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Racial differences in gait mechanics associated with knee osteoarthritis

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Abstract

Background & Aims—This study examines racial differences in gait mechanics in persons with knee osteoarthritis and the influence of anthropometrics, educational level, radiographic disease severity (rOA), and self-report measures of pain and disability on racial differences in gait.

Methods—One hundred seventy five (64 black and 111 white) adults with radiographic knee OA were tested. 3-D kinematic and kinetic data were collected while subjects walked at two self-selected speeds (normal and fast). Anthropometric data, radiographic level of OA, and self-report measures of pain and disability were also collected. Gait patterns were compared across groups and within groups.

Results—Black and white subjects did not differ significantly in radiographic OA. However, blacks walked significantly more slowly when asked to walk fast. At the normal speed, blacks had a smaller knee range of motion and loading rate than whites. Blacks also took longer to reach their peak maximum ground reaction force than whites. Within black subjects variations in gait mechanics were primarily explained by BMI, rOA, self-reported psychological disability, and pain self-efficacy. In white subjects, variations in gait mechanics were primarily explained by weight, age, velocity, psychological disability, and self-efficacy.

Conclusions—Blacks in this study had a pattern of gait mechanics generally associated with high levels of osteoarthritis; though they did not differ significantly in rOA from whites. The variability in gait patterns exhibited by blacks was most strongly related to variance in walking speed, anthropometrics, and perceived physical ability. Taken together, these results suggest that race is an important factor that must be considered in the treatment and study of osteoarthritis.

Keywords

Gait; Osteoarthritis; Racial differences; Disability

INTRODUCTION

Osteoarthritis (OA) is one of the most prevalent musculoskeletal conditions, affecting more than 4.3 million adults over age 60 (1). Previous studies have examined the many factors, including obesity (2), age (2, 3), gender (4), lower extremity injury (5), and disease severity

(6, 7), as well as self-report measures of pain, disability, and arthritis self-efficacy, (6, 7) that might explain variations in locomotor disability in persons with knee OA. As a result, it is known that age, body composition, radiographic disease severity, and self reports of pain and disability, as well as attitude and one's confidence about their ability to control arthritis, all strongly influence mobility and gait disability of knee OA patients through kinematic adaptations such as reduced walking speed and limb range of motion (2, 3, 8–14).

Another important factor that is likely to influence gait variations in patients with OA is race. Yet the relationship between gait disability associated with OA and race has been largely under-investigated. This is surprising considering emerging evidence of racial disparities in disability in other persistent pain conditions (15) and racial disparities in other substantial health issues in the United States, including heart disease, obesity, and diabetes. Moreover, blacks with knee OA have greater radiographic severity and more mobility impairment than whites with OA (16–18). Previous studies have explored racial variation in self reported OA symptoms (19), as well as the relationship between race and spatiotemporal gait variables such as speed and support time (20). They found that white participants walked faster, had longer stride lengths and spent more time in double support (20).

The primary goal of this study was to follow up on the intriguing results of Golightly and Dominick (19) and Sowers et al. (20) by examining if differences in gait mechanics exist between blacks and whites with knee OA in parallel with the psychosocial and spatio-temporal variables described in these previous studies. The secondary goal was to examine the degree to which these differences, if found, are influenced by anthropometrics (age, body mass index, height, and weight), radiographic disease severity, education level, and self-report measures of pain, disability, and self-efficacy.

METHODS

Patients

The sample consisted of 175 patients (64 black, 111 white; 42 men, 133 women) with knee osteoarthritis. All data presented were collected as part of a baseline evaluation of a subset of the participants enrolled in an ongoing study (OA Life) evaluating the separate and combined effects of lifestyle behavioral weight management and pain coping skills training interventions for knee OA. Study entry required that patients meet the American College of Rheumatology criteria for symptomatic knee OA, (21) along with the following inclusion criteria: body mass index greater than 25 kg/m² and less than 42 kg/m², chronic knee pain, and no other weight bearing joint affected by OA as assessed by clinical examination. Exclusion criteria included: a significant medical conditions that would increase risk of an adverse experience (e.g. myocardial infarction), already involved in regular exercise, an abnormal cardiac response to exercise, a non-OA inflammatory arthropathy, and regular use of corticosteroids. The study was approved by the Duke University Medical Center Institutional Review Board and all participants provided informed consent. Weight in kilograms and height in meters were recoded for each patient. Height and weight data were used to calculate body mass index (BMI).

Disease Severity

Weight-bearing, fixed-flexion (30 degrees) posterioranterior radiographs of both knees were taken with the SynaFlexer™ X-ray positioning frame (Synarc, San Francisco, CA) (22). Disease severity was assessed using the Kellgren and Lawrence (K/L) radiographic grading system.(23). This system rates the level of disease on a scale of 0–4, with a score of 0 representing no disease, 1 representing mild disease, 2 representing moderate disease, 3

representing moderate to severe disease, and 4 representing severe disease. For subjects with bilateral knee OA, the limb with the highest K/L grade, was recorded as the most affected limb. If both limbs had the same K/L grade, the right limb was used as the most affected limb. This most affected limb was the limb used in all data analyses. The breakdown of participants with unilateral versus bilateral knee OA was as follows: 148 bilateral (52 black, 96 white) and 27 unilateral (12 black, 15 white).

Gait Parameters

Three-dimensional kinematic data were collected using a motion analysis system (Motion Analysis Inc, Santa Rosa, CA). Following the practice trials, kinematic data were collected at 60Hz, as subjects walked along a 30 meter walkway at two speeds: the speed at which they normally perform their daily walking activities (normal) and the maximum speed they felt comfortable achieving (fast). These two speeds were chosen in order to get a sense of the speed at which the participants are most comfortable and to see how their gait mechanics change when they were presented with a challenge. Reflective markers were placed bilaterally at the following landmarks: anterior superior iliac spine, thigh, lateral knee (at the joint line), shank, lateral malleolus, calcaneus, and foot (2nd webspace). A marker was also placed at the superior aspect of the L5-sacral interface to aid in defining the pelvis. Patients performed five walking trials along the walkway at each of the self-selected speeds. Time synchronized ground reaction force data were collected at 1200Hz using AMTI force plates (Advanced Medical Technologies Inc., Watertown, MA). Variability in walking velocity for each speed was restricted to $\pm 5\%$; trials outside of this range or trials during which the subject did not contact at least one of the force plates cleanly were repeated. The range of $\pm 5\%$ was maintained using wireless infrared photocell timing devices (Brower Timing Systems, Draper Utah). EvaRT (Motion Analysis Inc, Santa Rosa CA) software was used to track the reflective markers and condition the data. The raw data were smoothed using a 4th order, recursive Butterworth filter with a 6Hz cutoff frequency. Three trials at each speed in which all markers were identified and the subject had clean contact with the force plate were reduced using OrthoTrak 6.3 (Motion Analysis Inc, Santa Rosa CA), and averaged to yield kinetic and kinematic data. Kinetic data were normalized to subject height and weight.

Pain, Disability and Arthritis Self-efficacy Measures

Pain and disability were assessed using two widely used, self-report measures: the Arthritis Impact Measurement Scales (AIMS) and the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) Version VA3.1. The AIMS is a 66 item, standardized instrument that provides three summary measures: pain, physical disability, and psychological disability. Research has supported the reliability of the AIMS and it is valid when used for different types of arthritis as well as within a range of social and demographic groupings and in different clinical settings. (24) The WOMAC OA index used in this study was a visual analog scale that consisted of three subscales that assessed pain (5 questions), stiffness (2 questions), and physical function activities (17 questions). The reliability and validity of this index has been supported by previous research. (25) The range of scores on each of these subscales was between 0–100mm; with higher WOMAC scores reflecting a worse condition. (25) Only the WOMAC function and stiffness scales were used for analysis in the current study, as self-reported pain was measured using the AIMS.

The Arthritis Self Efficacy Scale (ASES) was used to measure each patient's perceived self-efficacy for managing pain, physical function, and other related variables associated with chronic osteoarthritis (e.g. fatigue, psychological distress) (26). The ASES is a 20 question survey, which is divided into three subscales. For each item patients provide a rating ranging from 10–100, where a higher score indicates greater self efficacy. Each subscale (self-efficacy for pain, self-efficacy for function, and self-efficacy for other symptoms) is scored

by taking an average of the responses for that scale. A total score is obtained by summation of the scores from each of the three subscales. In the current study, only the values for the individual subscales were considered.

Statistical Analysis

Statistical analysis was performed using SPSS (version 12.0.1 for windows, SPSS, Inc Chicago IL). Independent samples t-tests were used to compare anthropometrics, disease severity, and gait mechanics, as well as self-reported disease-related characteristics of black and white patients. For each gait variable that was found to be significantly different between blacks and whites, stepwise regression analysis was used to examine the relationships of anthropometrics, rOA, education level, self reported pain and disability to that parameter ($\alpha=0.05$). These relationships were evaluated for each racial group separately, and at both speeds. Following this analysis, the partial r^2 values were examined and reported to measure the individual proportions of the variance in the gait parameters accounted for by the covariates. Lastly, to in order investigate the relationship between the covariates and race, logistic regression was conducted. A multivariable analysis was performed that included only variables for which racial differences were found to be significant in the univariate analysis ($\alpha=0.05$). Odds ratios were calculated to determine the likelihood that a variable was more strongly associated with a particular race. An odds ratio (OR) of 1 indicates that there were no differences between the groups; an OR >1 indicates that the value was higher in blacks.

RESULTS

Blacks in this study were significantly ($p<0.001$) younger than whites (Table 1). In addition, there was a significant difference in mean BMI ($p=0.013$) between blacks and whites (Table 1). BMI for blacks was 1.71 points higher than that of the white participants. However, there was no significant racial difference in height ($p=0.073$) or weight ($p=0.545$). There was also no significant difference between the K/L scores ($p=0.171$) for blacks and whites (Table 1). In short, although black subjects were younger and had higher BMI values than whites, they did not differ significantly in their radiographic disease severity (rOA).

Overall, the blacks in this study were less educated than their white counterparts. Thirty-five percent of the white participants had graduate and professional degrees compared to thirteen percent of the black population. The groups did have some similarity; approximately 30% of both groups had a 4 year college degree. However the groups differed in the number of participants who had one to four years of college; 37% of the white group was in this category contrasted by 23% of the black group.

There were no significant differences in walking velocity at the normal speed. However, as shown in Table 2, there was a significant difference in mean KROM ($p=0.024$) between blacks and whites at the normal speed. There was also a significant racial difference in mean loading rate ($p=0.005$) and time to peak vertical ground reaction force ($p=0.001$) at the normal speed. Blacks had a more limited range of motion at the knee, they loaded their limbs more slowly than whites and they took a longer time to reach their peak vertical ground reaction force. Lastly, at the fast speed, there was a significant difference in mean walking velocity between blacks and whites ($p=0.009$).

There were also racial differences in psychosocial measures. Blacks reported more pain associated with their OA using the AIMS scale ($p=0.006$) subscale. Blacks also had significantly higher ($p<0.001$) values for the WOMAC function and stiffness scales. Finally, blacks reported significantly lower self efficacy for physical function (FSE) than whites ($p<0.001$).

Within race analysis showed that different factors influence gait mechanics in blacks compared to whites. In the regression analysis at the normal speed for the blacks alone, BMI accounted for 23% of the variance in KROM and level of education accounted for an additional 8% of the variance. Radiographic disease severity (rOA) accounted for 30% of variance in loading rate and self reported psychological disability accounted for an additional 19%. In addition, self efficacy for pain accounted for 28% of the variance in time to peak vertical ground reaction force (Table 3). In the regression analysis at the fast speed including only black subjects, BMI accounted for 10% of the variation in velocity in the black participants.

In contrast, in the regression analysis at the normal speed for the whites alone, rOA accounted for the largest proportion of variance in KROM (14%), while weight accounted for 7% of the variance in KROM. Variance in loading rate was explained by weight (40%) and psychological disability (25%). Of the covariates that contributed to variance in time to peak at the normal speed for the white participants, velocity was the greatest contributor at 36%, followed by age (13%), self efficacy for pain (8%), and self reported pain (4%). At the fast speed, self efficacy for function and age were the strongest predictors (14% each) of the variance in velocity. BMI also accounted for 6% of the variance in velocity at the fast speed (Table 3).

A full sample analysis confirmed a significant influence of race on some of the gait variables. When all variables were considered together in a multivariable logistic regression model, three variables retained significance simultaneously. The results of this model are shown in Table 4. Significantly slower walking velocity at the fast speed was associated with the black participants (OR=0.148). Stated another way, for every unit increase in the fast velocity, the odds of being white were 6.7 times greater than the odds of being black. In addition, higher scores on the WOMAC function scale were significantly associated with black race.

DISCUSSION

A previous study by Golightly and Dominick demonstrated that blacks report more pain and disability associated with their OA disease and that different factors affect these self reported differences (19). Sowers et al. determined racial differences in spatiotemporal gait parameters (20). This study expands on those by investigating racial differences in gait mechanics in persons with OA and the different factors that affect those differences. These factors included many of the demographic and clinical variables examined in the previous study, as well as self reported pain, disability, and self-efficacy.

In the current study, the primary differences observed in gait mechanics were that blacks walked significantly more slowly than whites at fast speeds, and had a more limited knee range of motion and a slower loading rate at normal speeds. The racial difference in walking speed is consistent with previous research in persons without knee OA.(27) Blacks in this study had a pattern of gait mechanics generally associated with high levels of osteoarthritis (4, 28). Nonetheless, they did not differ significantly in disease severity (rOA) from whites. The findings regarding differences between blacks and whites in velocity at fast speed are particularly noteworthy in that they were still evident in logistic regression analyses that controlled for other potentially important predictors of black-white gait differences including anthropometrics, pain, disability, and self-efficacy measures.

It is possible that when blacks are asked to walk at a fast speed, they select lower walking speeds in order to moderate loading at the knee. Interestingly, the black patients' velocity was influenced more strongly by BMI than any of the other predictor variables. This is

particularly relevant in this study because, despite not differing significantly from whites in rOA, the black participants had a significantly higher BMI than whites. It could be argued that the racial differences seen in velocity at the fast speed and knee range of motion at the normal speed could be due to gender since 89% of the blacks in this study were female compared to a population of 69% white females. However, as previous research looking at the effects of gender on walking speed in persons with OA has pointed out, males and females walk at the same speed, (4) or males walk slower than females.(29, 30) Moreover, a study investigating gender differences in gait mechanics in persons with OA found no significant gender difference in knee range of motion. (30) Blacks also had a slower loading rate and took longer to reach their peak vertical ground reaction force. Since both of these variables were almost solely accounted for by self efficacy for pain, it is possible that blacks are loading their limbs more slowly in order to mediate pain.

Consistent with our findings, Sowers and colleagues also found BMI to be an important factor in the prevalence and progression of knee OA; even after adjusting for a number of risk factors such as age (18). Despite the clear relationship of BMI to velocity and KROM in blacks, BMI only accounted, at most, for 10% and 23% of the variance in these variables respectively. Other factors such as level of education and self-efficacy explained moderate proportions of variance in gait measures as well. However, it is clear that there are additional factors affecting gait mechanics in OA subjects. One possibility is kinesiphobia, or pain-related fear of movement. The blacks in this study reported higher levels of pain and disability compared to the whites which may be affecting their movement. This theory is supported by a study by Heuts et al., 2004 in which they found self-reported level of pain to be significantly correlated with functional limitations (31). This topic and its influence on racial differences in gait mechanics should be explored in future studies.

In addition to the significant differences in gait mechanics, racial differences in pain, physical disability, and psychological disability were also found. Significant racial differences existed in the WOMAC function and stiffness scales, with the black patients reporting higher scores in each area. This indicates that blacks report a higher degree of stiffness and functional difficulty associated with OA than their white counterparts. These findings are consistent with those of Golightly and Dominick who found that blacks reported significantly higher scores on the WOMAC function scales. (19) However, a few other studies that investigated racial differences in self reported arthritis symptoms using the WOMAC scales found no significant difference in pain and disability between black and white patients with OA.(32, 33) Blacks also had lower self efficacy for physical function than the whites, which indicates that they are much less confident in their ability to perform physical activities as a result of their osteoarthritis. These results are especially interesting considering the finding that the mean K/L grades were not significantly different between the two races examined in this.

The findings in this study have substantial implications for treatment of osteoarthritis. This study has demonstrated three important differences between black and white patients. First, blacks are younger and heavier than whites with the same rOA. The increased body mass may hasten the further progression of OA in these patients. Second, blacks have more extreme perceptions of pain and disability than whites with the same rOA. Such perceptions lead toward negative thinking regarding their disease and may also accelerate progression of the disease as such subjects may be less willing to pursue pathways for care. Finally, this study demonstrated gait disability between blacks and whites. Although, there were only a few significant racial differences in gait mechanics, the variables involved have broad impact. Velocity is correlated with several other factors including lower stride frequency and lower stride length. In addition blacks walked with stiffer knees and loaded their limbs more slowly. Both of these factors can influence progression of OA and quality of life in blacks

with OA compared to their white counterparts. Clinicians should be aware of these factors as they consider treatment regimes for their patients.

Previous studies have pointed out that a treatment plan inclusive of cognitive behavioral therapy could be very helpful for persons with OA; (9, 11). Given the findings of this study, clinicians should consider the different factors that influence gait mechanics in each race as they develop treatment plans. For example, the within group regression analysis showed that psychological disability influenced loading rate at the normal speed and functional self efficacy influenced fast walking velocity in white participants. thus taking this into consideration, the data presented here suggest training in coping skills targeted at raising self-efficacy for physical function and managing depression and anxiety associated with OA disease in white patients should be considered. The data also suggest that coping skills training designed to raise self-efficacy for pain and manage psychological disability should be strongly considered especially for interventions in black patients with knee OA.

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Table 1

Patient characteristics by race

	Total Sample (n=175)	Black (n= 64)	White (n= 111)	p-value
Age (years) *	58.54 (9.72)	53.84 (8.10)	61.12 (9.34)	<0.001
BMI (kg/m²) *	34.17 (4.36)	35.25 (4.19)	33.54 (4.40)	0.013
Height (m)	1.67 (0.08)	1.65 (0.06)	1.68 (0.09)	0.073
Weight (kg)	95.36 (15.81)	96.50 (11.47)	95.00 (17.74)	0.545
K/L grade	2.83	2.75*	2.89	0.369
College (%) *	84	77	88	0.004

Age, BMI, height, and weight are listed as mean (SD), * denotes a significant difference between blacks and whites, p<0.05

Table 2

Racial differences in Gait Mechanics

	Normal speed		Fast speed	
	Black (n= 64)	White (n= 111)	Black (n= 64)	White (n= 111)
Velocity (m/s)	1.07 (0.19)	1.12 (0.19)	1.44 (0.28)	1.56 (0.30)*
Stride Length (statures)	0.71 (0.09)	0.73 (0.11)	0.81 (0.12)	0.84 (0.13)
Stride Frequency (s⁻¹)	0.90 (0.09)	0.91 (0.08)	1.09 (0.14)	1.12 (0.11)
Support Time (%)	63.57 (2.92)	62.69 (3.67)	60.90 (4.38)	60.92 (3.93)
Knee Adduction Moment (NM/kg)	0.35 (0.18)	0.36 (0.20)	0.34 (0.18)	0.41 (0.22)
Knee range of Motion (degrees)	55.14 (8.49)*	58.26 (8.12)	58.17 (8.31)	60.70 (8.64)
Peak vertical GRF (BW)	1.03 (0.07)	1.05 (0.08)	1.15 (0.13)	1.18 (0.13)
Loading Rate	0.067 (0.020)*	0.089 (0.024)	0.14 (0.39)	0.15 (0.34)
Time to Peak (s)	0.27 (0.081)*	0.19 (0.046)	0.14 (0.48)	0.14 (0.30)

All values listed as mean (SD), * Denotes a significant difference between blacks and whites, p<0.05

Table 3

Contributions of anthropometrics, disease severity, pain, and disability measures, and level of education to variance in gait variables

Normal								
	Black (n=64)			White (n=111)				
	r ²	β	p		r ²	β	p	
KROM	BMI:	0.231	-0.523	0.0003	K/L:	0.136	-0.339	0.002
	Education:	0.077	-0.280	0.042	Weight:	0.072	-0.271	0.012
	K/L:	0.295	-0.810	0.002	Weight:	0.402	-0.830	0.001
	APSY:	0.189	-0.816	0.002	APSY:	0.249	-0.536	0.017
Time to Peak	PSE:	0.279	-0.528	0.010	Velocity:	0.362	-0.776	<0.0001
					Age:	0.129	-0.471	0.0002
					PSE:	0.077	0.448	0.002
					APAIN:	0.044	0.246	0.045
Fast								
	Black (n=64)			White (n=111)				
	r ²	β	p		r ²	β	p	
Velocity	BMI:	0.099	-0.314	0.026	FSE:	0.142	0.323	0.001
					Age:	0.138	-0.392	0.00004
					BMI:	0.060	-0.551	0.001
					Weight:	0.039	0.358	0.029

KROM=knee range of motion, APSY = AIMS psychological, APAIN= AIMS pain, FSE= self efficacy for function, and PSE= self efficacy for pain

Table 4

Odds Ratio derived from multivariable logistic regression model

	Odds Ratio	95% CI	P-value
Anthropometrics			
Age	0.914	0.873 – 0.957	<0.001
Gait mechanics			
Velocity (fast speed)	0.148	0.036 – 0.618	0.009
Pain, disability, and self-efficacy			
WOMAC Function	1.030	1.007 – 1.053	0.009

An odds ratio > 1 indicates that the condition is more likely in blacks.