present to a medical provider.

Chapter 3 further contributes to our understanding of why racial disparities in functional outcomes exist by evaluating postoperative rehabilitation utilization. Underutilization of rehabilitation services post-TKA could contribute to poorer functional improvement.[59] While underutilization of rehabilitation by minorities has been documented for diagnoses of stroke, brain injury, cardiac events, hip fracture, and spinal cord injury,[60–62] limited evidence exists regarding racial disparities in rehabilitation following TKA. Chapter 3 presents information as to the intensity of post-TKA physical therapy (PT) services received by racial groups, evaluating the full continuum of rehabilitation care from institutional facility services, home health PT, through outpatient PT services. Continuity of rehabilitation after discharge home may be an important factor in optimizing functional improvement.[59] Limitations in medical access or the presence of provider bias could affect continuity of rehabilitation care, thereby limiting functional improvements in minority patients. A conceptual diagram demonstrating the relationship of race with continuity of rehabilitation services is presented in Figure I.3. The diagram represents the presence of Black patients' exposure to systemic, direct, and indirect forms of discrimination throughout multiple time points, thus contributing to poorer pre-operative health, higher incidence of medical complications with surgery, and differences within post-acute discharge placement, all factors which may indicate a greater need for additional PT services after discharge home. Chapter 3 contributes novel information to the topic of disparities in functional outcomes, with regards to differences in patterns in post-TKA rehabilitation

utilization by race, as well as the effects of race on continuity of rehabilitation care after discharge home from TKA.

In summary, limitations in our understanding of why TKA disparities in utilization and functional outcomes currently exist. A more complete understanding of the reasons for racial/ethnic disparities can be achieved through the analyses of individual-level health, medical, and SES characteristics that are available within the diverse population of community-dwelling older adult women followed through WHI.

Table I.1: Summary of literature examining racial and ethnic disparities in TKA utilization

Author (year)	Data Type	Data Source	Outcome	Medical Access	Need and Appropriateness for TKA	Black vs. White comparisons	Hispanic vs. White comparisons	Other comparisons
Bang (2010)[27]	Administrative	National Inpatient Sample	Primary and revision TKA	median regional income	hospital discharge data used to determine comorbidity and obesity	OR=0.35 (0.31-0.40) Adjusted for age, sex, payer, hospital ownership, setting, comorbidity, and obesity in subset of adults 65 years and older	OR=0.40(0.32-0.50)	Other vs. White: OR=0.69 (0.47-1.02) Missing vs. White: OR=1.01 (0.89-1.14)
Chen (2013)[63]	Administrative	National Inpatient Sample	Primary TKA	median regional income	hospital discharge data used to determine comorbidity based on ICD-9	*OR=0.76, p<.01 Adjusted for age, sex, comorbidity, income, admission and hospital characteristics *Utilization rates assessed using denominator of patients with ICD-9 code indicating arthritis during hospitalization	*OR=0.66, p=0.07	
Cisternas (2009)[64]	Administrative	Medicare	Primary TKA	No	No	Unadjusted rate differences: In 2000: Women = 1.4/1,000 Men = 3.1/1,000 In 2006: Women = 2.9/1,000 Men = 4.7/1,000		
Collins (2016)[34]	Cohort	OAI		No	radiographic evidence of joint damage, pain, BMI, comorbidity	Adjusted for radiographic evidence of severity of joint damage, pain, BMI, and comorbidities		Non-White vs. White RR=0.43 (0.26-0.71)

Table I.1: Summary of literature examining racial and ethnic disparities in TKA utilization (continued)

Author (year)	Data Type	Data Source	Outcome	Medical Access	Need and Appropriateness for TKA	Black vs. White comparisons	Hispanic vs. White comparisons	Other comparisons
Dunlop (2003)[30]	Cohort	AHEAD	Hip or knee arthroplasty	Education, wealth, income, health insurance status	arthritis, activity limitations, comorbidity	Adjusted for variables of age, sex, need for TKA, and medical access within a subsample of adults with arthritis		Black and Hispanic vs. White OR=0.48 (0.21-1.08)
Dunlop (2008)[31]	Cohort	HRS	Hip or knee surgery	education, wealth, income, health insurance status	arthritis, activity limitations, obesity, comorbidity, disability, physical activity	HR=0.40 (0.19-0.58) Adjusted for age, sex, need for TKA, and medical access in subsample of adults 65 years and older	HR=0.87 (0.16-2.10)	
Hanchate (2008)[32]	Cohort	HRS	TKA	education, wealth, employed, health insurance	comorbidity, functional limitations	Women: OR=0.94(0.67-1.31) Men: OR=0.65(0.38-1.11) White women: OR=1.0 (ref) Adjusted for health and medical access within a subsample of adults with arthritis	Women: OR=0.94 (0.57-1.54) Men: OR=1.39 (0.83-2.33) White women: OR=1.0 (ref)	
Jha (2005)[15]	Administrative	Medicare	Primary TKA	No	No	Age-adjusted rate differences: In 1992: Women=0.85/1000 Men =1.10/1000 In 2001: Women=1.51/1,000 Men =3.20/1,000		

Table I.1: Summary of literature examining racial and ethnic disparities in TKA utilization (continued)

Author (year)	Data Type	Data Source	Outcome	Medical Access	Need and Appropriateness for TKA	Black vs. White comparisons	Hispanic vs. White comparisons	Other comparisons
Jones (2005)[29]	Administrative	VA	Primary TKA	No	OA diagnosis, orthopedist or Rheumatology consult	OR=0.72 (0.63-0.81) Adjusted for age, sex, and comorbidity within subsample of need for TKA		
Singh (2014)[16]	Administrative	Medicare	Primary TKA	No	No	Age- and sex-standardized rate differences: In 1991: 1.15/1,000 In 2008: 2.53/1,000		
Skinner (2003)[10]	Administrative	Medicare	Primary TKA	median regional income, level of racial segregation	No	Age-standardized rate difference: Women=1.13/1,000 Men =2.98/1,000 Income and segregation mitigated disparities differently by sex	Women=0.40/1,000 Men =1.36/1,000	
Skinner (2006)[41]	Administrative	Medicare	Primary TKA	Median regional income	No	Black women: OR=1.19 (1.16-1.22) White women: OR=1.35 (1.33-1.37) Black men: OR=0.42 (0.39-0.44) White men: OR=1.0 (ref) Adjusted for age, income, and region	Hispanic women: OR=1.28 (1.21-1.36) White women: OR=1.35 (1.33-1.37) Hispanic men: OR=0.80 (0.73-0.87) White men: OR=1.0 (ref)	
Steel (2008)[33]	Cohort	HRS	Hip or knee surgery	education, wealth	Functional limitations, arthritis dx., activity-limiting arthritis, joint pain/stiffness, medication/ treatment for arthritis	OR=0.47 (0.26-0.83) Adjusted for age, sex, medical access, obesity with subsample of adults with need for TKA		OR=0.53 (0.16-1.77)

Abbreviations: TKA: total knee arthroplasty, OAI: Osteoarthritis Initiative, AHEAD: Assets and Health Dynamics among the Oldest Old, HRS: Health and Retirement Study; VA: Veteran's Health Administration, dx.: diagnosis

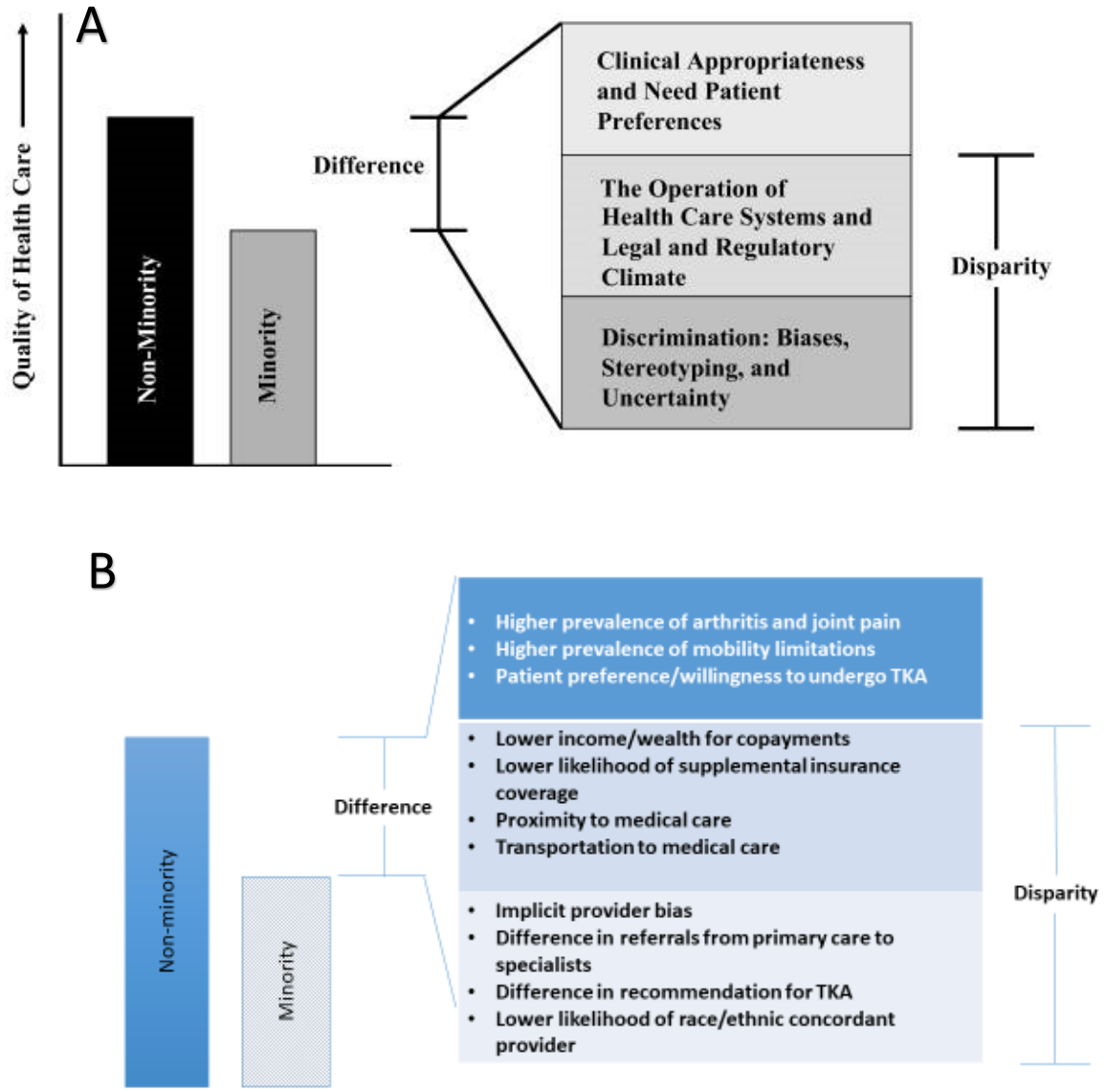

Figure I.1: Conceptual model for measuring racial/ethnic disparities in TKA utilization

A) Source: The Institute of Medicine (IOM 2003, p. 4) Definition of Racial/Ethnic Healthcare Disparities

B) Adaptation of IOM model applied to measurement of racial/ethnic disparities in TKA utilization

Figure I.2: Conceptual model for relationship of race/ethnicity, pre-operative and postoperative physical function

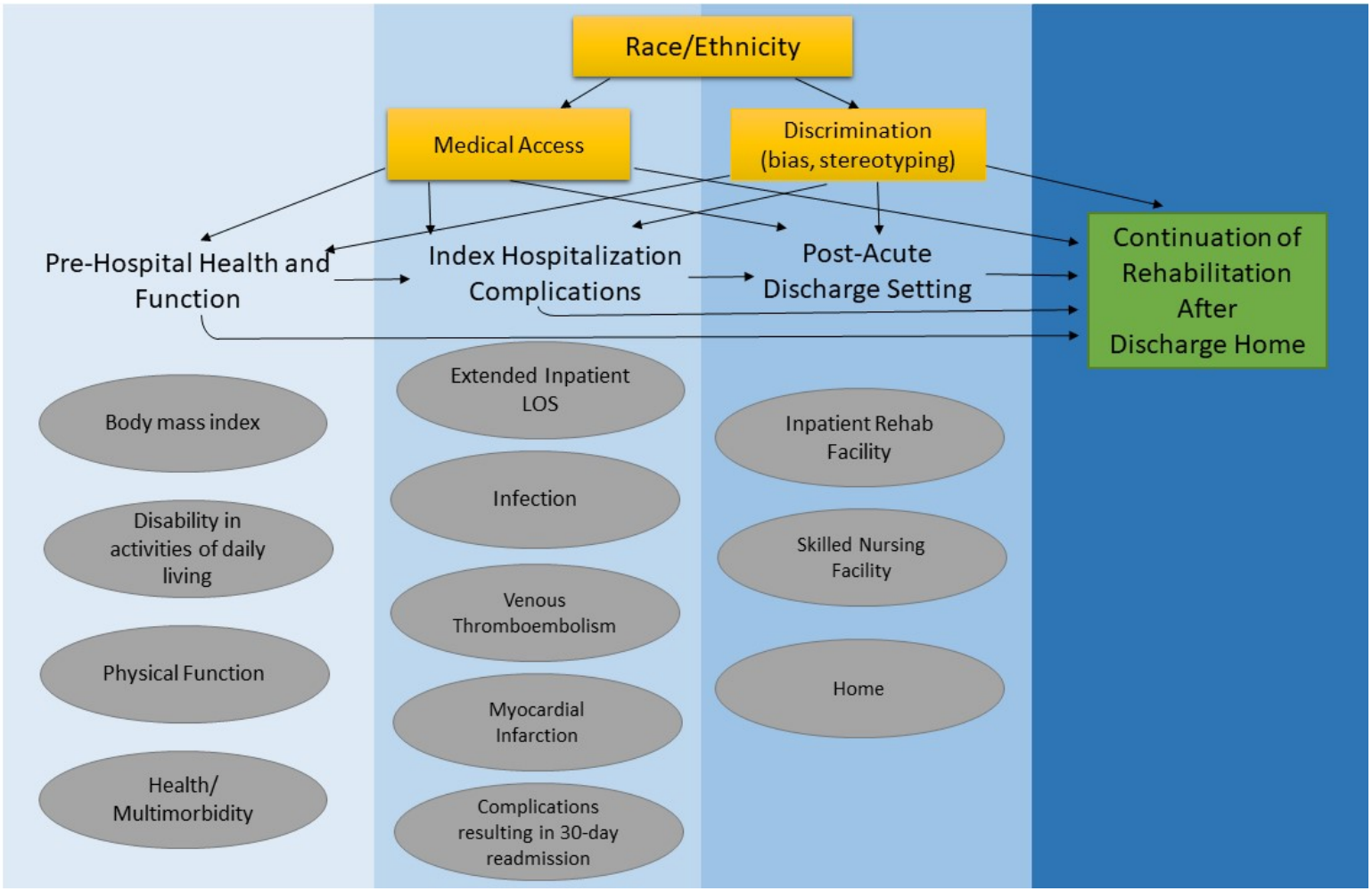

Figure I.3: Conceptual model for evaluation of racial disparities in post-TKA rehabilitation utilization

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CHAPTER ONE

Racial and Ethnic Disparities in Utilization of Total Knee Arthroplasty among Older Women

ABSTRACT

Objective: To evaluate racial and ethnic disparities in utilization of total knee arthroplasty (TKA) in relation to demographic, health, and socioeconomic status variables.

Design: Prospective study of 102,767 Women's Health Initiative postmenopausal women initially aged 50-79, examining utilization rates of primary TKA between non-Hispanic Black/African American, non-Hispanic White, and Hispanic/Latina women (hereafter referred to as Black, White, and Hispanic). A total of 8,942 Black, 3,405 Hispanic, and 90,420 White women with linked Medicare claims data were followed until time of TKA, death, or transition from fee-for-service coverage. Absolute disparities were determined using utilization rates by racial/ethnic group and relative disparities quantified using multivariable hazards models in adjusting for age, arthritis, joint pain, mobility disability, body mass index, number of comorbidities, income, education, neighborhood socioeconomic status (SES), and geographic region.

Results: TKA utilization was higher among White women (10.7/1,000 person-years) compared to Black (8.5/1,000 person-years) and Hispanic women (7.6/1,000 person-years). Among women with health indicators for TKA including diagnosis of arthritis, moderate to severe joint pain, and mobility disability, Black and Hispanic women were significantly less likely to undergo TKA after adjusting for age [Black: HR(95% confidence interval) =0.70 (0.63-0.79); Hispanic:

HR=0.58 (0.44-0.77)]. Adjustment for SES modestly attenuated the measured disparity, but significant differences remained [Black: HR=0.75 (0.67-0.89); Hispanic: HR=0.65 (0.47-0.89)].

Conclusions: Compared to White women, Black and Hispanic women were significantly less likely to undergo TKA after considering need and appropriateness for TKA and SES. Further investigation into personal-level and provider-level factors that may explain these disparities is warranted.

Key words: joint replacement, African American, Hispanic, arthritis, Medicare

INTRODUCTION

Total knee arthroplasty (TKA) is considered a cost-effective treatment for severe arthritis of the knee and can lead to improvements in physical function and quality of life.[1–3] Despite the known benefits of TKAs, racial and ethnic minority groups have significantly lower utilization rates of the procedure.[4–6] The reasons and underlying mechanisms remain to be identified.

Disparities in TKA utilization have been documented using healthcare administration data, where crude or age-adjusted rates have demonstrated significant differences in TKA utilization among racial/ethnic groups in the enrolled population.[4–6] However, these data sources fail to account for differences in need or appropriateness for the procedure, including severity of arthritis or activity limitation. In addition, racial/ethnic disparities involve a complex relationship of social and economic determinants, which impact healthcare utilization patterns. Despite the strong association between socioeconomic status (SES) and healthcare utilization, relatively few studies have investigated the influence of individual-level socioeconomic factors on racial/ethnic disparities in TKA utilization.[7,8]

This study examined disparities in rates of TKA utilization between non-Hispanic Black, non-Hispanic White, and Hispanic/Latina women enrolled in the Women's Health Initiative (WHI). WHI is a prospective study that recruited post-menopausal women from 40 clinical sites across the United States. Racial/ethnic disparities in rates of TKA utilization were examined adjusting for demographic, health, and socioeconomic status variables, including variables of need for and access to the surgery.

METHODS:

Participants:

This study used prospectively collected data from the WHI controlled trials (CT) and observational studies (OS). The WHI design is described in detail elsewhere.[9,10] Briefly, 161,808 post-menopausal women, aged 50-79, were recruited from 40 clinical centers in the United States, between October 1993 and December 1998. Participants were followed until study close in 2005, at which time surviving women were invited to participate in a series of WHI extension studies that have continued through today. Written informed consent was obtained from each study participant, and procedures were approved by institutional review boards at all participating institutions. Medicare enrollment and claims data have been linked to consenting WHI participants.

Women enrolled in WHI with linked Medicare fee-for-service (FFS) data were included in this study population (Figure 1.1). The sample was restricted to women who self-identified with one of three mutually exclusive racial/ethnic groups: non-Hispanic white, non-Hispanic black/African American, and Hispanic/Latino, hereafter referred to as White, Black, and Hispanic, respectively. We excluded participants whose original reason for Medicare eligibility was disability benefits or end-stage renal disease (ESRD). Women with prior TKA were excluded, as determined by self-report at WHI enrollment of a history of total joint replacement (other than hip). For women over age 65 at WHI enrollment, FFS claims indicating TKA prior to date of WHI enrollment were also used to identify prior TKA. Participants without Part A FFS coverage at WHI enrollment (for women over age 65) or who did not have Part A FFS coverage when they aged into Medicare (for women under age 65 at time of WHI enrollment) were excluded.

Determination of TKA

Primary TKA procedures were identified using the Ninth Revision of the International Classification of Diseases (ICD-9-CM) primary procedure code 81.54 in Medicare Provider Analysis and Review (MEDPAR) files and inpatient Medicare files. For participants with more than one TKA procedure during the study period, only the first procedure date was used.

Independent Variables

Age, race/ethnicity, income, and highest educational attainment were ascertained by questionnaire at WHI enrollment. Race/ethnicity was categorized into three mutually exclusive groups according to the race/ethnicity with which the participant reported she most identified. Education was classified as less than high school diploma, high school or general educational development (GED), some college or vocational training, or baccalaureate degree or higher, according to highest level of educational attainment. Household income was classified as less than $20,000, $20,000 to less than $50,000, or $50,000 or greater, according to reported family gross annual income. Neighborhood socioeconomic status (NSES) is an index variable computed from census-tract level data including percentage of adults older than 25 years with less than a high school education, percentage of male unemployment, percentage of households with income levels below the poverty line, percentage of households receiving public assistance, percentage of female-headed households with children, and median household income.[11,12] NSES index values range 0-100 with higher scores representing more affluence.

Health information was collected at WHI enrollment and at routine intervals during follow-up. Self-reported doctor-diagnosed medical conditions were used to categorize arthritis and multimorbidity. Medical history questionnaires were administered at baseline for all

participants, bi-annually for the first two years and annually thereafter for CT participants, and annually for OS participants. At baseline, women who reported diagnosis of arthritis other than rheumatoid arthritis (RA) were categorized as having osteoarthritis (OA). Questionnaires at follow-up specifically identified diagnoses of OA and RA. Self-report of doctor-diagnosed hypertension, coronary artery disease, diabetes, congestive heath failure, stroke or transient ischemic attack, osteoporosis, Alzheimer's disease, asthma, emphysema, or cancer was used to calculate total number of comorbidities (classified as none, one to two, three or more). This methodology is modeled from literature of multimorbidity within WHI,[13] using recommendations for standardization in research by the Multiple Chronic Condition Working Group within the Health and Human Services Office of the Assistant Secretary of Health[14,15] Joint pain was dichotomized based on report of joint pain and stiffness at a moderate or severe level. Mobility disability was categorized dichotomously according to whether participants reported any limitation in either "walking several blocks" or "climbing one flight of stairs" within the RAND 36-Item Health Survey questionnaire.[16] For CT participants, joint pain and mobility disability data were collected at WHI enrollment, at one year, and study close, with a 25% subsample completing additional surveys at three, six, and nine years. For OS participants, joint pain and mobility disability was collected at baseline and three years later. Mobility questions were administered annually to all Extension Study participants beginning 2005 and joint pain was ascertained at year two of the second Extension Study. Body mass index (BMI) was calculated from anthropometric measurements recorded by trained staff at WHI participants' baseline clinic visit, annually thereafter for CT participants, and at year three for OS participants. Height was measured to nearest 0.1 cm using a wall-mounted stadiometer and weight was measured to nearest 0.1 kg using a balance beam scale with participant wearing light clothes

without shoes. BMI, calculated as weight in kilograms divided by height in meters squared, was categorized as follows: underweight/ normal (healthy) weight (<25), overweight (25 to <30), obese I (30 to <35), obese II/ III (≥35).[17]

Need and Appropriateness for TKA

The National Institutes of Health (NIH) Consensus Statement on Total Knee Replacement identified the following as indicators for TKA: 1) radiographic evidence of joint damage, 2) persistent pain of moderate to severe magnitude that is not adequately relieved through nonsurgical management, and 3) diminished quality of life due to significant functional limitation.[1] The NIH Consensus Statement reported that few absolute contraindications to TKA exist and specified that neither advanced age nor obesity are by themselves absolute contraindications. In accordance with the indicators and contraindications identified in the NIH Consensus Statement, health variables of diagnosis of OA or RA, presence of moderate to severe joint pain, and mobility disability were used to identify a subsample of women classified as having "Need and Appropriateness for TKA." Radiographs were not available in this study and thus radiographic evidence of joint damage could not be included in the determination of need and appropriateness.

Follow-up time

Follow-up time for the full analytic sample was calculated from date of WHI enrollment for women age 65 or older and from date of Medicare enrollment for women under age 65 at WHI enrollment. Follow-up time in the subsample with need began at the first time point (baseline or later) when the participant reported diagnosis of OA or RA, moderate to severe joint

pain, and mobility disability. Observations were censored at death, when participants no longer had Part A FFS coverage, or at time of the last available FFS claims data (December 2014).

Statistical analyses:

Baseline demographic and health characteristics were examined by racial/ethnic groups. Chi-square and analysis of variance were used to test for significant differences between groups for categorical and continuous variables, respectively. Unadjusted utilization rates stratified by baseline characteristics were calculated to examine absolute rates of disparities. Numerators included number of primary TKAs and denominators were total person-years of follow-up within the subgroup. Presentation was restricted to baseline characteristics with more than 20 observed TKAs in the stratum.

To examine relative disparities in primary TKA utilization, time to first TKA was analyzed using Cox proportional hazards (PH) regression models. Assumption of PH of race/ethnicity was assessed through visual inspection of unadjusted Kaplan-Meier survival curves. PH of the multivariable models were assessed through correlation of Schoenfeld residuals with time. Variables were assessed for collinearity using cut-off tolerance value of <0.10. Age-adjusted race-specific hazards ratios (HR) were determined in the full analytic sample and within the subsample of need. Age and year at start of follow-up were dually included to adjust for late entry into the risk set. SES variables including income, education and NSES were included in a final regression model within the subsample of need to evaluate whether the association of race/ethnicity and rate of TKA was independent of SES. Geographic region is strongly linked to healthcare utilization in general and TKA utilization specificially,[18,19] and thus region was also included as a covariate in this model.

Quintiles of risk for TKA were created by ranking predicted probabilities of a TKA within five years, as determined using Cox-proportional hazards models with the following known predictors of TKA to rank risk profiles: age, OA, RA, joint pain, mobility disability, BMI, and multimorbidity. The most recent health variables before start of the follow-up period were used for each subject. Kaplan-Meier failure curves were stratified by ethnicity to visualize cumulative probability of TKA in each quintile of risk. Survival curves were compared between White women and each minority group using the log-rank test.

Several sensitivity analyses were performed. In the first set of sensitivity analyses, the analytic population was further restricted to WHI participants with continuous FFS coverage, rather than censoring at time of transition from FFS coverage. Because of missing data for income, it was removed from the final multivariable Cox model in additional analyses. Lastly, because mobility disability was not specifically linked to joint pain/stiffness and could have been due to other causes, we assessed changes in disparity measurements among our subsample with need after excluding any participants with self-reported doctor-diagnosed Parkinson's disease at any point during follow-up.

Statistical significance was set at $P<0.05$ for the analyses. Interactions were considered significant at $P<0.10$. All analyses were performed with SAS (Version 9.4; SAS Institute Inc., Cary, NC, USA).

RESULTS:

The study population included 102,767 women with an average follow-up time of 9.7 years; 88.0% of subjects were White, 8.7% Black, and 3.3% Hispanic. Baseline characteristics by race/ethnicity are presented in Table 1.1. Black and Hispanic women tended to be younger

and had lower income, educational attainment, and NSES compared with White women. Prevalence of self-reported doctor-diagnosed OA was similar for White and Black women (41.4% vs. 41.0%), while prevalence in Hispanic women was lower (33.2%). RA prevalence was highest in Black women (7.3%), followed by Hispanic (5.1%) and White women (3.9%). Black women had the greatest prevalence of moderate to severe joint pain (28%) followed by Hispanic (25.6%) and White women (23.2%). Similarly, Black women had the highest prevalence of mobility disability (33.8%) followed by Hispanic (28.7%) and White women (19.5%).

Crude utilization rates by baseline characteristics and race/ethnicity are presented in Table 1.2. White women had the highest rate of primary TKA at a rate of 10.7 per 1,000 person-years, followed by Black (8.5 per 1,000 person-years) and Hispanic women (7.6 per 1,000 person-years). These rates of TKA were greater in women with arthritis (15.3, 13.0, 11.0), moderate to severe joint pain (19.5, 16.5, 14.1), and mobility disability (18.9, 12.7, 11.2) respectively for White, Black and Hispanic women. Utilization rates were higher among women with higher levels of multimorbidity and BMI. Rates varied by region, with utilization in the Northeast tending to be lower than other regions. Black and Hispanic women had lower utilization in all strata of baseline characteristics compared to White women, with most differences reaching nominal statistical significance.

In the full analytic sample, after adjusting for age, Black women had a 22% lower rate (HR=0.78; 95% CI 0.72-0.85) and Hispanic women a 32% lower rate (HR=0.68; 95% CI 0.59-0.79) of TKA, compared with White women (Table 1.3). Disparities in receipt of TKA were more marked in the subset of 15,477 women who fit criteria for "Need and Appropriateness of TKA" either at baseline or during follow-up. In this subsample (n= 15,477), after adjusting for

age, Black women had a 30% lower rate (HR=0.70; 95% CI 0.63-0.79) and Hispanic women a 42% lower rate of undergoing TKA (HR=0.58; 95% CI 0.44-0.77) compared with whites. Further adjustment for region and SES variables of education, income, and NSES modestly attenuated the association between race/ethnicity and TKA, but statistically lower hazards of TKA persisted for both minority groups (Full regression results available in Table 1.4).

Figure 1.2 indicates that in the highest two quintiles of risk, Blacks and Hispanics were less likely to undergo TKA compared with Whites. Utilization was low in all racial/ethnic groups in the lowest three quintiles of risk during the five-year period.

Restricting the analytic population to women with continuous FFS coverage versus censoring time at transition from FFS to HMO led to similar hazard ratios. Results were similar when the income variable was not included in the final multivariable Cox model. Excluding participants ever diagnosed with Parkinson's disease from the subsample of need resulted in minimal changes in hazard ratios.

DISCUSSION:

In a nationwide cohort of postmenopausal women enrolled in Medicare FFS, Black and Hispanic women were significantly less likely to undergo TKA compared with Whites. After accounting for need and appropriateness for TKA, Black and Hispanic women experienced significantly lower utilization over time than White women. SES attenuated racial/ethnic disparities slightly, but Black and Hispanic women remained significantly less likely to undergo TKA compared with White women.

Similar to published findings using Medicare claims data, we found lower TKA utilization among Blacks and Hispanics among our analytic sample of Medicare FFS-insured,

older adult women.[4–6] Our evaluation of disparities within a subsample of women with "Need and Appropriateness" for a TKA procedure attempted to provide a more accurate measurement of disparity, which according to the Institute of Medicine (IOM) is defined as differences in the "quality of health care that are not due to access-related factors or clinical needs, preferences, and appropriateness of intervention."[20] Our finding of a widening of the relative disparities after restricting to this subsample with need suggests that rates calculated from healthcare administration data that rely on beneficiary enrollees as a denominator may be underestimating the disparities between racial/ethnic groups. Controlling for access-related factors including income, education and neighborhood SES allowed for investigation of the impact of SES on utilization patterns. While all participants had Medicare FFS insurance coverage, financial expenses including deductibles and copayments as well as lost wages are access factors expected to impact decision-making for this elective procedure. In this study, Black and Hispanic women had lower rates of TKA at all levels of SES. Inclusion of income, education, and NSES in the multivariable PH model attenuated the association between race/ethnicity and TKA, but significant differences between Black, Hispanic, and White women remained. While few data sources have been used to investigate the impact of SES on racial/ethnic disparities to date, our findings are consistent with research showing that black-white comparisons are not explained in large part by SES alone.[21] Few studies have examined utilization disparities between Hispanic and non-Hispanic populations, and the research to date offers conflicting findings.[7,8,18] Two studies using detailed SES data from the Health and Retirement Study found that medical access factors largely explained underutilization among Hispanic White compared with non-Hispanic White older adults. However, a study by Skinner et al.[18] using Medicare data found that ethnic differences in utilization rates varied by regional income level, and in low income regions,

Hispanic women had significantly lower utilization compared with non-Hispanic White women. In our study, access to care factors only modestly explained lower TKA utilization among both minority race/ethnic groups.

Medical treatment of advanced knee arthritis is considered preference-sensitive care, in which several treatment options exist and a decision to elect TKA should reflect informed patient preference. Though general indications for TKA exist, in practice, a significant portion of cases fall along a continuum of clinical certainty, where TKA would be considered the most appropriate treatment recommendation and, conversely, where TKA would not be indicated.[22] The decision to pursue TKA within the "grey zones" of clinical uncertainty may be influenced by provider opinion about the value of a TKA, and, consequently, provider biases may influence decision-making in these cases.[23] The presence of implicit racial bias and patient race preference on the part of the provider have been well-supported by the literature, yet the impact of these provider biases on clinicians' recommendations for TKA are less clear.[23–30] In our study, we stratified rates by quintile of risk to examine whether gaps in utilization were wider in risk profiles where there would likely be more uncertainty about the value of TKA and therefore, clinician discretion might be of greater impact. However, the largest gaps in TKA utilization were found in the highest risk quintile, or among those with the clearest indication for TKA, with only minimal differences noted in the moderate quintile. While provider bias and differential recommendations by patient race/ethnicity cannot be ruled out with our study design, the large gap in utilization between racial/ethnic groups amongst those with greatest risk/indications for TKA suggests other factors may be driving disparities.

Disparities in TKA utilization are likely multifactorial in cause, involving system-level factors such as access to care, provider-level factors including bias, discrimination, and culturally

competent communication, and patient-level factors including biologic and genetic characteristics as well as cultural beliefs, values, and health behaviors.[31] In our study, adjusting for region and SES only modestly attenuated racial and ethnic disparities in utilization, suggesting that while access to care impacts TKA utilization among older adult women, other patient- and provider-level factors may be largely contributing to such disparities. Patient preferences and willingness to undergo surgery are postulated to greatly affect utilization disparities[31–33] and may be a large factor in the gap in TKA utilization among women with highest risk and need for TKA in this study. Mistrust of the medical system and providers, fear of pain with surgery, poor knowledge about/familiarity with the TKA procedure, and a lack of perceived benefit of the TKA procedure have been documented to be highly prevalent in Black adults with arthritis.[34] These factors have been negatively associated with willingness to consider TKA as a treatment option.[35] Among Hispanics, lower perceived value of the TKA procedure has been reported.[36] Addressing fears and expectations of surgery are an integral part of communication for informed decision-making, and may be fundamental to improving uptake of TKA among minority women with highest risk/need of the procedure. Because health beliefs and attitudes regarding arthritis and surgical treatment may vary between racial/ethnic groups, communication during the decision-making process may also need to differ accordingly, in order to best achieve relationship-building and information-sharing.[28] The underrepresentation of orthopedic specialists of minority race/ethnicity presents a challenge,[37] as race/ethnic concordance of provider and patient has been shown to improve communication and may increase healthcare utilization by minorities.[38–40]

This study has several limitations. While diagnosis of arthritis, symptoms of moderate-to-severe joint pain, and presence of mobility disability were captured prospectively through this

study design, neither radiographic evidence of severity of joint damage nor clinical examination data was available to confirm a clinical need for TKA. Evidence suggests that pain tolerance and reporting may differ by race/ethnicity,[41] and the severity of joint pain does not always correlate with level of joint damage.[42] Therefore, it is possible that participants who presented with joint pain but had no significant knee joint damage were overrepresented in the subsample with need for TKA. In addition, mobility limitation was not directly linked with knee arthritis and could have been caused to other conditions. SES covariates were attained at WHI enrollment, and, therefore, baseline characteristics of income or neighborhood may not precisely reflect individual-level characteristics over time. TKA utilization varies by geographic region,[18] and, accordingly, we found significant differences in utilization by region. While we adjusted for region in our multivariate PH model, the adjustment by general area of the U.S. may not be precise enough to accurately measure geographic patterns of healthcare utilization, and there is a possibility that associations of race/ethnicity with TKA utilization were overestimated.[18] However, use of the NSES variable, which is calculated according to participant zip code, likely provided some additional level of adjustment for regional differences in utilization. The generalizability of this study is limited to older adult women with FFS Medicare coverage and may not be applicable to other populations including Medicare HMO beneficiaries. While all women had Medicare FFS coverage, we did not have information about supplemental insurance coverage during the period of follow-up, which may have impacted decisions to pursue surgical intervention.[7] Finally, we used the TKA utilization rate of White women as the reference. However, research suggests that women in need of TKA often delay or underutilize the procedure compared with men.[43,44] Therefore, it is important to note that the rate White women

receive TKA may not be an accurate reflection of appropriate surgical treatment for end-stage arthritis and may itself be reflective of underutilization.

Balancing these limitations, this study has several key strengths. The study adds new evidence to the current body of literature investigating disparities in receipt of TKA. To date, most research on this topic has relied on healthcare administration data alone, which fails to capture some important individual-level characteristics. We were able to use information from a large, diverse population of community-dwelling older women with prospectively collected data on severity of pain and activity limitations. Individual-level SES data allowed us to investigate the influence of medical access factors on disparities. A major strength of this study is the sample size of Hispanic women that allowed us to examine Hispanic and non-Hispanic comparisons in more detail than previous studies.

These findings have important implications for equity in delivery of healthcare services. Among women age 65 and older, Hispanic and Black women were significantly less likely to undergo TKA, a procedure that is considered highly cost-effective for treatment of end-stage knee arthritis. This study contributes to the body of evidence that disparities in TKA utilization persist when accounting intergroup differences in need and appropriateness for TKA, as well as SES factors. Black and Hispanic women may be underutilizing a procedure that could improve mobility, reduce pain, and increase their quality of life. While personal preference and cultural beliefs should be honored, it is important that inferior medical care not be provided to minorities due to reasons such as inadequate patient knowledge or patient misconceptions, poor patient-provider communication, or discrimination. Further research into patient- and provider level factors affecting decision-making in patients of minority race/ethnicity may help develop

strategies for provision of more equitable treatment of patients experiencing painful and activity-limiting arthritis.

Chapter 1, in full, has been submitted for publication of the material. Cavanaugh, Alyson M; Rauh, Mitchell J; Thompson, Caroline A; Alcaraz, John; Mihalko, William M; Bird, Chloe E; Eaton Charles B; Rosal, Milagros C; Li Wenjun; Shadyab, Aladdin H; Gilmer, Todd; LaCroix, Andrea Z.. Alyson Cavanaugh was the primary investigator and author of this material.

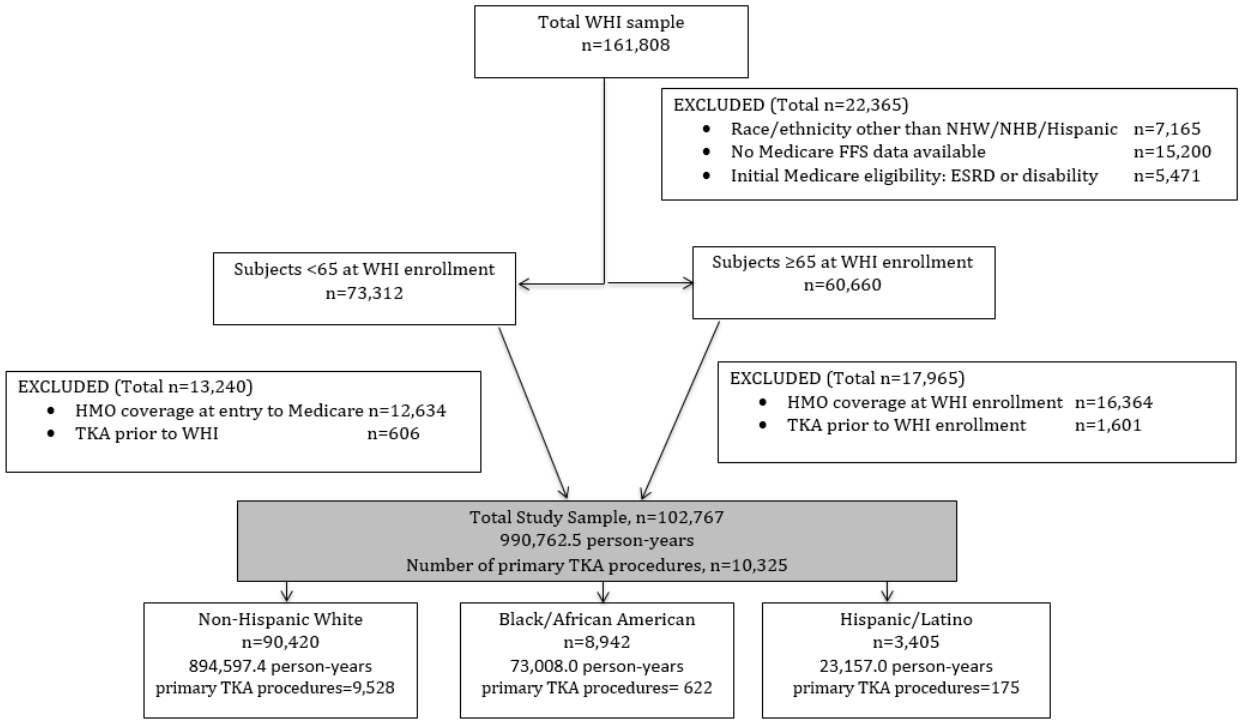

Figure 1.1: Study population determination flow chart

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Table 1.1: Baseline characteristics of WHI fee-for-service Medicare enrollees by race/ethnicity (n=102,767)

Characteristic	Black/African American (n=8,942)	Hispanic/ Latino (n=3,405)	Non-Hispanic White (n=90,420)	p-value
Age at WHI enrollment				<0.0001
50-<55	1,608 (18.0)	840 (24.7)	11,111 (12.3)	
55-<60	2,148 (24.0)	1038 (30.5)	18,574 (20.5)	
60-<65	2,349 (26.3)	793 (23.3)	21,610 (23.9)	
65-<70	1,571 (17.6)	457 (13.4)	19,966 (22.1)	
70-<75	904 (10.1)	210 (6.2)	13,652 (15.1)	
≥75	362 (4.0)	67 (1.9)	5507 (6.1)	
Marital status (% married)	4,821 (54.7)	2,124 (64.0)	62,556 (69.8)	<0.0001
Educational Level				<0.0001
Less than high school	864 (9.8)	770 (22.9)	2,581 (2.9)	
High school diploma or GED	1,154 (13.0)	563 (16.8)	15,517 (17.2)	
Some college/vocational training	3,410 (38.5)	1,197 (35.6)	33,090 (36.8)	
Baccalaureate degree or higher	3,436 (38.7)	831 (24.7)	38,798 (43.1)	
Family Income				<0.0001
<$20,000	2,144 (25.7)	1,013 (32.5)	10,188 (12.0)	
$20,000-<$50,000	3,660 (43.9)	1,279 (41.0)	37,774 (44.4)	
≥$50,000	2,541 (30.4)	827 (26.5)	37,164 (43.6)	
Neighborhood SES, mean (SD)	64.47 (11.8)	68.96 (10.5)	77.37 (6.9)	<0.0001
BMI				<0.0001
Underweight/Normal weight	1,493 (16.8)	872 (25.9)	34,101 (38.1)	
Overweight	2,939 (33.2)	1,321 (39.2)	31,542 (35.2)	
Obese I	2,483 (28.0)	757 (22.5)	15,576 (17.4)	
Obese II	1,198 (13.5)	297 (8.8)	5,865 (6.5)	
Obese III	754 (8.5)	121 (3.6)	2,546 (2.8)	
# of comorbidities				<0.0001
0	3,063 (34.3)	1,842 (54.1)	45,761 (50.6)	
1-2	5,183 (58.0)	1,424 (41.8)	40,519 (44.8)	
3 or more	696 (7.7)	139 (4.1)	4,140 (4.6)	
Osteoarthritis (% yes)	3,667 (41.0)	1,129 (33.2)	37.394 (41.4)	<0.0001
Rheumatoid arthritis (% yes)	649 (7.3)	175 (5.1)	3,563 (3.9)	<0.0001
Joint pain (% yes)	2,465 (28.0)	845 (25.6)	20,897 (23.2)	<0.0001
Mobility disability (% yes)	2,989 (33.8)	949 (28.7)	17,478 (19.5)	<0.0001
Region				<0.0001
Northeast	1535 (17.2)	463 (13.6)	23,132 (25.6)	
South	4,468 (50.0)	1,563 (45.9)	24,517 (27.1)	
Midwest	2,214 (24.7)	169 (5.0)	23,895 (26.4)	
West	725 (8.1)	1,210 (35.5)	18,876 (20.9)	

Abbreviations: WHI, Women's Health Initiative; GED, general education diploma; SES, socioeconomic status; SD, standard deviation.

Table 1.2: Crude TKA utilization rates by baseline characteristics[a]

	Rate per 1,000 person-years[b]			Absolute difference per 1,000 person-years[c]		Percent difference[d]	
	Black	**Hispanic**	**White**	**White/ Black**	**White/ Hispanic**	**White/ Black**	**White/ Hispanic**
Crude	8.5	7.6	10.7	2.1§	3.1§	19.6	29.0
Age at WHI enrollment							
50-<55	9.0	9.5	11.8	2.9*	2.2	24.6	18.6
55-<60	9.8	6.4	12.1	2.4*	5.8§	19.8	47.9
60-<65	9.3	6.4	11.7	2.4*	5.3§	20.5	45.3
65-<70	7.8	9.9	10.4	2.6*	1.5	25.0	14.4
≥70	6.6	6.7	8.6	2.0*	1.9	23.3	22.1
Educational Level							
Less than high school	8.5	6.7	10.3	1.8	3.6*	17.5	35.0
High school diploma or GED	9.8	7.8	11.0	1.2	3.2*	10.9	29.1
Some college/vocational training	8.4	8.5	11.1	2.7§	2.6*	24.3	23.4
Baccalaureate degree or higher	8.4	6.8	10.2	1.8*	3.4*	17.6	33.3
Family Income							
<$20,000	7.7	6.8	9.9	2.1*	3.0*	21.2	30.3
$20,000-<$50,000	8.6	7.5	10.9	2.3§	3.4*	21.1	31.2
≥$50,000	9.1	8.5	10.7	1.7*	2.2	15.9	20.6
NSES							
Below median	8.5	7.4	10.8	2.3§	3.4§	21.3	31.5
Above median	8.7	8.0	10.5	1.8*	2.5*	17.1	23.8
Marital status							
Currently married	9.1	8.2	10.9	1.8*	2.7*	16.5	24.8
Not currently married	7.9	6.4	10.1	2.2§	3.7§	21.8	36.6

Table 1.2: Crude TKA utilization rates by baseline characteristics,[a] continued

	Rate per 1,000 person-years[b]			Absolute difference per 1,000 person-years[c]		Percent difference[d]	
	Black	**Hispanic**	**White**	**White/ Black**	**White/ Hispanic**	**White/ Black**	**White/ Hispanic**
BMI							
Underweight/ Normal weight	2.3		5.1	2.8§		54.9	
Overweight	6.6	5.2	10.5	3.9§	5.3§	37.1	50.5
Obese I	10.1	12.1	16.9	6.8§	4.8*	40.2	28.4
Obese II/III	14.1	19.1	24.8	10.8§	7.1*	40.3	28.6
Arthritis	13.0	11.0	15.3	2.3*	4.3§	15.0	38.6
Moderate-to-Severe Joint Pain	16.5	14.1	19.5	3.0*	5.4*	15.4	27.7
Mobility Disability	12.7	11.2	18.9	6.2§	7.6§	32.8	40.2
# of comorbidities							
0	7.5	6.4	9.6	2.1*	3.2§	21.9	33.3
1-2	8.7	8.6	11.7	3.0§	3.0*	25.6	25.6
3 or more	11.1		11.8	0.7		5.9	
Region							
Northeast	7.5	6.0	9.1	1.5*	3.1*	16.5	34.1
South	9.1	8.3	10.5	1.3*	2.2*	12.4	21.0
Midwest	7.8		12.9	5.2§		40.3	
West	9.3	7.6	9.9	0.6	2.2*	6.1	22.2

Abbreviations: TKA, total knee arthroplasty; BMI, body mass index.

[a] Presentation of utilization rates restricted to cells with at least 20 observed TKAs.

[b] Crude utilization rate determined by number of primary TKAs by 1,000 person years of follow-up.

[c] Absolute difference computed as White-Minority.

[d] Percent difference computed as (White-Minority)*100/White.

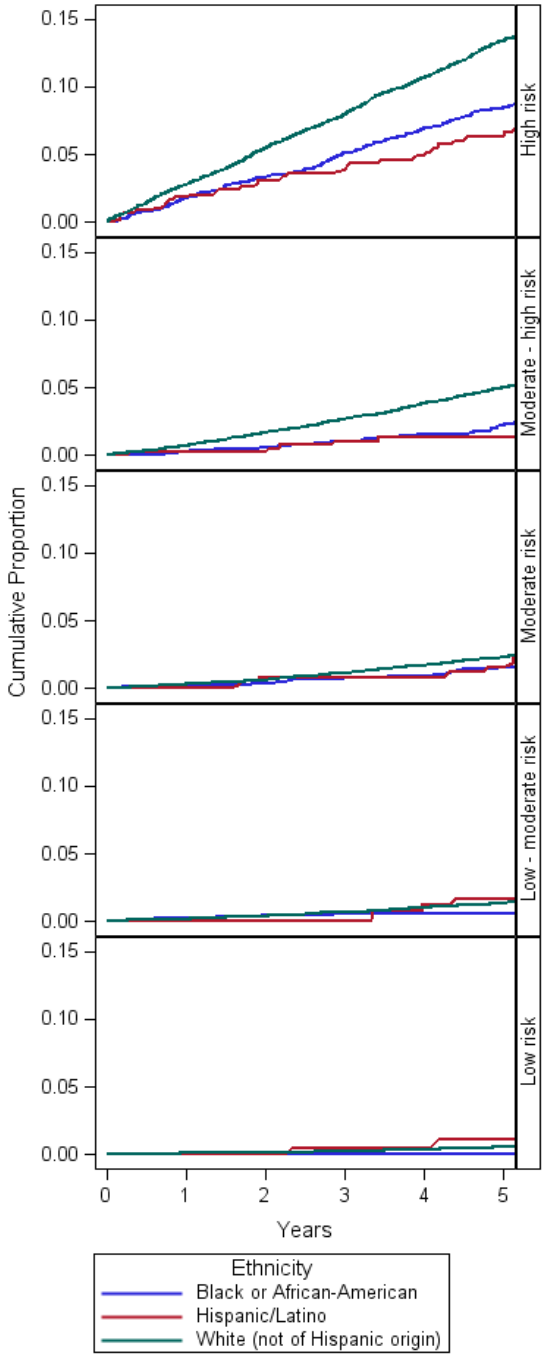

Figure 1.2: Proportion of women who underwent TKA by race/ethnicity by quintile of risk

Risk quintiles determined through adjustment of age, diagnosis of OA, RA, joint pain, mobility disability, BMI, and number of comorbidities

Table 1.3: Adjusted hazard ratios for primary TKA, Women's Health Initiative, 1993-2014

	Full Sample (n=102,767)	**Subsample of Need for TKA[a] (n=15,477)**	
	Adjusted for age HR (95% CI)	**Adjusted for age HR (95% CI)**	**Adjusted for age, region, and SES[b] HR (95% CI)**
Black/African American	0.78 (0.72-0.85)	0.70 (0.63-0.79)	0.75 (0.67-0.88)
Hispanic/Latina	0.68 (0.59-0.79)	0.58 (0.44-0.77)	0.65 (0.47-0.89)
White	1.0 (ref)	1.0 (ref)	1.0 (ref)

Abbreviations: TKA, total knee arthroplasty; HR, hazard ratio; CI, confidence interval; SES, socioeconomic status.

[a] Sample restricted to women with diagnosis of osteoarthritis or Rheumatoid arthritis, moderate to severe joint pain, and mobility disability.

[b] All models adjusted for age and year at start of follow-up. Final model additionally adjusted for region, highest educational attainment, income, and neighborhood SES.

Table 1.4: Adjusted hazard ratios for primary TKA for full medical access model, Women's Health Initiative, 1993-2014

	Subsample of Need for TKA[a] (n=15,477) HR (95% CI)
Race/ethnicity	0.75 (0.67-0.88)
Black/African American	0.65 (0.47-0.89)
Hispanic/Latina	1.0 (ref)
White	
Age (years)	1.03 (1.02-1.05)
Year	1.00 (0.99-1.01)
Education	
Less than high school	1.03 (0.91-1.17)
High school diploma or GED	0.96 (0.78-1.18)
Some college/vocational training	1.03 (0.94-1.14)
Baccalaureate degree or higher	1.0 (ref)
Income	
<$20,000	0.69 (0.59-0.79)
$20,000-<$50,000	0.86 (0.78-0.95)
≥$50,000	1.0 (ref)
Neighborhood SES	1.00 (1.00-1.01)
Region	
Midwest	1.28 (1.12-1.47)
Northeast	1.00 (0.87-1.15)
South	1.07 (0.93-1.22)
West	1.0 (ref)

Abbreviations: TKA, total knee arthroplasty; HR, hazard ratio; CI, confidence interval; GED; general education diploma; SES, socioeconomic status.

[a] Sample restricted to women with diagnosis of osteoarthritis or Rheumatoid arthritis, moderate to severe joint pain, and mobility disability.

[b] All models adjusted for age and year at start of follow-up. Final model additionally adjusted for region, highest educational attainment, income, and neighborhood SES.

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CHAPTER TWO

Racial and Ethnic Disparities in Physical Function before and after Total Knee Arthroplasty

ABSTRACT:

Importance: While racial/ethnic differences in functional outcomes following total knee arthroplasty (TKA) exist, whether such differences are solely a reflection of differences in pre-surgical function has not been thoroughly investigated.

Objective: To examine trajectories of physical function by race/ethnicity before and after TKA in older women.

Design: Prospective Women's Health Initiative cohort with linked Medicare claims data

Setting: Community-dwelling population

Participants: A total of 10,325 women throughout USA with Medicare fee-for-service who underwent primary TKA between 1993-2014.

Exposure(s): Race/ethnicity comparisons between non-Hispanic Black/African-American, non-Hispanic White, and Latino/Hispanic hereafter referred to as Black, White, and Hispanic.

Main Outcomes: Physical functioning (PF) scale scores and self-reported activity limitations with walking one block, several blocks, and climbing one flight of stairs during the were measured by the RAND-36 questionnaire, during the decade before and after TKA, with a median of nine PF measurements collected over time per participant.

Results: Compared with White women, Black women had PF scores 5.8 points lower on average during the decade prior to TKA ($p<0.0001$), higher odds of experiencing difficulty with walking a single block (OR =1.86, 95% CI: 1.57-2.21), walking multiple blocks (OR=2.14, 95% CI: 1.83-2.50), and climbing a flight of stairs (OR=1.81, 95% CI: 1.55-2.12) five years prior to TKA. After adjusting for PF at 1-year prior to TKA, postoperative PF scores remained lower for Black women at 1-year post TKA (mean difference=3.2, $p<0.001$) but were similar between Black and White women from years 3 through 10 post-TKA. Hispanic women showed physical function scores that were similar to those of White women during the pre- and post-TKA periods.

Conclusions and Relevance: Compared with White women, Black women had significantly poorer PF for the decades prior to and following TKA. Black women reported less functional return following surgery which was largely explained by poorer pre-operative PF. Reducing disparities in post-TKA functional outcomes should target maintenance of function pre-operatively in the early stages of arthritic disease and/or reduction of delays to receiving TKA once need arises.

INTRODUCTION:

Racial and ethnic disparities in utilization of total knee arthroplasty (TKA) are well-documented.[1–3] Less studied, but equally important, are the racial and ethnic disparities in outcomes following TKA procedures.[4] While current evidence is limited regarding disparities in functional outcomes, studies suggest that racial/ethnic minorities experience lower satisfaction, higher postoperative pain, more residual joint stiffness, and poorer physical function (PF) following total joint arthroplasty compared to Whites.[4]

The reasons for racial/ethnic disparities in functional outcomes following TKA are not well understood, but several plausible hypotheses exist. One hypothesis is that minority patients may present with poorer PF at time of TKA. Pre-operative function is a well-known strong predictor for postoperative function,[5,6] and Black and Hispanic patients undergoing TKA have been shown to have poorer PF than Whites at time of TKA.[7–10] The few studies to date examining pre- and post-TKA function by race have relied on single-surgeon or single-institution databases, where pre-operative functional status was measured at a time period immediately preceding surgical intervention.[7,11] While PF measures immediately prior to surgery provide useful information, it may also be important to investigate the progression of functional limitations over a longer period of time. Minorities with painful arthritis often experience longer delays in obtaining medical care, and delays in surgical intervention may be important in postoperative prognosis.[12] A longer duration of living with limited mobility could contribute to further deterioration in muscle strength, restrictions in joint range of motion, and altered pain pathways.[13–15]Thus, both the level of PF at time of surgery and the duration of PF limitations may be important prognostic factors for functional outcomes after TKA.

The purpose of this study was to use prospectively collected data from a large cohort of community-dwelling older adult women to assess functional status trajectories of older women by race and ethnicity during the decades leading to and following TKA.

METHODS:

Participants

This study used prospectively collected information from the Women's Health Initiative (WHI) Clinical Trials (CT) and Observational Study (OS), which are described in detail elsewhere.[16,17] Briefly, WHI is a longitudinal study that enrolled 161,808 postmenopausal women throughout 40 clinical centers in the United States between 1993 and 1998. Women representing minority racial and ethnic groups were recruited to proportionately represent the US population of 50-79 year-old postmenopausal women and include 17% of the total WHI sample. Women in WHI were followed until 2005, and surviving women were then invited to participate in subsequent Extension Studies from 2005-2010 and 2010 through present. Medicare fee-for-service (FFS) claims data have been linked to 145,753 (90%) of WHI participants.

The study population for this analysis included women enrolled in WHI who self-identified as non-Hispanic White, non-Hispanic Black, or Hispanic/Latina and had Medicare data claims available (Figure 2.1). Medicare Part A FFS claims were used to identify women who underwent first primary TKA from time of WHI enrollment through December 31, 2014, using the Ninth Revision of the International Classification of Diseases (ICD-9) primary procedure code 81.54. Because the focus was on PF trajectories from time of first TKA, women with TKA prior to WHI enrollment were excluded. Self-report of joint replacement, other than hip replacement, or a documented procedure code of 81.54 in FFS claims prior to WHI enrollment were used to identify prior TKA. Women without continuous FFS coverage from

time of WHI enrollment or time of Medicare enrollment until time of TKA were excluded, as we were unable to determine surgical history without continuous FFS coverage.

Measures

Physical function, a composite score (0-100), was derived from the RAND-36 physical functioning scale of the RAND-36 questionnaire, which includes ten survey questions regarding self-perceived difficulty in specific functional activities.[18] Higher scores indicate higher function. WHI CT participants completed this questionnaire at the screening visit, at one year of follow-up, and at study close, with a 25% subsample of CT participants completing additional surveys at three, six, and nine years of follow-up. Surveys were administered to WHI OS participants at baseline and three years later. Surveys were administered annually to all Extension Study participants beginning in 2005.

The responses from three items of the RAND-36 questionnaire were treated as binary outcomes to determine specific activity limitations prior to TKA. If a woman responded that her health either limited her "a little" or "a lot" in climbing one flight of stairs, walking one block, or walking several blocks, she was classified as having activity limitation with the corresponding functional task.

Demographic information including race/ethnicity, income, and educational attainment were collected through questionnaires administered at WHI screening and baseline clinic evaluations. Race/ethnicity was categorized according to self-identified racial or ethnic groups that the participant most identified with and was limited to responses of White (not of Hispanic origin), Black or African-American (not of Hispanic origin), or Hispanic/Latina (ancestry is Mexican, Cuban, Puerto Rican, Central American, or South American), referred to hereafter as

White, Black and Hispanic. Self-reported annual income at baseline (classified as <$20,000, $20,000 to <$50,000, and $50,000 and greater) and highest educational attainment (classified as less than high school diploma or GED, high school diploma or GED, some college or associate degree, Baccalaureate degree or higher) were used to assess socioeconomic status (SES). Neighborhood socioeconomic status (NSES), a computed variable based on 2000 census tract-level data on poverty, education and other SES variables within the geographical region was also included as a measure of SES.[19,20] NSES values range from 0-100, with higher values representing more affluent census tracts.

Data collection for body mass index (BMI) occurred at WHI enrollment, with height and weight collected from trained assessors. Height was measured using a wall-mounted stadiometer to the nearest 0.1 cm. Weight was measured on a balance beam scale with participant wearing light clothes without shoes and calculated to the nearest 0.1 kg. BMI was calculated as weight in kilograms divided by height in meters squared and categorized according to World Health Organization cut-points: underweight (<18.5), healthy weight (18 to <25), overweight (25 to <30), obese I (30 to <35), obese II (35 to<40), and obese III (≥40).[21]

Marital status, living arrangement, presence of depressive symptoms, and participation in physical activity were determined by participant responses to questionnaires at data collection prior and most recent to date of TKA. Marital status was dichotomized (yes/no) according to response of being currently married or in an intimate relationship. Living arrangement was dichotomized (yes/no) based on whether the participant lived alone. Presence of depressive symptoms was determined using Burnam's 8-item scale for depressive disorders, which combines six questions from the short-form of the Center for Epidemiological Studies Depression (CESD) Scale and two items from Diagnostic Interview Schedule (DIS).[22] A cut-off

of 0.06 was used to determine presence of depressive symptoms.[23] Time spent in moderate to vigorous physical activity (MVPA) was based on self-reported frequency and duration of activities of various intensities. MVPA was classified as greater than or equal to 150 minutes per week, 1-<150 minutes/week, or none. Questionnaires used to determine marital status and depressive symptoms were collected at the same time points described above for ascertaining PF scores for CT and OS participants, with the depressive symptom questions additionally administered in the second year of the extension study. Living arrangement was collected at baseline for all participants, at year one for CT participants, year three for OS participants, and in the second year of the second extension study. MVPA data was collected at baseline for all participants, at years one, three, six, and nine for CT participants, annually from years three through eight for CT participants, and at year two of Extension study two.

Medicare FFS claims data were used to determine age and multimorbidity scores. Age corresponds to age at time of TKA procedure. Multimorbidity scores were calculated using the Centers for Medicare and Medicaid Service Hierarchical Conditions Categories (CMS-HCC) risk adjustment scores, with scores lower than 1.0 indicating relatively healthy individuals. Medical claims starting one year prior to date of surgery were included in the calculation of the CMS-HCC risk score. FFS claims from hospital inpatient, hospital outpatient, and physician claims were included to calculate dichotomous values for the 70 HCC conditions. The 2014 Model Version 2213.87 was used, and only diagnoses collected according to CMS data collection instructions were included.[24] Therefore, diagnosis codes from inpatient skilled nursing facility providers, hospital swing-beds, hospice, home health, free-standing ambulatory surgical centers, and non-accepted outpatient physician specialties were excluded from calculation of the CMS-HCC score.[25]

Statistical methods:

Demographic and health characteristics were compared across race/ethnicity groups. Chi-square, analysis of variance, and Kruskal-Wallis tests were used to test for significant differences between groups for categorical, normally distributed continuous, and non-normally distributed continuous variables, respectively.

Assessment of pre-TKA functional status and temporal changes

Generalized linear mixed modeling was used to estimate PF at 1-year prior to surgery at individual participant level. PF scores from the 10-year period prior to date of surgery were included in the model. Mixed modeling allows for correlated within-subject PF scores over time and allows the asynchronous timing of data collection for PF scores relative to the date of TKA. Time was treated continuously. Quadratic and cubic functions of mean-centered time were introduced in the model to allow for a non-linear relationship, and retained if significant at $p<0.05$ using a likelihood ratio test comparing nested models. A random intercept and slope at the participant level were included in the model. The predicted value at 1 year prior to surgery was used as the pre-operative functional level for subsequent modeling.

Functional trajectories over time were modeled using generalized estimating equations (GEE) in the pre- and postoperative periods. GEE modeling allowed for correlated within-subject PF data to estimate marginal means by racial/ethnic group. Pre-operative PF was modeled for a period of up to 10 years prior to surgery. Race/ethnicity and age at time of TKA were independent variables included in the GEE models. Quadratic and cubic time variables were included to allow for non-linear changes in PF over time. Interaction terms for time and race/ethnicity were also included to allow for differing rates of change in PF by the racial/ethnic groups over time. These interactions were retained in the model if Wald test statistic was

significant at $p<0.10$. Because differences in PF between racial/ethnic groups pre- and post-TKA would be compared, women without both pre- and post-TKA PF measurements were excluded from the GEE models examining PF. To examine whether race/ethnicity associations with pre-operative PF varied by SES, the variables NSES, income, and education were stratified at their median values and interaction terms for each were added into three separate GEE models. An autoregressive working correlation structure was used for all GEE models.

To investigate specific activity limitations by race/ethnicity in the years leading to TKA, GEE modeling was used with race/ethnicity and age at time of TKA as independent variables. Outcomes of difficulty with walking one block, walking several blocks, and climbing a flight of stairs were each treated as binary variables (limited a little or a lot vs. not limited). Quadratic and cubic functions of time, and interactions of time function by race/ethnicity were assessed and retained in the model if found significant at $p<0.10$. Predicted probabilities of experiencing any difficulty with each of the three activity limitations were determined during a ten-year interval prior to surgery for visual representation of the data.

Assessment of post-TKA functional status and temporal changes

Unadjusted means of PF both pre- and post-TKA were calculated at annual increments for each race/ethnic group and included all available PF scores collected within 364 days of the start of the year. For example, Year 1 after TKA includes PF scores collected at day 365 through day 729 after TKA. Postoperative scores collected during the first postoperative year were not included because of an assumed temporary decline during the initial postoperative recovery period.[26]

GEE modeling of PF scores in the postoperative decade used PF measurements collected from 365 days post-TKA through postoperative year 10 and were performed using the same methodology as described in the pre-TKA period, Postoperative PF measures within one year following TKA were not included because of presumed variability during immediate recovery.[26] To evaluate whether poorer pre-operative PF explained differences in postoperative function by race/ethnicity, the estimated 1-year pre-operative PF score determined using the generalized linear mixed models described above was added as an independent variable in the postoperative function GEE model. Specific time periods of 1 and 2 years, 5 years, and 10 years from TKA were selected to examine disparities in short, mid and long-term outcomes, respectively.

Health characteristics that were hypothesized to affect loss-to-follow up, including age at TKA, multimorbidity, BMI, physical activity, and depressive symptoms, as well as race/ethnicity were compared between participants who were included in the GEE models and those who were excluded due to missing post-TKA PF measures. Chi-square, t-test, and Kruskal-Wallis tests were used to test for significant differences between groups for categorical, normally distributed continuous and non-normally distributed continuous data, respectively.

P-values were considered significant at values <0.05. P-values for interactions were considered significant at values <0.10. All analyses were performed using Statistical Analysis Software Version 9.4 (SAS Institute Inc., Cary, NC, USA).

RESULTS:

Study population

Overall, 10,325 women from WHI who underwent primary TKA were included. Most (92.2%) of the study population self-identified as non-Hispanic White, followed by

Black/African American (6.0%), and Hispanic/Latina(1.7%). The average age at TKA was 74.6 years for White, 73.1 for Hispanic and Black women(Table 2.1). Compared with White women, Black women were less likely to be married and more likely to have lower income and educational attainment, lower NSES, higher BMI, higher multimorbidity score, and lower MVPA participation. Hispanic women were less likely to be married than White women and more likely to have lower income and educational attainment, lower NSES, higher BMI, lower MVPA, but have a lower multimorbidity score.

Analyses for PF were restricted to participants with both pre- and post-TKA measurements available. Comparison of participants included and those excluded from PF GEE models revealed significant differences between the groups with regards to race/ethnicity, age at TKA, BMI, multimorbidity scores, MVPA, and presence of depressive symptoms. Those without post-TKA PF measures were older, had poorer health and more likely to be Black or Hispanic than White.

Physical function prior to TKA

All racial/ethnic groups had declining trends in PF during the decade pre-operatively with some functional improvements after TKA (Figure 2.2). Black women had significantly lower PF scores during the pre-operative period, averaging 5.8 points lower compared with White women after adjusting for age (Table 2.2, Figure 2.3A). Compared with white women, Hispanic women also had lower pre-operative PF scores (mean difference = 2.7, p=0.12) but this difference was not statistically significant. After introduction of an interaction term for SES by race/ethnicity, race/ethnicity was no longer significantly associated with PF and tests for interaction between race and NSES, education, or income were p=0.07, p=0.09, and p=0.08 in each of the 3 respective models. Differences in PF between Black and White women were more pronounced

among women with SES characteristics below median levels compared with those with higher SES levels (Figure 2.3).

In analyses of specific activity limitations (difficulty with walking one block, walking several blocks, and climbing one flight of stairs) in the decade prior to TKA, the odds of experiencing these mobility impairments increased in the years approaching surgery for all race/ethnic groups (Table 2.3, Figure 2.4). Compared with White women, Black women had higher odds for activity limitations in the decade pre-operatively ($p<0.0001$) after adjusting for age, indicating earlier onset of activity limitations. White women experienced higher rates of developing these limitations in the immediate years preceding TKA compared with Black women (Table 2.3, Figure 2.4). Hispanic and White women had similar trajectories in experiencing walking limitations. However, Hispanic women had significantly higher odds of experiencing difficulty with climbing a flight of stairs, demonstrating 67% higher odds of difficulty with stair ascent during the year prior to TKA compared with White women (OR=1.67, 95% CI 1.21-2.31)

Physical function after TKA

Black women had significantly lower post-TKA PF scores compared with White women ($p<0.0001$). At one-year post-TKA, Black women had mean PF scores 7.8 points lower than White women, which represented a widening of the gap noted pre-operatively (mean difference 1-year pre-TKA=5.8). However, the difference in PF between racial groups narrowed over time due to a more gradual decline in PF among Black women, with a mean difference of 3.2 at year ten post-TKA. White women, on average, had reached peak PF by the first year post-TKA and then experienced a comparatively steeper decline in function over time (race/ethnicity by time interaction p-value=0.06). Black women did not reach peak PF until year 3 postoperatively and

then experienced a more gradual decline in function in later years. Hispanic women showed similar mean PF scores compared with White women during the 10-year postoperative period, and no significant differences were noted between the two groups ($p=0.12$).

Adjustment for pre-operative PF attenuated the racial/ethnic differences in postoperative PF (Table 2.2, Figure 2.5). When adjusting for pre-operative function, Black women had significantly lower PF scores initially post-TKA compared with White women (mean difference at 1-year post-TKA =3.2, $p<0.001$), but by the third year post-TKA no significant differences persisted between any race/ethnicity groups. Over the postoperative decade, after adjusting for pre-TKA function, Black women had significantly slower overall rate of decline in PF than White women ($p=0.03$).

DISCUSSION:

In a population of community-dwelling older women who underwent TKA, Black women had significantly poorer PF scores than White women during the decade before TKA which persisted in the decade post-TKA. After adjustment for pre-operative PF, Black women had lower PF scores than their White counterparts initially for the first three years following surgery, but then on average had similar PF scores for the remainder of the ten-years follow-up. Hispanic and White women had similar pre- and postoperative PF scores.

Our findings are consistent with the growing body of evidence that Black patients have poorer post-TKA PF than Whites.[4] Functional outcome disparities after TKA have been less commonly studied in the Hispanic population, but our results are congruent with two other studies finding that Hispanic ethnicity was not significantly associated with PF outcomes.[7,27]

Pre-operative PF, a strong predictor of postoperative PF,[5,6] has been hypothesized to explain functional outcomes disparities by race. Consistent with prior studies, we found that Black women had poorer pre-TKA function than White women.[7,12,27] This study extends previous findings by revealing that Black women not only have lower PF immediately preceding surgery, but that PF limitations were present earlier and for a longer duration prior to TKA. Kamath et al.[12] found that Black women who underwent TKA waited more than three years on average after onset of painful symptoms before visiting an orthopedist, a delay of more than 20 months compared with other race/ethnicity groups. In our study, Black women were more likely to report substantial mobility limitations including difficulty with walking short distances and difficulty with climbing stairs at a younger age and at an earlier point in time prior to undergoing TKA. White women who received a TKA were more likely to develop limitations of walking several blocks and climbing stairs in the years immediately prior to undergoing TKA. These findings suggest that White women are more expedient in seeking and/or accessing surgical treatment after onset of limitations compared with Black women. After adjustment for pre-TKA PF, no differences in mid- and long-term functional outcomes were found implying that efforts to reduce disparities by race in TKA functional outcomes might best be targeted pre-operatively by preserving functional mobility among Black women and reducing delays to surgical intervention once clinical need for TKA arises.

The earlier onset of activity limitations among Black women is of concern due to the cyclic relationship between further reductions in physical activity, increases in weight gain and BMI, and further restrictions in mobility,[30] all of which are associated with poorer outcomes after TKA.[5,31,32] Indeed, in our sample, Black women had higher BMI and lower physical activity. Preserving mobility and preventing further functional decline among Black women may

ultimately need to include strategies such as weight management, physical activity promotion, or targeted interventions aimed at functional mobility, such as physical therapy. Through our analysis, it is unclear whether onset of mobility limitations preceded or followed a diagnosis of arthritis. Nonetheless, once painful joints affect mobility, uptake of evidence-based treatments of arthritis may help to manage pain and slow declines in function, but have been demonstrated to be less utilization by Black adults. Black adults with arthritis have been shown to be less likely to seek medical or pharmaceutical treatments for pain management that could allow more mobility,[33] instead preferentially relying on coping mechanisms such as using hope and prayer.[33] Black adults with arthritis are less likely than their White counterparts to receive physical therapy services which are directly aimed at maintaining function and promoting physical activity.[34] Ultimately, reaching Black adults with arthritis earlier in the disease process and increasing uptake of treatments that are evidence-based and aimed at preserving the highest possible functional mobility may help reduce the observed disparities post-surgically following TKA.

Reducing delays to surgical treatment once clinical need for TKA arises and thus conservative treatments no longer prove effective may help to improve prognosis postoperatively. The reasons for delayed surgical intervention from time of onset of mobility limitations among Black women likely include a combination of economic, social, and cultural factors. Lower economic resources to cover copayments, deductibles, and lost wages during surgical recovery may contribute to postponing medical care and/or surgical intervention.[35–37] In our study, women with fewer financial resources had poorer pre-TKA function in general, and the racial disparities in pre-operative PF were wider in this group than among women with greater social and financial resources. In addition to limited financial resources, Black women in

our study had few social resources, as they were less likely to be married and more likely to live alone. Lack of available physical support in the home may theoretically contribute to initial reluctance to elect surgical intervention, although available evidence to date has failed to find an association between social support and willingness to undergo TKA among older Black adults.[35,38] Health literacy and cultural differences in health behaviors and beliefs may also play a substantial role. A high prevalence of mistrust of medical professionals, preference for use of alternative treatments, and misconceptions about expectations from arthritis treatments have been shown to impact health-seeking behaviors and treatment decisions for arthritis.[39–41] Reducing delays to surgical intervention once clinical need arises may help reduce the observed disparities post-surgically following TKA but a more thorough understanding of the reasons for delayed TKA among Black women is needed.

The continued persistence of a gap between Black and White women in short-term outcomes after adjustment for pre-operative PF warrants further investigation. While White women in the study had reached peak PF by 1-year post-TKA, Black women did not reach peak PF until almost 3 years following TKA. Studies have linked Black race with use of low-volume surgeons and institutions for TKA,[42,43] which may result in higher complication rates and slower recovery. Few studies have yet addressed rehabilitation following TKA according to race,[44,45] but differences with post-acute rehabilitation care may additionally contribute to delayed functional recovery. While this gap in function persists in short-term follow-up even after adjustment of pre-operative function, it is promising to recognize that mid- and long-term outcomes were similar between race/ethnicity groups.

Our study has several limitations. We assessed PF using the RAND-36, which is a generic, patient-reported measure, and not a knee- or arthritis-specific tool nor a performance-

based measure. Nevertheless, the PF scale of the RAND-36 provides a global view of self-perceived mobility required for daily living and has been widely used in studying outcomes following joint arthroplasty.[46] The results from this study reveal large variability in estimated PF in Hispanic women, and the findings for this group should be interpreted with caution. The variability is likely due to the smaller sample size of the group as well as probable heterogeneity within the group in terms of participant characteristics, customs, and beliefs, which may result in great diversity in experiences and outcomes. Loss to follow up bias is possible as subjects included in the GEE PF models tended to be younger and healthier. Nonetheless, because Black and Hispanic women were more likely to be lost to follow up than White women, the gap between Whites and minorities may in fact be underestimated. This study population was limited to women with Medicare FFS coverage, and, therefore, findings may not be generalizable to managed care beneficiaries, men or younger populations. However, older women are the demographic group most likely to receive TKA and thus the examination of this very large cohort of aging women remains highly valuable.[47]

Balancing these limitations were several key strengths. The Medicare-WHI linked data allowed an investigation of PF from a large, diverse population of women throughout the USA, using prospectively-collected individual-level measurements that would not be available from medical claims data alone. Prospectively-collected PF measurements allowed for investigation of disparities over a long period including the decade pre-operatively, which, for most women, likely included several years prior to the first encounter with specialist care. This study specifically focused on older adult women, the demographic most likely to receive at TKA.[47] Given women's longevity and the likelihood of living alone in older age,[48] understanding functional outcomes after TKA within this group has substantial public health benefit.

CONCLUSIONS:

In conclusion, we found that Black women had poorer PF following TKA compared with White women of similar age. This disparity in PF by race was largely, but not fully, explained by poorer pre-operative PF. Black women had poorer PF scores and were more likely to have difficulties with daily mobility activities including walking and climbing stairs for many years prior to surgery. Efforts to reduce the racial gap in postoperative function should be aimed at reducing disparities in function pre-operatively and at reducing delays in time from disability to surgery in the population of older Black women. Further investigation into the social, economic, and cultural determinants of delayed TKA utilization among Black women in warranted. In addition, further research is needed to explain why Black women experience poorer PF in short term follow-up after TKA compared with other race/ethnic groups, even when accounting for pre-operative function. Similarly, additional research is needed to understand the greater diversity in experiences among Latinas.

Chapter 2, in full, is currently being prepared for submission for publication of the material. Cavanaugh, Alyson M; Rauh, Mitchell J; Thompson, Caroline A; Alcaraz, John; Mihalko, William M; Bird, Chloe E; Corbie-Smith G; Rosal, Milagros C; Li Wenjun; Shadyab, Aladdin H; Gilmer, Todd; LaCroix, Andrea Z.. Alyson Cavanaugh was the primary investigator and author of this material.

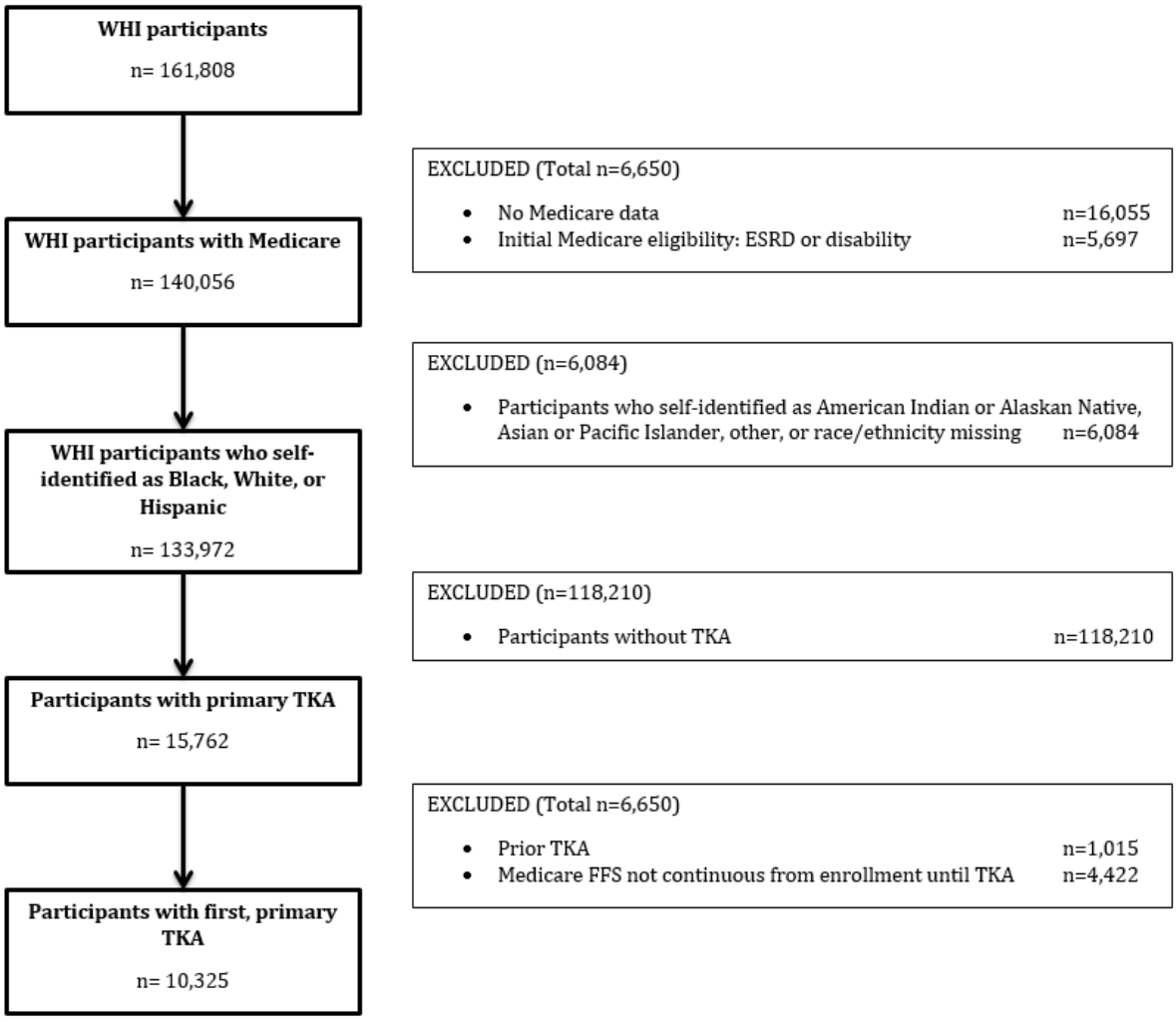

Figure 2.1: Study Population Determination Flow Chart

Table 2.1: Demographic and health characteristics of study participants by race/ethnicity

Characteristic	**White** n=9,528	**Black/ African American** n=622	**Hispanic/Latino** n=175	p-value
Age at surgery, *mean (SD)*	74.64 (5.52)	73.11 (5.30)	73.13 (5.24)	<0.0001
Region, *n (%)*				<0.0001
Midwest	20,85 (21.9)	144 (23.2)	22 (15.8)	
Northeast	2,671 (28.0)	98 (15.8)	90 (51.4)	
South	3,070 (32.2)	335 (53.9)		
West	1,702 (17.9)	45 (7.2)	54 (30.9)	
Marital Status, *n (% yes)*	6,519 (68.8)	335 (54.1)	112 (65.1)	<0.0001
Live Alone, n (% yes)	2,628 (29.8)	200 (35.8)	36 (24.7)	0.004
BMI, *n (%)*				<0.0001
Underweight/Normal weight: <25 kg/m^2	1,815 (19.2)	3 (5.0)		
Overweight: 25-<30 kg/m^2	3,323 (35.2)	167 (27.1)	48 (27.8)	
Obese I: 30- <35 kg/m^2	2,473 (26.2)	198 (32.1)	58 (33.5)	
Obese II/II: ≥35 kg/m^2	1,831 (19.4)	220(35.7)	68 (27.8)	
Multimorbidity Score (CMS-HCC), *median (IQR)*	0.61 (0.35-0.92)	0.65 (0.41-0.99)	0.55 (0.35-0.96)	<0.0001
Moderate-to-Strenuous Physical Activity, *n (%)*				<0.0001
None	3786 (39.8)	295 (47.6)	90 (52.0)	
1-<150 minutes/week	3,147 (33.1)	209 (33.7)	42 (24.3)	
>150 minutes/week	2,578 (27.1)	116 (18.7)	41 (23.7)	
Depressive Symptoms, n (% yes)	897 (9.4)	74 (12.0)	35 (20.6)	<0.001

Table 2.1: Demographic and health characteristics of study participants by race/ethnicity, continued

Characteristic	**White** n=9,528	**Black/ African American** n=622	**Hispanic/Latino** n=175	p-value
Educational Level, *n (%)*				<0.0001
Less than high school	248 (2.6)	52 (8.4)	28 (16.2)	
High school	1,698 (17.9)	89 (14.4)	31 (17.9)	
Some college	3,569 (37.6)	225 (36.3)	70 (40.5)	
College graduate	3,977 (41.9)	254 (41.0)	44 (25.4)	
Family Income, *n (%)*				<0.0001
<$20,000	939 (10.5)	126 (21.6)	40 (24.7)	
$20,000-<$50,000	4,136 (46.1)	262 (44.9)	69 (42.6)	
≥$50,000	3,897 (43.4)	195 (33.5)	53 (32.7)	
Neighborhood SES, *mean (SD)*	77.3 (7.0)	65.8 (11.4)	70.2 (10.5)	<0.0001

Abbreviations: CMS-HCC, Centers for Medicare and Medicaid Service Hierarchical Conditions Categories
Presentation of data is restricted to cells with counts >20

Table 2.2: Generalized estimating equation parameter estimates and predicted means at selected time points for physical function scores of women receiving TKA from the Women's Health Initiative, 1993-2014, n=7,987[a]

	Pre-TKA Physical Function Adjusted for age			**Post-TKA Physical Function** Adjusted for age			**Post-TKA Physical Function** Adjusted for age and pre-operative function		
	Estimate	Standard error	p-value	Estimate	Standard error	p-value	Estimate	Standard error	p-value
Intercept	71.37	3.08	<0.0001	136.32	3.55	<.0001	68.84	3.00	<0.0001
Race/Ethnicity									
Black	-5.83	1.11	<.01	-8.32	1.68	<.0001	-3.63	1.34	<.01
Hispanic	-2.74	1.700	0.12	-2.99	3.00	0.32	-2.02	2.45	0.41
White	0	(ref)		0	(ref)		0	(ref)	
Age	-0.26	0.04	<0.0001	-1.00	0.05	<.0001	-0.78	0.04	<0.0001
Pre-Operative	-	-	-	-	-	-	0.86	0.01	<0.000
Physical Function									1
Time from TKA(in	-8.59	0.29	<0.0001	0.29	0.37	0.43	0.33	0.37	0.38
years)	-1.18	0.07	<0.0001	-0.25	0.07	<.001	-0.24	0.07	<0.001
Quadratic time	-0.06	0.00	<0.0001	0.01	0.00	0.02	0.01	0.00	0.02
Cubic time									
Interaction with time[b]									
Black				0.50	0.27	0.06	0.51	0.24	0.04
Hispanic				0.33	0.46	0.47	0.35	0.43	0.42
White				0	(ref)		0	(ref)	

Table 2.2: Generalized estimating equation parameter estimates and predicted means at selected time points for physical function scores of women receiving TKA from the Women's Health Initiative, 1993-2014, n=7,987[a], continued

	Pre-TKA Physical Function Fit for age 74 at TKA[b]		**Post-TKA Physical Function** Fit for age 74 at TKA[b]		**Post-TKA Physical function** Fit for age 74 at TKA and pre-operative function of 60[c]	
	predicted mean	(95% CI)	predicted mean	(95% CI)	predicted mean	(95% CI)
1 year from TKA						
Black	53.6	(51.5-55.8)	54.5	(51.7-57.4)	59.5	(57.3-61.8)
Hispanic	56.7	(53.2-60.2)	59.7	(54.4-65.1)	61.0	(56.8-65.2)
White	59.5	(58.9-60.0)	62.4	(61.7-63.1)	62.7	(62.1-63.1)
2 years from TKA						
Black	59.1	(56.9-61.2)	54.7	(52.1-57.2)	59.7	(57.6-61.7)
Hispanic	62.2	(58.7-65.6)	59.6	(54.7-64.6)	61.0	(57.2-64.8)
White	64.9	(64.3-65.5)	62.0	(61.4-62.5)	62.3	(61.8-62.7)
5 years from TKA						
Black	67.1	(65.0-69.3)	52.9	(50.6-55.2)	58.2	(56.4-60.0)
Hispanic	70.2	(66.7-73.7)	57.4	(52.7-62.0)	59.0	(58.8-59.7)
White	72.9	(72.4-73.5)	58.7	(58.1-59.3)	59.3	(60.8-61.8)
10 years from TKA						
Black	73.9	(71.7-76.1)	46.7	(42.9-50.4)	52.4	(49.2-55.7)
Hispanic	77.0	(73.5-80.5)	50.3	(43.3-57.3)	52.5	(46.2-58.8)
White	79.7	(79.0-80.4)	50.0	(49.1-50.8)	51.0	(50.3-51.8)

[a]Physical function scores correspond to RAND-36 physical function scale

[b]Race/ethnicity by time interaction was not significant at p<.10 level and dropped from the pre-operative physical function model.

[c]Estimated physical function for age 74 at time of TKA and physical function of 60 at 1-year prior to TKA based on generalized estimating equation models that include age at TKA and physical function scale scores at 1 year prior to TKA.

Abbreviations: TKA, total knee arthroplasty; CI, confidence interval

Table 2.3: General estimating equation (GEE) parameter estimates and odds ratios from marginal logistic regression models for outcomes of experiencing specified activity limitations in the decade prior to TKA, Women's Health Initiative, n=9,920[a]

	Walking One Block			**Walking Several Blocks**			**Climbing a flight of stairs**		
	Estimate	Standard error	p-value	Estimate	Standard error	p-value	Estimate	Standard error	p-value
Intercept	-2.18	0.23	<0.0001	-1.08	0.14	<0.0001	-0.70	0.25	<0.0001
Race/Ethnicity									
Black	0.62	0.09	<0.0001	0.62	0.10	<0.0001	0.40	0.10	<0.0001
Hispanic	0.06	0.17	0.74	0.27	0.19	0.16	0.52	0.18	<0.01
White	0	(ref)		0	(ref)		0	(ref)	
Age	0.02	0.00	<0.0001	0.02	0.00	<0.0001	0.01	0.00	<0.01
Time from TKA(in	0.60	0.04	<0.0001	0.48	0.02	<0.0001	0.46	0.03	<0.0001
years)	0.10	0.01	<0.0001	0.07	0.01	<0.0001	0.07	0.01	<0.0001
Quadratic time	0.01	0.00	<0.0001	0.00	0.00	<0.0001	0.01	0.00	<0.0001
Cubic time									
Interaction with Time*									
Black				-0.03	0.02	0.07	-0.04	0.24	<0.0001
Hispanic				0.01	0.03	0.71	0.01	0.02	0.79
White				0	(ref)		0	(ref)	

Table 2.3: General estimating equation (GEE) parameter estimates and odds ratios from marginal logistic regression models for outcomes of experiencing specified activity limitations in the decade prior to TKA, Women's Health Initiative, n=9,920[a,] continued

	AOR (95% CI)		AOR (95% CI)		AOR (95% CI)	
1 year prior to TKA						
Black	1.86	(1.57-2.21)	1.91	(1.60-2.28)	1.55	(1.29-1.85)
Hispanic	1.06	(0.75-1.49)	1.29	(0.92-1.80)	1.67	(1.21-2.31)
White	1.0	(ref)	1.0	(ref)	1.0	(ref)
2 years prior to TKA						
Black	1.86	(1.57-2.21)	1.96	(1.67-2.31)	1.61	(1.36-1.90)
Hispanic	1.06	(0.75-1.49)	1.27	(0.94-1.73)	1.66	(1.23-2.23)
White	1.0	(ref)	1.0	(ref)	1.0	(ref)
5 years prior to TKA						
Black	1.86	(1.57-2.21)	2.14	(1.83-2.50)	1.81	(1.55-2.12)
Hispanic	1.06	(0.75-1.49)	1.22	(0.90-1.66)	1.61	(1.20-2.17)
White	1.0	(ref)	1.0	(ref)	1.0	(ref)
10 years prior to TKA						
Black	1.86	(1.57-2.21)	2.48	(1.94-3.17)	2.20	(1.72-2.82)
Hispanic	1.06	(0.75-1.49)	1.15	(0.68-1.93)	1.55	(0.96-2.49)
White	1.0	(ref)	1.0	(ref)	1.0	(ref)

*Interaction with time not significant at p<.10 level and dropped from model for outcome of walking one block.

Abbreviations: TKA, total knee arthroplasty; AOR, adjusted odds ratio; CI, confidence interval

[a] Odds ratios are adjusted for age, time, quadratic time, cubic time, and interaction of race/ethnicity by time as reported in GEE model estimates listed above

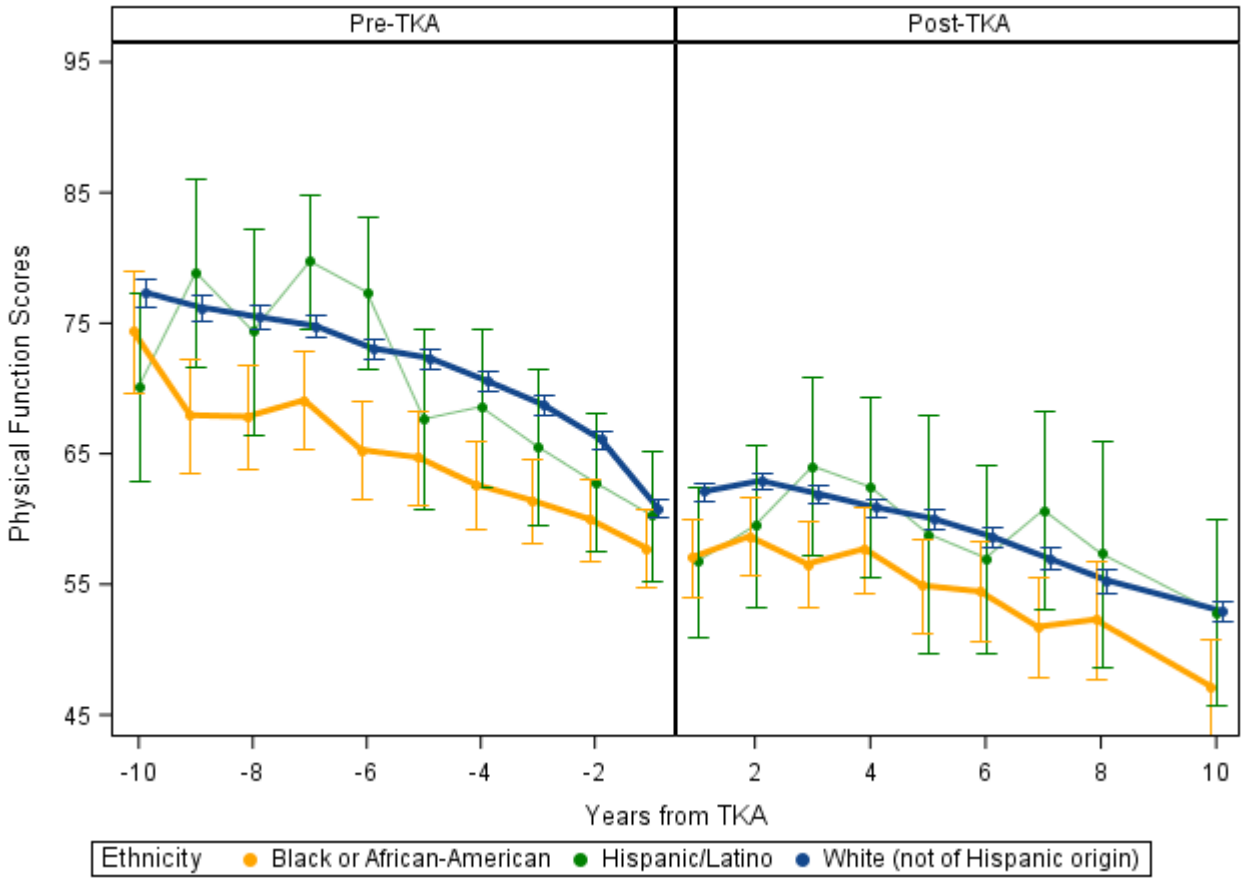

Figure 2.2: Unadjusted mean physical function pre- and post-TKA by race/ethnicity

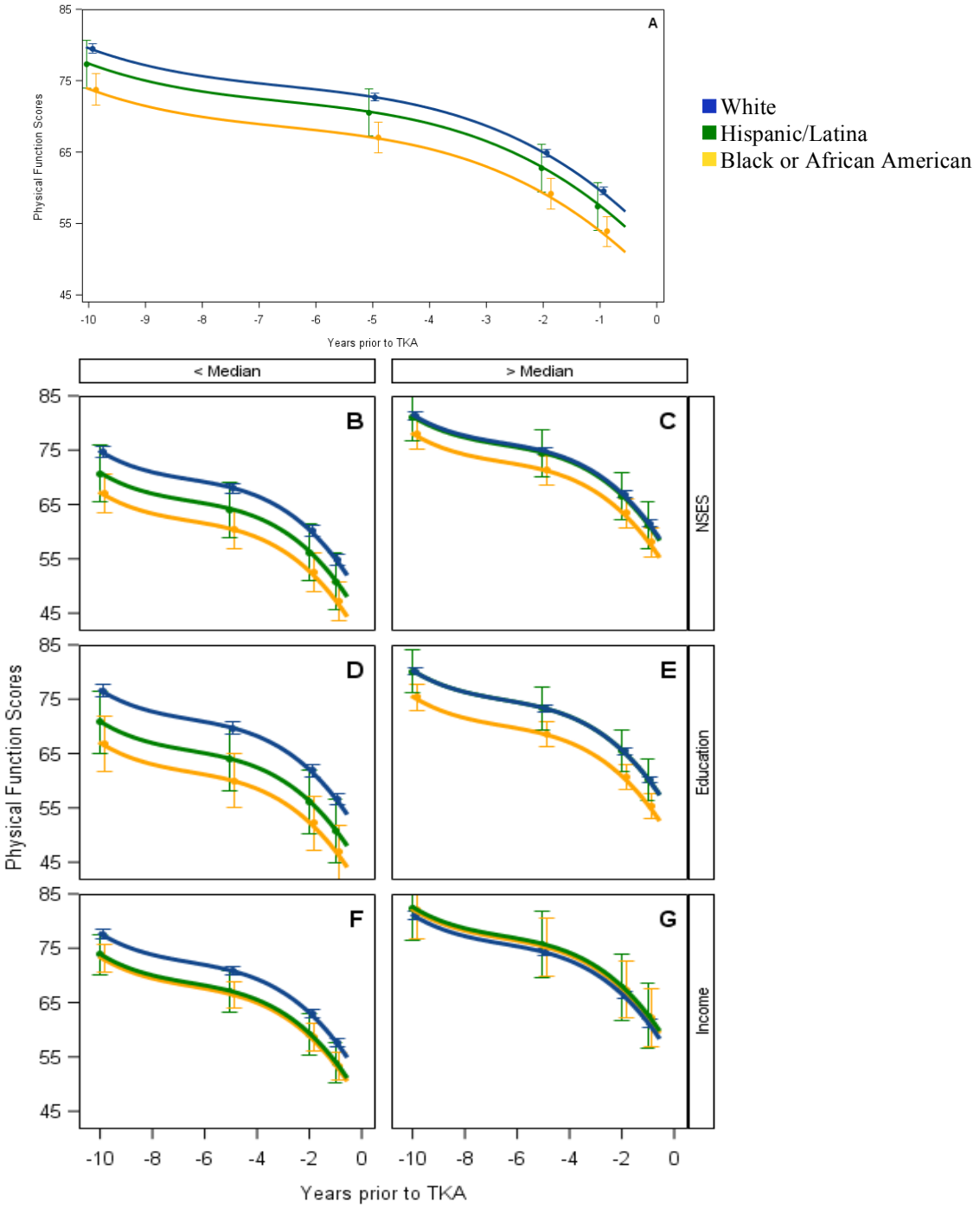

Figure 2.3: Pre-operative physical function for the decade prior to TKA by race/ethnicity, in full analytic sample and with stratification by socioeconomic status.

Values are predicted marginal means from GEE models fit for age 74 at time of TKA. A) full analytic sample B) women with education of high school completion/GED or lesser attainment C) women with educational attainment of some college/ vocational training or higher D) women with annual family income less than $35,000 E) women with annual family income $35,000 or greater F) women with neighborhood socioeconomic status (NSES) <77.68 G) women with NSES ≥77.68.

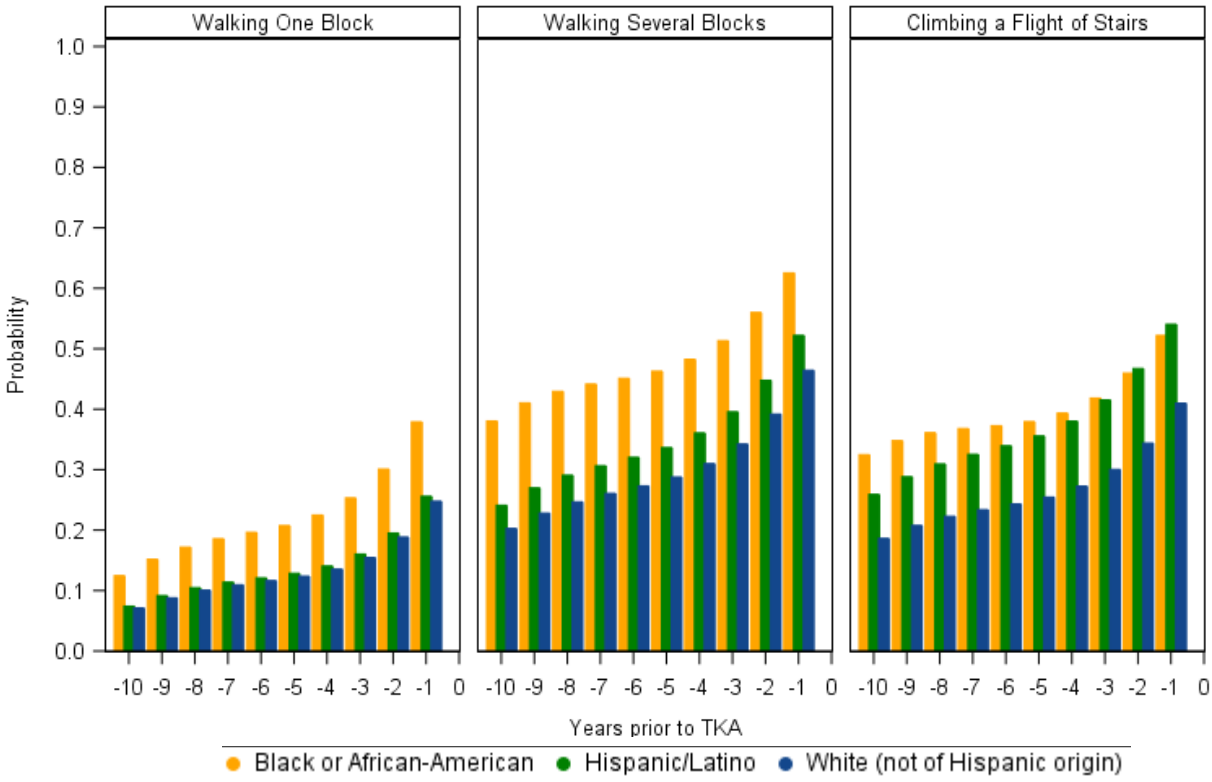

Figure 2.4: Probability of experiencing difficulty with activity in the decade prior to TKA, by race/ethnicity.

Predicted probability determined from generalized estimating equation models fit for age 74 at time of TKA.

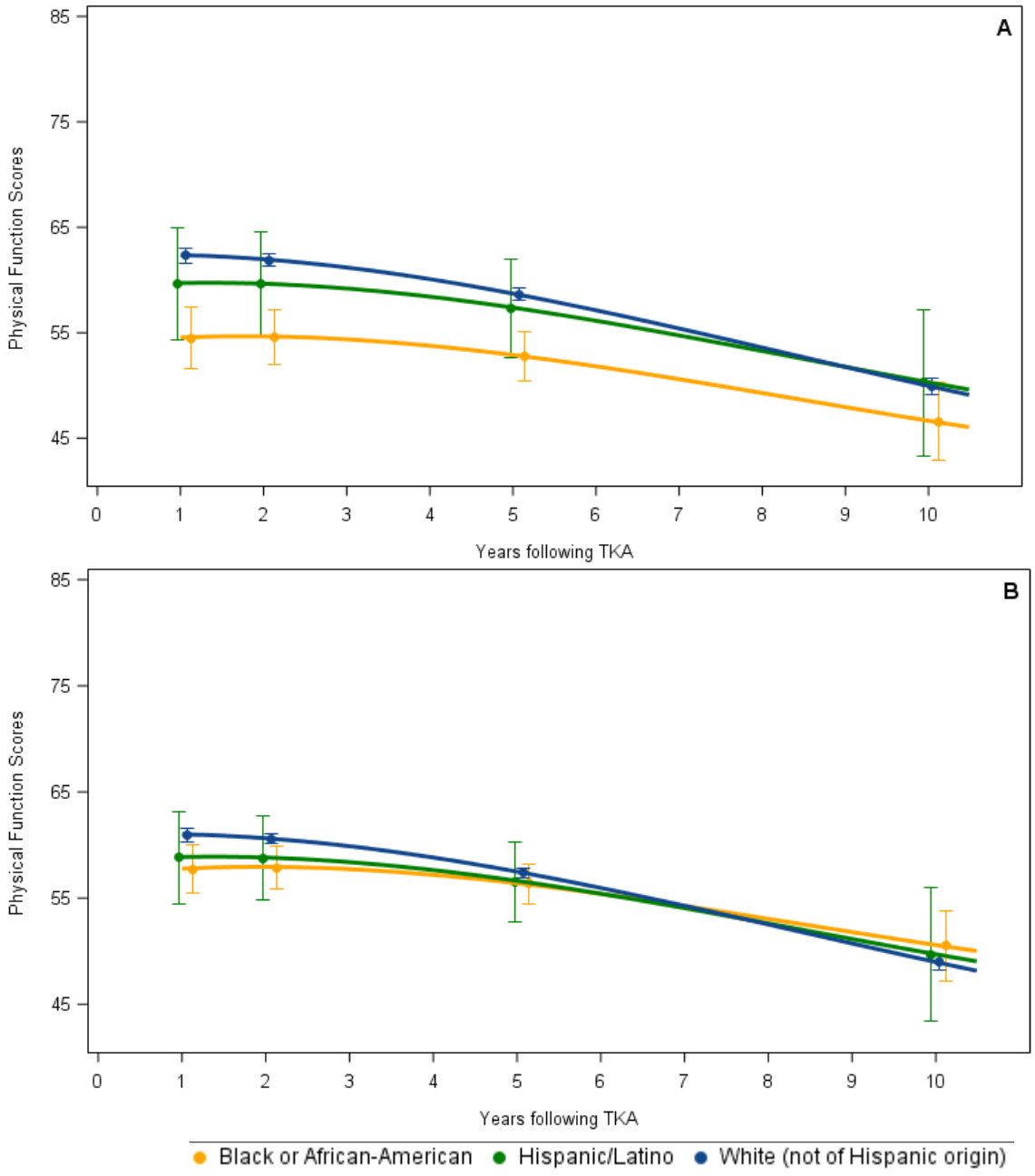

Figure 2.5: Physical function in the decade following TKA without and with adjustment for pre-operative function

A) Adjusted for age; physical function estimates from model fit for age 74 at time of TKA
B) Adjusted for age and pre-operative physical function at 1-year prior to TKA; physical function estimates from model fit for age 74 at TKA and pre-operative physical function scale score of RAND-36=60

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CHAPTER THREE

Rehabilitation after Total Knee Arthroplasty: Do Racial Disparities Exist?

ABSTRACT

Objective: To estimate racial disparities in rehabilitation utilization following total knee arthroplasty (TKA)

Design: Prospective Women's Health Initiative cohort with linked Medicare claims data

Setting: Community-dwelling population

Participants: A total of 8,349 older women from throughout the US who underwent primary TKA between 2006 and 2013

Interventions: Not applicable

Main Outcome measures: Rehabilitation utilization was measured by post-acute discharge destination (home, skilled nursing facility, inpatient rehabilitation facility), facility length of stay, and number of home health and outpatient physical therapy (PT) sessions.

Results: Non-Hispanic Black women had worse physical function (median score: 65 vs. 70) and higher likelihood of disability (13.2% vs. 6.9%) than White women prior to surgery. After TKA, Black women were more likely to be discharged post-acutely to an institutional facility (64.3% vs. 54.5%) than non-Hispanic White women, were more likely to receive home health PT services (52.6% vs. 47.8%), and received higher numbers of both home health and outpatient PT sessions. After stratification by post-acute discharge setting, the likelihood of receipt of home or outpatient PT services was similar between racial groups. No significant difference in receipt of

home or outpatient PT services was found after use of propensity score weighting to balance health and medical characteristics that indicate severity of need for PT services.

Conclusions: Utilization of rehabilitation services was generally comparable between Black and White women who received TKA when accounting for need for services. There was no evidence of underutilization of post-TKA rehabilitation services, and thus disparities in post-TKA functional outcomes do not appear to be a result of inequitable receipt of rehabilitation care.

INTRODUCTION:

Total knee arthroplasty (TKA) may soon be the most common elective procedure performed in the United States, with an estimated 4.7 million Americans living with a total knee replacement in 2010.[1] Despite the prevalence of the procedure, Black adults are significantly less likely to undergo a total knee arthroplasty (TKA).[2] Black adults have lower willingness to consider a TKA as a treatment option, citing lower expectations of benefit from the procedure as one reason for their preference.[3] Unfortunately, the limited expectations of benefit among Black patients with arthritis may not be wholly unjustified. Black patients who undergo total knee arthroplasty (TKA) tend to have poorer functional outcomes compared to white patients.[4,5] The reasons underlying disparities in functional outcomes remain unexplained. While racial patterns of utilization of rehabilitation care post-TKA have not been comprehensively evaluated, the underutilization of postoperative rehabilitation care could potentially contribute to the poorer physical function outcomes in black patients. Race disparities in rehabilitation utilization have been well-documented for other diagnoses and conditions including stroke and cardiac events.[6–9] While the underutilization of outpatient physical therapy services for black adults with arthritis has been reported,[10] disparities in physical therapy following TKA have yet to be comprehensively studied.

Rehabilitation, with a focus on physical therapy (PT), is indicated for improving range of motion and strength, reducing pain, and improving functional mobility following TKA. While physical therapy is considered standard care following TKA, no formal consensus about the optimal intensity, duration, or setting for physical therapy services has been established.[11,12] Physical therapy during acute hospitalization following surgery is primarily focused on early mobilization for discharge to post-acute setting. Post-acute rehabilitation focuses on maximizing

functional recovery and has been shown to be associated with improved short term outcomes including reduced pain and improved physical function.[13]

The purpose of this study was to provide detailed information on whether rehabilitation utilization following TKA differs between non-Hispanic White and Black/African American older women. Post-acute discharge destination, uptake and intensity of home health physical therapy (HHPT) and outpatient physical therapy (OPPT) were examined through unadjusted analyses, through stratification by post-acute discharge setting, and with use of propensity score weighting to balance indicators of need for more intensive PT services.

METHODS:

Study population

This study used data from the Women's Health Initiative (WHI) Clinical Trials (CT) and Observational Study (OS). WHI is an ongoing prospective study described in detail elsewhere.[14,15] Briefly, 161,808 post-menopausal women were recruited from 40 clinical centers throughout the United States from 1993-1998 and followed prospectively until study close in 2005. A series of extension studies began in 2005, and surviving women who consented are still followed to present day. Medicare claims data are linked to consenting WHI participants. The analytic population for this study was limited to women in WHI who underwent TKA from July 1, 2006 through December 31, 2013 and who self-identified as non-Hispanic White or non-Hispanic Black/African American race, hereafter referred to as White and Black, respectively (Figure 3.1). Medicare fee-for-service (FFS) claims were used to identify women with TKA using the Ninth Revision of the International Classification of Diseases, Ninth Revision, (ICD-9) primary procedure code 81.54.

The analytic sample included women who received either unilateral or bilateral procedures on date of surgery. However, staged procedures, where a contralateral TKA was performed within one year from first TKA were excluded, as this additional surgery would likely initiate another postoperative rehabilitation course of treatment within the year. If a WHI participant had a contralateral TKA performed more than 1 year after the first primary TKA, only the first TKA was included in the analysis, as rehabilitation utilization within-individual and between successive TKAs is likely highly correlated. We excluded women who died within 90 days of procedure. Women without FFS Part A and B coverage for the year prior to and the year following surgery were excluded, as this limited our ability to determine pre-TKA health status and to determine rehabilitation utilization for the postoperative year.

The analysis was restricted to women receiving TKA on or after July 1, 2006, which was the effective date of a Centers for Medicare & Medicaid Services (CMS) policy change commonly referred to as the "60% rule."[16] According to the policy, 60% of an IRF patient population must be admitted for treatment of thirteen qualifying diagnoses in order for the facility to qualify for Medicare payments. While TKA is included in the list of thirteen diagnoses, the diagnosis is only eligible to be included in the compliance threshold if bilateral TKA procedures are performed or if the patient has comorbidities of advanced age (over 85 years) or extreme obesity (body mass index over 50). The "60% rule" is a relaxation of the "75% rule" implemented in 2004. Time trends have found significant changes over time with a reduced proportion of TKA patients discharged to IRF settings coinciding with the timing of the implementation of the policies.[17] We have limited our study to those receiving TKA after implementation of the "60% rule," which is still in effect today, to reflect current rehabilitation utilization practices.

Demographic and Health Variables

Demographic characteristics including race, highest educational attainment, income, and geographic region were collected at time of WHI enrollment through questionnaire. Neighborhood socioeconomic status(NSES) was a computed variable derived from participant zip code residence at time of enrollment and corresponds to 2010 census tract information regarding levels of poverty, education and other SES variables within the geographic region. NSES values range 0-100 with higher numbers corresponding to higher affluence.

Information about marital status, living arrangement, and physical function status was collected at baseline and through mailed follow-up questionnaires. The data collected prior to and closest to date of surgery was used for analysis. Marital status was dichotomized (yes/no) according to self-report of being currently married/in an intimate relationship. Living arrangement was dichotomized as living alone or living with others. Special services available at residence was determined through response to the question "Does the place (home, apartment, assisted living facility) where you live have special services for older people (such as help with transportation, meals, medicines, or bathing)?" Questions regarding physical function and activities of daily living (ADL) were collected as part of the RAND 36-Item Health Survey questionnaire.[18] Physical function was derived from the physical function subscale of the Rand-36 and ranges from 0-100. ADL disability was categorized dichotomously according to any reported limitation in the Rand-36 item assessing ability to bathe and dress independently. Marital status, physical function, and ADL data were collected at WHI enrollment, at one year of follow-up and study close, with a 25% subsample completing additional surveys at three, six,

and nine years of follow-up for CT participants. For OS participants, marital status, physical function, and ADL data was collected at baseline and three years later. Beginning in 2005, the RAND-36 questions were administered annually to all Extension Study participants. Data regarding living arrangements were administered at baseline for all participants, at study closeout for CT participants, and the second year of Extension Study 2.

Multimorbidity at time of surgery was calculated according to the CMS Hierarchical Condition Category (CMS-HCC) model, which is used for risk adjustment for capitation payments.[19] The HCC includes 70 disease categories, determined by ICD-9 billing codes used in Part A and B FFS claims for beneficiaries for one year preceding the date of surgery for TKA. The average risk adjustment score is set at 1.0.[20] Those with lower scores are considered relatively healthy individuals with lower than average healthcare spending.

Acute inpatient hospitalization length of stay is typically longer for patients with more medical complexities and may represent intraoperative complications or postoperative complications in recovery.[21] Acute hospitalization length of stay was determined through Medicare Provider Analysis and Review (MEDPAR) files from the hospitalization claims from TKA procedure and was categorized as: 3 or fewer days, 4 to 6 days, or 7 or more days. Major medical complications related to TKA were determined through ICD-9 codes that indicated myocardial infarction (ICD-9 codes: 410.00, 410.01, 410.10, 410.11, 410.20, 410.21, 410.30, 410.31, 410.40, 410.41, 410.50, 410.51, 410.60, 410.61, 410.70, 410.71, 410.80, 410.81, 410.90, 410.91); venous thromboembolism (VTE) (ICD-9 codes: 415.1, 415.11, 415.19, 451.11, 451.19, 451.2, 451.81, 451.9, 453.40, 453.41, 453.42, 453.8, 453.9); and wound infection (ICD-9 code:

682.5, 682.6, 682.8, 682.9, 998.51, 998.59).[3] Readmissions within 30 days were defined as readmission to any acute care hospital within 30 days of discharge.

Outcomes:

Post-Acute Discharge Destinations:

Discharge destination following the index hospital admission, when TKA was performed, was categorized as home, IRF, or skilled nursing facility (SNF), as determined by discharge destination code from the inpatient hospitalization claims. Discharge destinations of hospice, long-term care hospital, or other hospital or care facilities were excluded from analyses due to small counts of participants discharged to these settings. LOS in institutional settings (IRF and SNF) were determined contingent on post-acute discharge to that setting and were summed for participants with more than one admission to the respective setting within 30 days from TKA procedure. SNF claims were identified through the SNF indicator code in MEDPAR files. IRF claims were identified using special unit codes identifying PPS-exempt rehabilitation unit or hospital within MEDPAR files.

Home Health Physical Therapy (HHPT):

Home health visits were determined through Home Health claims using revenue center codes 042x or with CPT codes G0151, G0157, and G0159. Dates of service for HHPT within 365 days of the date of surgery were summed to calculate total number of HHPT visits. Number of HHPT visits were determined regardless of initial discharge destination.

Outpatient Physical Therapy (OPPT):

Intensity of OPPT services were determined through Medicare Outpatient and Carrier claims data. Physical therapy visits were located in the outpatient file using revenue center codes beginning with 042x.[22] Physical therapy visits were located in the Carrier file using provider specialty code 65. Dates of service for OPPT within 365 days of the date of surgery were summed to calculate total number of OPPT visits.

Additional Physical Therapy:

After discharge from post-acute destination, additional PT services may be received as part of the continuum of rehabilitation. Receipt of either HHPT or OPPT was categorized as receiving additional PT services.

Statistical methods

Descriptive statistics of participant characteristics by race were tested using chi-square and t-test for categorical and non-normally continuous data, respectively. Wilcoxon-Mann-Whitney test was used for non-normally distributed continuous variables.

To evaluate racial disparities in receipt of additional PT services after discharge to the home, log-binomial regression was performed with stratification by post-acute discharge destination. Stratification was performed because the intensity of rehabilitation received differs dramatically by post-acute discharge destination, and therefore, the need for additional physical therapy services (HHPT or OPPT) was hypothesized to differ by post-acute discharge setting. In addition, pre-operative functional status also likely affects discharge destination placement and may factor into need for additional PT services.[23] It was assumed that stratification would provide some control for level of need for additional PT, but it was suspected that residual confounding after stratification would remain. Thus, propensity scores were used make the two

race groups more comparable based on pre-hospital health status and surgical/medical complications, as these could warrant more or less therapeutic intervention. Inverse probability of treatment weighting (IPTW) was used to achieve balance of pre-hospital discharge characteristics between racial groups with a goal of evaluating the influence of race in regards to access to and coordination of rehabilitation care after discharge to the home. Similar propensity score weighting methodology has been previously used to evaluate racial disparities in rehabilitation utilization after traumatic brain injuries and burn injuries.[24,25]

Propensity scores were determined for the subgroups of women in each of the three post-acute discharge destinations using logistic regression with race regressed on age at time of TKA, BMI, multimorbidity, pre-operative physical function, ADL disability, bilateral versus unilateral procedure, and medical complications including acute hospitalization LOS, MI, VTE, infection, and 30-day readmission. Common support was assessed through graphical comparisons of the propensity score distributions.[26] Stabilized IPTW was applied,[27] and mean standardized differences were compared in unweighted and weighted baseline covariates. Distributions of continuous variables in the weighted sample were assessed using graphical comparisons.[28] After achieving balance, the likelihood of receiving additional PT services (either OPPT or HHPT), OPPT, and HHPT was then determined using log-binomial regression models for each outcome, with race as the predictor variable and stabilized weights applied to balance the medical/health characteristics listed above.

All analyses were performed using Statistical Analysis Software Version 9.4 (SAS Institute Inc., Cary, NC, USA). P-values were considered significant at values <0.05.

RESULTS:

This study included 8,349 women who underwent TKA, with 92.8% of the sample White women and 7.3% Black women. Black women who underwent TKA tended to be younger ($p<0.0001$), less likely to be married ($p<0.0001$) and more likely to live alone ($p<0.001$) (Table 3.1). In general, Black women had lower incomes, education, and neighborhood SES than White women ($p<0.0001$ each). While multimorbidity scores appeared comparable for White and Black women (median CMS-HCC score=0.6 for both groups), Black women were more likely to have ADL disability (13.2% vs. 6.9%, $p=<0.0001$) and lower physical function (Black: median score=65 vs. White: 70, $p=<0.001$). There was no significant difference between Black and White women in the proportion who underwent bilateral procedures. Black women were significantly more likely to experience VTE after TKA ($p=0.04$) and be readmitted within 30 days ($p=0.04$), but no significant difference was detected in other medical complications of joint infection or MI.

Following TKA, Black women were less likely than White women to be discharged home post-acutely (35.8% vs.46.1%, $p<0.0001$; Table 3.2) and thus more likely to be discharged to institutional settings. Proportions of women discharged to IRF settings were similar between racial groups (43.7% vs. 43.4%), but Black women were more likely to be discharged to SNFs than White women (20.6% vs. 11.0%). When discharged to institutional rehabilitation settings, Black women had longer stays, thus receiving more days of rehabilitation. For those discharged to SNFs, Black women had median LOS five days longer than White women ($p<0.0001$), and for those discharged to IRFs, Black women had longer median LOS by one additional day (equivalent to three additional hours of therapy services) compared to White women ($p=0.01$). A higher proportion of Black women received HHPT services (52.6% vs. 47.8%, $p<0.02$), and, conditional on receiving HHPT, Black women received more visits (median number of visits 10

vs. 9, p<0.001). There was no significant difference in receipt of any OPPT, but for those who did receive OPPT, Black women received more visits than White women (median number of visits 17.5 vs. 16.0, p=0.01)

Likelihood of use of PT services after discharge home was assessed through stratification by initial post-acute discharge setting. There was no significant difference between racial groups in utilization of additional PT services (HHPT or OPPT) whether women were post-acutely discharged to a SNF [RR: 1.01; 95%CI: 0.93-1.10;(Table 3.3)], IRF (RR: 0.92; 95%cCI 0.83-1.02), or directly home (RR:0.91, 95%CI 0.82-1.02).

Propensity score weighting was used to balance health and medical characteristics that might warrant more or less intensive PT services after discharge home and including age at TKA, body mass index, CMS-HCC score, pre-operative physical function score, pre-operative ADL disability, bilateral TKA procedure, and medical complications including myocardial infraction, venous thromboembolism, infection, length of stay during index hospitalization, and 30-day hospital readmission. The mean stabilized weight was equal to 1.00 in each of the three strata of discharge destination, with a standard deviation of 0.19, 0.24, and 0.44 in the home, SNF, and IRF strata, respectively. The minimum and maximum weights were 0.25-6.01, 0.13-7.74 and 0.26-9.58 in the home, SNF, and IRF strata, respectively. The absolute standardized difference ranged from 0.02 to 0.55 among unweighted covariates and were <0.20 among all weighted covariates.

After weighting using propensity scores, there remained no significant difference in receipt of additional PT services for women post-acutely discharged to an IRF (RR=1.00, 95% CI: 0.92-1.08), SNF (RR=0.94, 95%CI: 0.86-1.04) or home(RR=0.93,95% CI 0.84-1.04).

DISCUSSION:

In this study of post-menopausal women with Medicare FFS coverage, Black women who underwent TKA were more likely to receive post-TKA physical therapy services and received more physical therapy services compared to White women. Prior research has demonstrated that Black women with need of TKA are significantly less likely than their White peers to undergo the procedure, and among women who elect to undergo TKA, Black women are more likely to delay surgical intervention, live multiple years with mobility limitations, and present at time of surgery with worse physical function.[29,30] Because of long-standing deficits in mobility, more intensive rehabilitation services may be required to optimize functional outcomes among Black women. In this study, Black women had poorer functional status prior to undergoing TKA, experienced longer length of acute hospitalization following TKA, and had more frequent complications requiring readmission within 30 days. With unadjusted analyses, Black women received more intensive rehabilitation services. After accounting for higher levels of need for rehabilitation among Black women, utilization of PT services after discharge home appeared similar between race groups.

With relatively short acute hospitalization stays post-TKA, the bulk of rehabilitation services are typically received through post-acute care. With the rising attention on cost-effectiveness of healthcare delivery, there has been a trend over the past few decades towards post-acute discharge to home instead of institutional settings following TKA.[17] Home discharge post-TKA has been associated with better clinical outcomes and lower insurance costs.[17,31,32] Despite this movement toward home discharge, Black women in this study were more likely to receive institutional care post-acutely following TKA than White women. Our findings of a higher likelihood of institutional discharge placement by Black Medicare beneficiaries are

consistent with several studies that have addressed predictors of post-acute discharge destination and found older adult Black patients were more likely to be discharged to institutional settings than home, and, conditional on discharge to an institutional setting, are more likely to receive IRF care compared to SNF.[33–35] Factors such as level of severity/need for more intensive care are known to influence post-acute discharge destination.[35] In our study, Black women had higher BMI, lower physical function, and greater prevalence of ADL disability prior to TKA, signifying a poorer pre-morbid status and potential greater need for institutional care following surgery. In addition to pre-hospital health/functional levels, availability of family support, residence in an urban versus rural setting, proximity to institutional care facilities, and socioeconomic status are known determinants of discharge placement. In our study, Black women were significantly less likely to be married and more likely to live alone, which would likely affect the ability to safely discharge home following TKA. The association of lower SES and institutional placement is not well understood, but it has been hypothesized that the association of lower SES with poorer pre-morbid health condition may indicate more intensive support following TKA. Alternatively, lower SES may indicate fewer resources and support available for home discharge placement.[33]

With the emergence of bundled payment initiatives, acute care facilities likely have greater motivation to discharge patients to a home setting, as this may allow them to retain a greater proportion of the overall payment for the procedure. As more patients may be discharged to a home setting in the coming years, it is critical to ensure that patients are linked to and receive necessary rehabilitation interventions to ensure optimal outcomes. Often after discharge to home, whether immediately post-acute or after receiving services from an institutional setting, additional physical therapy services, either HHPT and/or OPPT are needed. These additional physical therapy services are aimed at progressing the patient's strength, motion, mobility, and

endurance to optimize function in the home and/or community settings. While some patients receive HHPT followed by OPPT, others may receive one type of service, and others may receive no additional services. Though limited, the research available to date has failed to show significant differences in functional outcomes when comparing receipt of OPPT versus HHPT,[13] and thus in this study, we focused on the receipt of any additional type of service (HHPT or OPPT) after discharge to home rather than focusing on receipt of a specific type of additional PT. After stratifying by discharge destination and after additionally accounting for pre-surgical health and surgical complications, our study failed to find a significant difference between racial groups in utilization of additional PT services (OPPT or HHPT). Despite significant differences in SES which are known to affect healthcare utilization,[36] our findings suggest that Black and White women post-TKA have similar likelihood to receive additional PT services in the home or outpatient settings.

These findings have important implications for the changing reimbursement climate and the rise of bundled care initiatives for payment following TKA. Prevention of discontinuous rehabilitation care is vital to ensuring optimal outcomes. Our findings reveal that regardless of initial post-acute discharge destination, Black women are equally likely to access and use additional PT services. These findings provide reassurance that once safe discharge to home is possible, continuity of rehabilitation does not differ by race. Our data suggests a slight preferential use of HHPT among Black women discharged from the IRF, which may be attributed to the ease of receiving services in the home rather than in an outpatient setting (i.e., no Medicare co-payments or additional costs, no need for transportation, nor associated transportation costs).

Our failure to find evidence of underutilization of rehabilitation among Black women

suggests that disparities in post-TKA functional outcomes are not the result of differences in post-acute rehabilitation. Black women had poorer pre-operative health and function and received more intensive rehabilitation services. While it appears that Black women receive equitable rehabilitation care post-TKA when accounting for need, it may not be enough to counteract the racial disparities in physical function that persist for multiple years prior to TKA.

Several limitations of our study are noteworthy. We did not examine receipt of institutional rehabilitation care received outside of post-acute discharge placement, which may have impacted the total amount of rehabilitation utilization received by a small percentage of the sample who received either multiple institutional rehabilitation services or who received services different than those specified in acute hospitalization claims data. Functional outcomes were not linked with utilization. Although it appear that utilization of additional PT services was similar when accounting for need, we cannot be certain that the amount of PT was optimal for functional improvement. At this time, no conclusive evidence exists that demonstrates superiority of OPPT over HHPT for functional outcomes post-TKA,[13] and thus receipt of any type of additional service was used to signify that patients were linked with appropriate rehabilitation care. Future studies linking HHPT and/or OPPT utilization with improvement of functional outcomes are necessary to determine best pathways and settings for optimal improvement.

These limitations are balanced by key strengths. This study used prospectively collected self-reported data in combination with medical claims data, which allowed for the assessment rehabilitation utilization while accounting for pre-operative function and health, as well as TKA-related medical complications. Whereas previous studies of post-acute discharge destination have focused on single institution data or on state inpatient databases,[33,34] this study population included a large group of diverse, community-dwelling older women throughout the United

States, thus allowing for a greater generalizability of findings.

In summary, there was no evidence of lower utilization of post-TKA rehabilitation among Black women, and thus racial disparities in post-TKA functional outcomes do not appear to be a result of inequitable receipt of rehabilitation care. Further research into the functional improvements achieved with rehabilitation may help to explore whether intensity of post-TKA rehabilitation can mediate differences in physical function present prior to surgery.

Chapter 3, in full, is currently being prepared for submission for publication of the material. Cavanaugh, Alyson M; Rauh, Mitchell J; Thompson, Caroline A; Alcaraz, John; Bird, Chloe E; Gilmer, Todd; LaCroix, Andrea Z.. Alyson Cavanaugh was the primary investigator and author of this material.

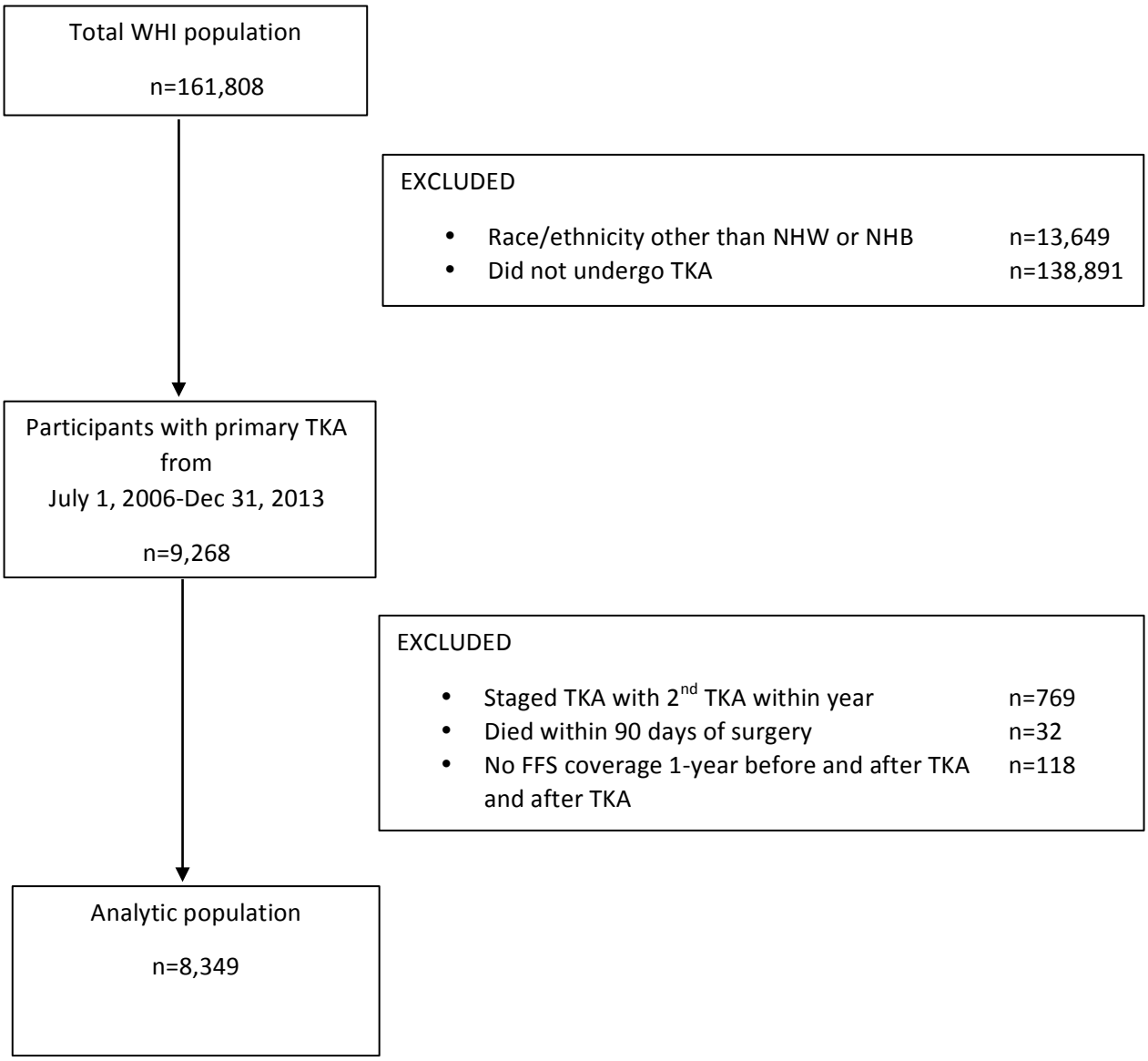

Figure 3.1: Study Population Determination Flow Chart

Table 3.1: Descriptive statistics of women who underwent primary TKA from 2006-2013, Women's Health Initiative, n=8,349.

Characteristic	Black/African American n=603	Non-Hispanic White n=7,746	p-value
Age at surgery, mean (SD)*	74.3 (5.5)	76.5 (5.6)	<0.0001
Marital status (% married) †	344 (58.1)	5,626 (73.1)	<0.0001
Living alone (% yes) †	204 (37.9)	2,184 (30.4)	<0.001
Special services available at residence†	41 (10.3)	837 (13.1)	0.10
BMI†			<0.0001
Underweight/Normal weight	28 (4.7)	1,572 (20.4)	
Overweight	171 (28.5)	2,762 (35.9)	
Obese I	185 (30.9)	2,078 (25.6)	
Obese II	111 (18.5)	932 (12.1)	
Obese III	104 (17.4)	433 (5.7)	
Multimorbidity Score, median (IQR)‡	0.6 (0.4-0.9)	0.6 (0.4-0.9)	0.96
Pre-surgical functional status, median, (IQR) ‡	65 (40-85)	70 (45-85)	0.0001
ADL disability (% yes) †	78 (13.2)	532 (6.9)	<0.0001
Family Income†			<0.0001
<$20,000	120 (21.4)	769 (10.5)	
$20,000-<$50,000	244 (43.5)	3,316 (45.2)	
≥$50,000	197 (35.1)	3,252 (44.3)	
Education†			<0.0001
Less than high school	58 (9.1)	237 (2.9)	
High school	97 (15.2)	1,539 (18.9)	
Some college	241 (37.8)	3,168 (38.9)	
College graduate	241 (37.8)	3,202 (39.3)	
NSES, mean (SD)*	65.4 (11.6)	77.2 (6.8)	<0.0001

Abbreviations: BMI, body mass index; NSES, neighborhood socioeconomic status; ADL, activities of daily living.

*p-value determined by t-test.

† p-value determined by chi-square test.

‡ p-value determined by Wilcoxon-Mann-Whitney test.

Table 3.2: Descriptive statistics of rehabilitation utilization following total knee arthroplasty by race

		Black	White	p-value
	Subjects, *n(%)*	603 (100)	7,746 (100)	
Acute Hospitalization Length of Stay (LOS)	≤ 3 days, *n(%)*	402 (66.7)	5,486 (70.8)	<0.001
	4-6 days, *n(%)*	167 (27.7)	2,041 (26.4)	
	≥ 7 days, *n(%)*	34 (5.6)	219 (2.8)	
Discharge destination following acute hospitalization for TKA	Skilled nursing facility, *n(%)*	257 (43.7)	3,289 (43.4)	<0.0001
	Inpatient rehabilitation facility, *n(%)*	121 (20.6)	830 (11.0)	
	Home, *n(%)*	210 (35.8)	3.462 (46.1)	
Post-acute Institutional Rehabilitation Length of Stay (LOS) by Setting*	Skilled nursing facility LOS, *median (IQR)*	18 (13-23)	13 (8-19)	<0.0001
	Inpatient rehabilitation facility LOS, *median (IQR)*	10 (9-12)	9 (7-11)	0.01
Home Health PT (HHPT)	Received any HHPT, *n(%)*	317 (52.6)	3,701 (47.8)	0.02
	Number of HH visits, *median (IQR)*[§]	10 (7-13)	9 (6-12)	<0.001
Outpatient PT (OPPT)	Received any OPPT, *n(%)*	292 (48.4)	3,999 (51.6)	0.13
	Number of OPPT visits, *median (IQR)* [§]	17.5 (12-26.5)	16 (10-24)	0.01

Abbreviations: SNF, skilled nursing facility; IRF, inpatient rehabilitation facility; HH, home health; OPPT, outpatient physical therapy.
*Conditional on post-acute discharge to respective setting.
§Conditional on receiving the corresponding type of rehabilitation services.

Table 3.3: Unadjusted and weighted relative risks of receiving additional physical therapy services after discharge home among Black versus White women following TKA, stratified by post-acute discharge destination

	Initial Post-Acute Discharge Destination		
	Skilled Nursing Facility	Inpatient Rehabilitation Facility	Home
Additional PT (home or outpatient)			
Unadjusted RR	1.01 (0.93-1.10)	0.92 (0.83-1.02)	0.91 (0.82-1.02)
Weighted RR	0.94 (0.86-1.04)	1.00 (0.92-1.08)	0.93 (0.84-1.04)
Home Health PT			
Unadjusted RR	1.20 (1.06-1.35)	1.11 (0.94-1.32)	1.01 (0.88-1.16)
Weighted RR	0.99 (0.86-1.15)	1.28 (1.10-1.49)	1.03 (0.90-1.17)
Outpatient PT			
Unadjusted RR	0.99 (0.89-1.12)	0.77 (0.65-0.93)	0.95 (0.81-1.10)
Weighted RR	0.98 (0.86-1.11)	0.68 (0.55-0.84)	0.96 (0.83-1.12)

Abbreviations: RR, relative risk; CI, confidence interval; PT, physical therapy
Inverse probability of treatment weighting using propensity score for race regressed for covariates of age at TKA, body mass index, CMS-HCC score, pre-operative physical function score, pre-operative ADL disability, B TKA procedure, surgical/medical complications including myocardial infraction, venous thromboembolism, infection, acute inpatient length of stay, 30-day readmissions.

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INTEGRATIVE DISCUSSION

Racial and ethnic disparities in TKA utilization have been recognized for several decades.[1,2] Despite the awareness of this issue, minimal progress to reduce or eliminate gaps in utilization has occurred.[2,3] While the causes of disparities are likely multifactorial, patient preference is postulated to greatly contribute to the underutilization.[4] One common reason why minorities with arthritis report they are unwilling to undergo TKA is a belief that they expect limited benefit from the procedure.[5,6] Unfortunately, it appears that this belief may in face have credence. Black adults undergoing TKA tend to have worse outcomes than their White counterparts.[7] This dissertation was focused on providing a more thorough understanding of the mechanisms of disparities in utilization and outcomes following TKA for a purpose of gaining a better understanding of how health, function, and medical access factors influence disparities in utilization and functional outcomes.

Chapters 1-3 offer new knowledge to our understanding of racial/ethnic disparities in the utilization and outcomes of TKA with three key findings: 1) When compared to White women, Black and Hispanic women with painful, activity-limiting arthritis are less likely to receive TKA. Among those who undergo TKA, Black women have delayed receipt of TKA from the point of onset of mobility limitation. 2) Black women have poorer functional outcomes after TKA when compared to White women. However, these functional outcomes disparities are largely explained by poorer pre-operative function. 3) An underutilization of physical therapy and rehabilitation care following TKA was not detected and is not likely to be a reason for disparities in functional outcomes. These findings offer important insight to consider when developing strategies to improve healthcare treatment for minorities with arthritis. Efforts to reduce racial/ethnic disparities in TKA rates and outcomes should focus on early involvement of

medical and health services to maintain mobility, culturally competent information-exchange between patient-provider among surgical candidates for TKA, and reduction of delays to surgical intervention once clinical need arises.

Underuse and delayed utilization of TKA

Chapter 1 titled *Racial and Ethnic Disparities in Utilization of Total Knee Arthroplasty among Older Women* assessed the relationship of demographic, socioeconomic, and health characteristics with TKA utilization and reported that Black and Hispanic women were less likely to undergo TKA regardless of need and SES. The findings of Chapter 1 add to the growing body of research suggesting that racial/ethnic disparities in TKA utilization are not merely a reflection of economic disadvantage.[8] While access to care factors may not be inconsequential to patients' decisions to pursue TKA, differences in SES do not appear to be the driving force between the large gaps in utilization.

At the time of publication of "Unequal Treatment: Confronting Racial and Ethnic Disparities in Health Care," a lower incidence of arthritic disease among minority racial/ethnic groups was postulated to account for some of the differences in TKA utilization.[1] However, the findings from Chapter 1 are consistent with several recent studies reporting that differences in utilization are not explained by a lesser need for the procedure.[9,10] In fact, Black and Hispanic women within WHI had a greater prevalence of experiencing moderate to severe joint pain and mobility limitations compared to White women. After accounting for health status variables of need and appropriateness for TKA, the measured racial and ethnic disparities in utilization widened, indicating disparate care among women with painful, activity-limiting arthritis. The study described in Chapter 1 is the largest cohort study to evaluate racial and ethnic disparities to date, allowing for the investigation of TKA utilization between Black, Hispanic, and White

women in relation to need for and medical access to the procedure. Chapter 1 provides novel information to the topic by using stratification by risk/need for TKA to further investigate gaps in utilization. The racial/ethnic gaps in utilization were most pronounced among the women with the highest need/risk for the procedure, suggesting that Black and Hispanic women with the greatest indication of need for TKA may be underutilizing this evidence-based effective treatment.

While system-level, provider-level, and patient-level factors all likely contribute to disparities in utilization, there is a growing recognition that patient preference may be a considerable determinant of TKA underutilization among minorities.[4] The question remains whether the high proportion of minorities who report unwillingness to undergo to surgery is the reflection of a cultural belief that should be honored during the shared decision-making process, or is instead a failure of the healthcare system to adequately communicate the benefits of the TKA procedure. A growing body of research suggests the latter, finding that Black and Hispanic patients not only have different perceptions of the risks and expectations of the TKA procedure, but also a diminished understanding of the surgical and rehabilitation process compared with White patients.[5,11] Mistrust of medical providers, prominent among older Black adults, may also play a role in impeding true information-sharing between patients-providers and may impact the quality of communication.[12,13] Minority patients are more likely to be dissatisfied with communication from the provider, even when receiving the same informational content as their White counterparts.[14] Minorities are less satisfied that they received an explanation about the diagnosis, treatment options, and expectations in a manner that was respectful and not ‘”talking down” to them.[15] This information regarding communication and perceptions of communication is particularly important when assessing the impact of the finding from Chapter 1, that gaps in

utilization are most prominent among women with greatest need, and therefore, among women who might have most benefit from the procedure.

Chapter 2, entitled *Racial and Ethnic Disparities in Physical Function before and after Total Knee Arthroplasty*, reported that among women who underwent TKA, Black women spend a prolonged duration of time living with mobility limitations prior to receiving surgery. Decisions to undergo TKA, as described above, include knowledge of the procedure, risks, and benefits. Knowledge and perceptions about TKA may not only contribute to underuse among Blacks and Hispanics but may also contribute to delayed use of TKA among Black women. Black women may be unwilling to undergo TKA until a final breaking point when pain and disability become unbearable in daily life. Our findings are consistent with those of Kamath et al.[16] who found Black women reported an average wait of more than three years from the time of onset of symptoms before orthopedic consultation, compared to an average wait of 15 months for other women. While the study by Kamath et al.[16] relied on participant recall to determine delay, the study presented in Chapter 2 used prospectively collected physical function data further validating that Black women wait longer from the time of disability to surgery. Unfortunately, by delaying surgery, Black women may be experiencing reduced quality of life for years prior to TKA and may, in fact, limit their prognosis for improvements postoperatively.

Disparities in Functional Outcomes Postoperatively explained by Pre-Operative Function

Chapter 2 *Racial and Ethnic Disparities in Physical Function before and after TKA* investigated whether disparities in functional outcomes after TKA were largely a reflection of differences in pre-operative physical function. Prior research investigating racial and ethnic disparities in outcomes has found that Black adults undergoing TKA tend to have poorer

function after TKA compared to Whites.[7] However, research comparing functional outcomes between Hispanic and non-Hispanic populations have offered conflicting results.[17,18] Prior evidence on the topic has largely relied on single surgeon or single institution studies,[7] thus limiting the generalizability of the findings. Our investigation of 10,325 women in WHI who underwent TKA found that Black women had poorer physical function post-TKA than White women but failed to find any significant difference between Hispanic and White women. After adjusting for differences in pre-operative physical function, postoperative function was similar between all racial and ethnic groups. The use of prospectively collected physical function measures over an extended follow-up time allowed for a more thorough characterization of functional status by race/ethnicity in the decades both before and after TKA. Whereas previous studies have collected physical function at a single time point immediately preceding TKA,[17,19] the prospectively collected physical function measures from WHI provided insight into women's physical function for years prior to when they might have sought medical care.

The findings from Chapter 2 revealed that Black women had poorer function for the entire decade prior to surgery, compared to White Women. Basic daily mobility including walking a single black, walking several blacks, and climbing a flight of stairs was limited for a higher proportion of Black women. These mobility limitations were present earlier and for a longer duration of time for Black women, when compared to White women. These findings are consistent with other studies of physical function and disability among adults with arthritis, which reported a higher prevalence of mobility disabilities among Black adults.[20,21]

The study presented in Chapter 2 has provided novel information to our understanding of disparities in functional outcomes after TKA by characterizing the substantial limitations that are present at an earlier time and for an extended duration among Black women. The cyclic

relationship between mobility limitations, reduced physical activity, and obesity is of concern regarding the duration of experiencing mobility limitations among Black women who ultimately underwent TKA.[22] Poorer pre-operative functional mobility, lesser physical activity, and higher BMI are associated with poorer functional outcomes after TKA.[23–25] Therefore, interventions aimed at improving or maintaining physical function pre-operatively are critical for ensuring optimal outcomes after TKA. However, it is unrealistic to expect improvements in physical function at the end stages of arthritic disease. Therefore, regardless of whether orthopedic surgery might be indicated in the future, health goals should focus on optimizing functional mobility and preventing disability among patients in the early stages of arthritic disease. Eliminating racial disparities in post-TKA functional outcomes is dependent on maintaining functional mobility among Black women with arthritis, and, in the event that significant mobility limitations due to arthritic disease do arise, reducing delays to surgical intervention.

Differences in Postoperative Rehabilitation

Chapter 3 entitled *Rehabilitation after Total Knee Arthroplasty: Do Racial Disparities Exist?* provided a comprehensive evaluation of postoperative rehabilitation care by race to assess the hypothesis that Black patients may receive less rehabilitation, thus contributing to functional outcomes disparities. Measuring the effects of race on healthcare utilization can be challenging, due to cumulative effects of disadvantage, bias or prejudice, and discrimination that occur throughout the lifetime.[26] Appropriate analytic methodologies are needed to manage complexities in the interrelationship of confounding variables associated with racial disparities.[27] Chapter 3 utilized IPTW by propensity score to help balance health, functional, and medical characteristics that differed between racial groups at time of discharge to the home after TKA. The use of causal inference methods such as IPTW for evaluating racial disparities has been

debated, with some researchers arguing that "causes" are manipulable interventions, not characteristics intrinsic to an individual.[28,29] Yet, recent work in health services research has applied the use of propensity scores to evaluate the effects of race on healthcare utilization by attempting to define the "treatment" of race and explicitly stating the counterfactual question being evaluated.[30,31] Within Chapter 3, rather than the treatment directly equating with the coefficient of race, treatment instead represents factors that are difficult to directly observe or measure, including a combination of bias, discrimination, and medical access inequities that might be encountered differently by racial groups at time of discharge home after TKA. The counterfactual specifically questioned "How much less likely (or more likely) were Black women to receive PT services, if they had the same health, medical, and functional characteristics as White women when discharged home after TKA?" With our use of propensity scores in Chapter 3, a pseudopopulation was created where health, medical, and functional characteristics at a time point pre-discharge were balanced between groups. Thus the members of White and Black group were considered exchangeable in all regards, with exception to the exposure (bias, discrimination, and medical access inequities) experienced at or after the time of discharge home. Within the study, the lack of unmeasured confounders, which is necessary for true exchangeability, is however debatable. The practicality of knowing and measuring all confounders with racial disparities research is dubious,[27,32] but expertise in the content area was applied to create as thorough a set of confounders as possible using current available topic knowledge. It has been argued that the use of causal inference thinking and methodology should not be avoided with racial disparities research, even though potential limitations in determining true overall effects of race exist.[29] In fact, use of IPTW has several advantages over more traditional regression methods, as it may allow for a better detection of misspecification in model

design, allows for the inspection of overlap of distribution of baseline covariates, and may provide more interpretable findings than the use of regression methods that account for effect modification.[33,34]

The findings from Chapter 3 revealed that Black women tended to receive more intensive post-acute rehabilitation care, including institutionalized rehabilitation care with longer lengths of stay and more HHPT and OPPT. The study failed to find racial differences in utilization of PT services once patients were discharged to the home after accounting for differences in need for PT. Interestingly, a study by Sandstrom et al. using the Medical Expenditure Panel Survey found that Black patients with arthritis were almost half as likely to receive outpatient PT.[35] Our null finding of a disparity in rehabilitation utilization after the TKA procedure could be due to several reasons. Orthopedists often use the ability to comply with postoperative rehabilitation as a factor in determining their recommendations for TKA, restricting the option of surgery to patients who appear to be willing and able to complete postoperative rehabilitation.[36] Additionally, patients who are unwilling, unmotivated, or unable to participate in a lengthy rehabilitation process following the TKA procedure may simply reject this treatment option if offered or conversely may not have ever pursued an orthopedist consultation. Therefore, the population who receives TKA may represent a group of women who are willing to and have the ability to adhere to post-TKA rehabilitation recommendations, and this group may be different from the overall population of adults living with arthritis. Alternatively, this lack of a disparity in postoperative rehabilitation may, in fact, signify that the healthcare system is equitably meeting the needs of both racial groups in terms of the provision of rehabilitation care. Service coordination may be adequately linking patients to services and rehabilitation professionals may be adequately providing appropriate rehabilitative services. Because services may potentially be

provided in the home or in an outpatient setting (dependent on initial homebound status), medical access and transportation difficulties may have a limited impact on the continuity of rehabilitation care after discharge to the home. Regardless of the reason for this null finding, Black women do not appear to be receiving lesser rehabilitation care after TKA, and therefore this does not appear to be a reason for disparities in postoperative rehabilitation. However, equitable provision of postoperative care may be delivered at a point that is too late to overcome the disabling effects of prolonged mobility limitations that are experienced prior to TKA, which are disproportionately prevalent among Black women. Ultimately, the findings from Chapter 3 provide further support that strategies to reduce racial disparities in postoperative function might be best targeted pre-operatively.

Future Directions

Socioeconomic position and access to care, while not irrelevant, do not appear to be the primary reasons for racial/ethnic disparities in TKA utilization. Mounting evidence suggests that patient preference and willingness to undergo the procedure may be critical factors affecting TKA utilization.[4,37] Because the widest racial/ethnic gaps in utilization are found among women with the greatest need for the procedure, future studies should examine shared decision-making and communication processes among surgical candidates. Further investigation into characteristics of provider-patient communication and their association with TKA utilization would be beneficial in understanding how to reshape willingness to undergo the procedure. While several studies have found that the use of decision aids in the decision-making process have been linked to lower utilization of elective orthopedic surgeries,[38,39] a randomized-controlled study by Ibrahim et al.[40] found the use of video decision aid resulted in higher utilization among Black patients. This idea should be explored further, with the recognition that

communication and educational interventions that are (or are not) effective with White patients may have a different impact on patients of other race/ethnicity.[41] Culturally competent communication does not equate to providing the same communication regardless of racial/ethnicity, but in fact, signifies a need to recognize that cultural differences may require adaptations in mode or mechanisms of communication.[42] Therefore, further studies specifically evaluating communication and decision-making processes among racial/ethnic minority groups is needed.

Additionally, it should be considered that the burden of reducing racial/ethnic disparities in TKA utilization has largely been passed to physicians whose role is to communicate treatment options and provide recommendations for surgical intervention. However, it is important to recognize that other members of the healthcare system could play an important role in reducing disparities. For example, Black patients who eventually underwent TKA experienced multiple years with mobility limitations pre-operatively, which implies a need for physical therapy intervention during this pre-operative period. Yet, analysis of Medical Expenditure Panel Survey data has revealed Black patients with arthritis were less likely to receive PT services compared with White patients.[35] Lack of physical therapy intervention may be a missed opportunity to prevent or slow further functional declines. In addition to service provision, physical therapists are responsible for coordination of care, often recommending specialist consultation when prognosis for improvement with conservative treatment is poor. Whether PT services expedite orthopedist consultation and/or surgical intervention among minorities with end-stage arthritis is not known. In fact, limited knowledge regarding the common pathways from providers to surgeons pre-operatively exists. Improving our understanding of the processes of care from the time of symptom onset through surgery could provide more insight about potential missed

opportunities to link minority patients with appropriate healthcare, thus affecting delays to surgery.

Limitations

Limitations of this dissertation should be acknowledged. Standards of race/ethnicity reporting have changed over time with the recognition of the growing proportion of the U.S. population who identify with multiple groups.[43,44] The timing of the race/ethnicity data collection within WHI was prior to the adoption of the most recent standards, and thus racial/ethnic groups in this dissertation were categorized according to WHI protocols in use at the time of enrollment. These three groups likely have substantial heterogeneity, and, in particular, the Hispanic/Latina population may include many diverse subgroups of women from different national origins, cultures, and social customs. There are some inherent limitations due to the sources of data that should be recognized. While the WHI-Medicare linked data provided demographic, health characteristics, and health utilization data from a diverse population of women, no detailed clinical information was available, as would be available in radiography reports, medical records, or rehabilitation records. Indicators of need within this dissertation were, therefore, approximations derived from either self-reported data of symptoms or by use of ICD-9 diagnostic or procedure codes in claims data. Medicare assessment files were not available and therefore need for additional PT services was determined through pre-hospital characteristics of health and function. However, future studies with access to the Functional Independence Measure (FIM) and Outcome and Assessment Information Set (OASIS) within the Medicare assessment files would be able to link rehabilitation utilization with the need for services based on FIM and OASIS scoring. SES data were collected at baseline but updated financial information regarding employment status, income, and supplemental insurance coverage at the

time of TKA would have further strengthened our investigation of the impact of SES on the decision to pursue surgery.

Conclusions

Regardless of race or ethnicity, adults with arthritis should receive equitable health and medical treatment. Lower utilization of TKA procedures in Black and Hispanic women with painful, activity-limiting arthritis suggests inequitable care. Further understanding of the patient and provider factors that impact decision-making for the treatment of arthritis is needed to determine why gaps continue to persist and why Black women tend to receive delayed surgical intervention. Delayed use of TKA among Black women may contribute to decreased quality of life due to mobility limitations pre-operatively and contributes to poorer functional outcomes after surgery. While Black women receive similar or more rehabilitation care following TKA, this rehabilitation postoperatively may not be able to mitigate the negative consequences from prolonged mobility limitations experienced pre-operatively. Therefore, strategies to reduce disparities in outcomes postoperatively should be targeted early in the arthritic disease process with a focus of maintaining mobility and, if clinical need arises, reducing delays to surgical intervention.

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