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The Relationship of Self-Reported Pain and Functional Impairment to Gait Mechanics in Overweight and Obese Persons with Knee Osteoarthritis

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Abstract

Objective—To examine the degree to which 2 commonly used measures of pain and disability, the Arthritis Impact Measurement Scales (AIMS) and Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), relate to objective gait measurements.

Design—Descriptive study of the influence of self reported pain and perceived functional impairment on gait mechanics in osteoarthritic adults.

Setting—University clinical research laboratory.

Participants—Overweight/obese adults with radiographic knee osteoarthritis (OA), as well as pain and disability associated with the disease (N=179).

Interventions—Not applicable.

Main Outcome Measures—The AIMS and WOMAC were administered to determine self-report measures of pain and disability. Speed, stride length, support time, knee angle, and peak vertical ground reactions force were determined from 3-dimensional kinematic and kinetic data collected on subjects walking at self-selected normal and fast speeds. Anthropometric data and radiographic levels of OA were also collected.

Results—Pearson's correlation analysis showed that the AIMS physical disability score was inversely correlated with speed, stride length, KROM, at both speeds, and with PVF at the fast speed. The WOMAC function score was inversely correlated with speed and stride length at both speeds and with peak vertical force at fast speed. The WOMAC pain score was inversely correlated with speed and PVF at the fast speed. Regression analysis revealed that the AIMS physical disability score and body mass index accounted for the greatest variation in speed at normal speed. Overall, AIMS physical disability and WOMAC function explained a larger proportion of variance in gait mechanics than radiographic measures of OA disease severity.

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Conclusions—Taken together, the results suggest that the AIMS physical disability and WOMAC function scores are associated with some important measures of gait impairment.

Keywords

Gait; Joint diseases; Osteoarthritis; Pain; Rehabilitation

OA is one of the most prevalent rheumatic diseases, affecting the knees of up to 37.4% of adults over age 60 [1]. Knee OA is the most common cause of disability in community dwelling elderly adults [2]. Pain in the affected joint is one of the most frequent complaints of patients suffering from OA and is commonly accompanied by decreased patient mobility and increased stiffness[3, 4]. OA sufferers are often unable to execute activities of daily living such as walking up stairs or standing from a seated position, and they may also be unable to complete the physical activities prescribed as part of the treatment plan for their OA disease. Over the past 2 decades, clinicians and researchers have increasingly relied on self-report measures to assess pain, psychological disability, and physical disability in OA patients. Among the most widely used self-report measures are the AIMS and the WOMAC questionnaires. These standardized self-report instruments are convenient, disease-specific, and are increasingly being incorporated into clinical practice and research studies.

The most reliable, direct, and objective way to assess movement disability in OA patients is to document gait patterns during walking. Many studies have compared gait patterns in individuals with knee OA with those of healthy controls [5–8]. These studies have generally found that OA patients tend to walk at slower speeds than healthy subjects and tend to exhibit limited KROM compared to controls[7, 8]. In addition, patients with knee OA have been shown to demonstrate both altered ground reaction forces and shorter stride lengths compared to, age-matched controls[6, 9, 10].

The degree to which a patient's description of his/her own pain and disability relates to actual limitations in gait is poorly understood. Although researchers typically employ a variety of self-report instruments for evaluating pain, psychologic disability, and physical disability including gait difficulties, few studies have attempted to correlate these datasets and explore their relationship quantitatively. In addition, many OA patients have co-morbid conditions, including obesity that affect not only disease progression, but may also affect their psychologic well-being and gait, independent of the actual extent of OA in their joints[11–13]. People with OA who are overweight ($25 \leq BMI \leq 29$) or obese ($BMI \geq 30$) are more likely to experience increased levels of pain. [14] Understanding the relationship between OA, self-reported pain and disability measures, and gait is critically important to developing a full understanding of the effect that OA has on a patient's life, the progression of the disease for individual patients, and effective pathways for intervention.

Based on the model that gait disability is influenced not only by the degree of OA and obesity, but also by a person's level and perception of pain, measuring a person's self-reported level of disability and pain has become accepted [15]. While some research has focused on biomechanic aspects of disablement in knee OA [6–8, 16, 17], and other studies have explored psychosocial influences on function [11, 13, 18–21], to date, the interplay of all these variables and gait disability have not been investigated in a large sample Determining which aspects of gait mechanics have clinical relevance will greatly advance our understanding of this disease and our ability to establish efficacious treatment strategies for OA patients. Thus, the primary aim of this study was to examine which self-reported measures of pain and disability collected via the AIMS and WOMAC relate to objective performance measures, determined using gait kinetics and kinematics in obese patients with knee OA of varying radiographic degree. In patients who have knee OA, gait patterns may also be influenced by age, radiographic disease severity (RDS) and BMI [22, 23]. Furthermore, overweight and obese patients with OA are likely to experience pain with movement, which may have a negative influence on physical function as manifested through gait mechanics. This was an interesting aspect of the present study that was focused on a sample of overweight and obese OA patients. Thus, a secondary aim of this study was to evaluate the contributions of self-report measures of pain and disability as well as RDS, and BMI to gait patterns of people with knee OA.

METHODS

Subjects

A total of 179 patients (43 men, 136 women) with radiographic OA in at least one knee (152 bilateral and 27 unilateral) and persistent knee pain participated in this study. All participants in this study were recruited as part of an ongoing study (OA Life) testing the separate and combined effects of a lifestyle behavioral weight management intervention and pain coping skills training intervention for obese OA patients. All participants signed an informed consent form approved by the Duke Medical Center Institutional Review Board. To be included in the study, patients had to be overweight or obese (BMI between 25 and 42 Kg/m^2), meet the American College of Rheumatology criteria for symptomatic knee OA, have chronic knee pain, and have no other weight bearing joint affected by OA on the basis of 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 anthropathy, morbid obesity, and regular use of corticosteroids. Weight-bearing, fixed-flexion (30deg) posterioranterior radiographs of both knees were taken with the SynaFlexer X-ray positioning frame.24, [a] The knee x-rays were graded by an experienced reader for OA severity on the basis of the K/L grading system (0–4 scale) [25]. For patients with bilateral knee OA, the knee with the higher 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.

Self Report Measures of Pain and Disability

Two standardized instruments were used to assess self-reports of pain and disability. First, the AIMS was used to assess pain, physical disability and psychologic disability. The range of scores on the AIMS scales is 0 to 10, with 0 representing good health status, and 10 representing poor health status. Research has supported the reliability of the AIMS and found it is valid when used with different types of arthritis, with a range of social and demographic groupings, and in different clinical settings [26].

Second, the WOMAC Version VA3.1 was used to assess self-reports of pain, stiffness, and physical function. 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 (17 questions). The reliability and validity of this index has been supported by previous research [27]. The range of scores on each of these subscales was between 0 and 100mm; with higher WOMAC scores reflecting a worse condition [27].

Gait Parameters

Reflective markers were placed at the superior aspect of the L5-sacral interface as well as bilaterally at the following landmarks: acromion process, lateral epicondyle of the humerus,

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[a]SynaFlexer X-ray positioning frame; Synarc, 575 Market Street, 17th Floor San

wrist, anterior superior iliac spine, thigh, lateral knee (at the joint line), shank, lateral malleolus, calcaneus, and foot (2nd webspace). In addition, markers were placed bilaterally on the medial femoral condyle and medial malleolus for identification of joint centers during the collection of a static trial. Once the static trial was completed, the medial markers were removed. In preparation for data collection, patients practiced walking along a 30 meter walkway at 2 differentiable and consistent self-selected speeds: the speed at which they normally perform their daily walking activities (normal) and the maximum speed they felt comfortable achieving (fast). These 2 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. Average normal and fast gait speed was determined from the average walking speed obtained during the 3 practice trials at each speed (normal and fast). Gait speed was measured using 2 wireless infrared photocell timing devices[b] positioned 5 meters apart. Following the practice trials, 3-dimensional kinematic data were collected at 60Hz using a motion analysis system[c] while patients completed 5 walking trials at each speed. Time synchronized ground reaction force data were collected using 2 AMTI force plates[d] at a sampling rate of 1200Hz. Variability in walking speed for each speed was restricted to ±5% of their average walking speed; trials outside of this range or trials during which the subject did not contact at least 1 of the force plates cleanly were repeated. The raw motion capture data were smoothed using a 4th order, recursive Butterworth filter with a 6Hz cutoff frequency. Three trials at each speed in which all of the reflective markers could be identified and in which the subject had clean contact with the force plates were used for analysis. Spatiotemporal variables (speed, and SL) as well as PVF and KROM across an entire gait cycle were computed using OrthoTrak 6.3[e]. SL data were normalized to subject height while ground reaction force data was normalized to body weight. The aforementioned gait variables were chosen as dependent variables based on findings from prior research. For example, OA patients walk slower, have shorter stride lengths, and a smaller KROM than their counterparts without OA[6, 10, 28, 29]. In addition, researchers have found that leg stiffness is proportional to ground reaction force; with less compliant gait producing a higher PVF[30–32]. Therefore we wanted to examine how self-reported stiffness actually reflects true stiffness as manifested through KROM and PVF.

Statistical Analysis

Statistical analysis was performed using SPSS (version 12.0.1 for windows[f]). Correlation analyses were performed to examine the associations between self-reported pain and disability assessed using the AIMS and WOMAC scales, demographics (age, gender, race), BMI, and RDS, and gait measures (speed, SL, KROM, and PVF) at each speed. Independent variables that were related to the gait measures ($p<0.05$) were retained for further analyses[33]

Stepwise regression analyses were used to determine the contributions of perceived pain and functional impairment to variance in gait mechanics[18, 34]. In each regression analysis, the self report measures of pain and disability as well as demographics, BMI and RDS were entered as independent variables. The subscales of the AIMS and WOMAC were considered separately during all analyses. The current study had adequate power for regression analysis; there were at least 15 cases per predictor [34].

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[b]Brower Timing Systems, 12660 South Fort Street, Suite 102Draper UT 84020
[c]Motion Analysis Corporation, 3617 Westwind Blvd. Santa Rosa, CA 95403
[d]AMTI force plates; Advanced Medical Technologies Inc., 176 Waltham Street Watertown, MA 02472-4800
[e]OrthoTrak 6.3; Motion Analysis Corporation , 3617 Westwind Blvd Santa Rosa CA
[f]SPSS (Version 12.0.1), SPSS, Inc, 233 S. Wacker Drive, 11[th] Floor Chicago IL 60606

RESULTS

Descriptive data and means and standard deviations for the pain and disability measures for the study participants are described in table 1. When walking at their normal speed, the study participants demonstrated a mean walking speed of 1.106 ± 0.191 m/s. When walking at the fast speed, the study participants had a mean walking speed of 1.52 ± 0.298 m/s. Table 2 gives detailed information regarding the gait mechanics at both speeds.

As can be seen in table 3, for the normal speed condition, correlation analysis revealed that BMI, RDS, and AIMS physical disability were correlated with the majority of the gait variables. WOMAC function was correlated with gait speed and SL, while the AIMS pain score was also correlated with speed. Thus, when walking at their normal speed, the OA patients in this study reporting problems with physical function and more disability were more likely to walk slower, take shorter strides, and have a smaller KROM.

As can be seen in table 4, there were a number of significant correlations between the self-report measures of pain and disability variables and the gait parameters at the fast walking speed. Significant inverse correlations were found between WOMAC function score and speed, SL, and PVF. In addition, AIMS physical disability score was also found to be inversely correlated with each of the 4 dependent variables. Taken together, these findings indicate that, when participants were asked to walk fast, those who reported higher levels of physical disability and functional limitations were more likely to do so at a slower speed, with smaller strides, and a more limited KROM.

The stepwise regression analysis (see table 5) revealed that AIMS physical disability score and BMI explained the highest proportions of variance in the gait parameters at the normal walking speed. Radiographic disease severity also accounted for small portions of variance in speed, KROM and PVF. The regression analyses conducted for the fast walking speed revealed that the WOMAC function score explained a significant proportion of variance in speed (10%) and SL (4%). The AIMS physical disability score explained a significant proportion of variance in KROM (10%), SL (7%), and PVF (4%). BMI also explained a significant proportion of variance in PVF (20%), SL (9%), speed (5%), and KROM (5%). Disease severity (RDS) explained a significant proportion of variance in KROM (9%) and PVF (3%).

DISCUSSION

Consistent with previous research, OA patients in this study walked more slowly [7, 35], took shorter strides, [35] exhibited lower PVFs,[35] and limited KROM [6, 7] compared to normative values from the literature. Also in agreement with previous research, radiographic disease severity (RDS) explained some of the variation in gait patterns[36, 37].

The primary question addressed in this study was whether self-report measures of perceived pain and functional limitation (AIMS and WOMAC measures) were correlated with objective measures of gait in obese persons with OA. Based on the concept that gait impairment is influenced not only by the degree of OA and obesity, but also by a person’s level and perception of pain, measuring a person’s self-reported level of pain and functional limitation has become accepted [15]. While the AIMS and WOMAC questionnaires provide convenient assessment methods, it is unknown whether answers given by patients on these questionnaires accurately reflect gait impairment. The results obtained in this study demonstrated that self-report measures of functional impairment were significantly correlated with gait speed indicating that OA subjects who find it more difficult to complete daily activities and consider themselves more functionally limited, walk more slowly. In addition, self-reported physical disability and function contributed to between 10% and 14%

of variance in gait speed. Moreover, previously reported evidence suggests that obese individuals prefer to walk more slowly than their normal-weight peers,[38,39] making the relationships observed in the current study more impressive since they were apparent even after controlling for variables that are considered to be important in explaining gait speed in OA patients(BMI, RDS).

Pain levels experienced by OA patients is believed to be a significant contributor to reduced walking speed in patients with knee OA compared to healthy controls. [40] In concurrence, this study determined that patients who reported more pain on the AIMS pain subscale also walked more slowly when asked to walk faster than their normal walking speed. Furthermore patients who reported more pain via the WOMAC pain scale walked more slowly and exhibited lower PVF.

The data presented in this paper also demonstrate that in this large sample, variation in several important gait parameters is more strongly influenced by perception of physical impairments than by RDS. The findings from the regression analyses suggest that the influence of a patient’s perception of his/her physical limitations on gait variance appears to increase with increasing stress on the locomotor system. At the fast speed, a self-report of functional impairment was significantly correlated with each of the gait parameters except for SL. At the fast speed, the WOMAC function score was the strongest predictor of variance in movement speed and SL while the AIMS physical disability score was the strongest predictor variance in KROM and the second strongest predictor of variance in SL and PVF. In interpreting these findings, it is important to keep in mind that the predictive utility of self-report measures in explaining gait may be underestimated, since measures of functional impairment were entered into the regression only after controlling for other variables (BMI, disease severity) that are important in understanding gait mechanics.

The results of correlation analyses suggested that, at the fast speed, the strength of the relationship between perceived physical limitation, as measured by WOMAC function score, and walking speed tended to increase. In an investigation of knee biomechanics of moderately severe knee OA, Landry et al, did not observe that walking faster enhanced or revealed any additional biomechanic differences between the OA and control groups [41]. It may be that the patients with moderate disability in this study continued to employ the same gait strategies at the fast speed as they did at their normal speed as the Landry data would suggest, but that the strategies of the more severely disabled patients in the present study failed under the higher stress condition since the biomechanic benefit of walking more slowly has been shown to be highly patient specific and vary with disease severity [42]

CONCLUSIONS

The purpose of this study was to see how self report measures of pain and disability relate to objective measures of physical performance (gait mechanics). The results showed that the predictors included in our study accounted for about approximately 20 to 30% of the variance in gait mechanics. Our findings serve as an objective validation that specific measures within the AIMS and WOMAC reflect gait impairments. WOMAC function, WOMAC pain, and AIMS physical disability all track limitations in speed and SL while AIMS physical disability also tracks limited KROM when the locomotor system is under greater stress. In addition, these measures explained variance in certain gait parameters beyond the variance accounted for by RDS or by BMI. This is a significant finding because it highlights the importance of recognizing and addressing a patient’s own perception of pain and functional impairment to understand and to treat osteoarthritis. However, since these self-report measures of pain and disability only account for a portion of the variance in the aberrant gait patterns of OA sufferers, perhaps something else is driving the OA patients to

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report the levels of pain, stiffness and disability they are experiencing as a result of their OA disease. Maybe pain cognitions such as pain catastrophizing, pain related fear, or self-efficacy are influencing the subject's appraisal of their pain and symptoms; thereby causing their self-report measures to reflect their true level of physical function. Future research should be conducted to determine what else is contributing to the altered gait mechanics. The authors also suggest that future work should be conducted to look at the effects of interventions designed to reduce pain and disability (e.g. weight loss or pain coping skills interventions) on gait mechanics.

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List of Abbreviations

AIMS	Arthritis Impact Measurement Scales
BMI	body mass index
K/L	Kellgren/Lawrence
KROM	knee range of motion
OA	osteoarthritis
PVF	peak vertical force
RDS	radiographic Disease Severity
SL	stride length
WOMAC	Western Ontario McMaster Universities Osteoarthritis Index

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Table 1

Descriptive Subject Characteristics, and Pain and Disability Measures

	Mean	SD
Age (years)	57.9	10.0
BMI (kg/m^2)	34.3	4.4
Height (m)	1.67	0.07
Weight (kg)	95.58	15.5
AIMS Pain subscale (0–10)	5.80	1.83
AIMS Physical Disability subscale (0–10)	1.67	1.19
AIMS Psychological subscale (0–10)	2.90	1.55
WOMAC Pain subscale (0–100)	45.11	19.4
WOMAC Function subscale (0–100)	47.42	19.1
WOMAC Stiffness subscale (0–100)	56.35	24.2

Table 2

Gait Mechanics

	Normal	Fast
Velocity (m/s)	1.106 (0.191)	1.52 (0.298)
Stride Length (statures)	0.729 (0.101)	0.823 (0.151)
Knee range of Motion (degrees)	57.75 (8.29)	59.97 (8.96)
Peak vertical GRF (BW)	1.05(0.0946)	1.16 (0.143)

All values listed as mean (SD)

Table 3

Correlations between self report measures, BMI, rOA, and gait variables at the normal speed

	BMI	rOA	WOMAC Function	AIMS Physical	AIMS Pain
Velocity (m/s)	−0.28**	−0.17*	−0.24**	−0.29**	−0.16*
Stride Length (statures)	−0.29**	−0.17*	−0.20**	−0.22**	NS
KROM (degrees)	−0.25**	−0.26**	NS	−0.21**	NS
PVF (BW)	−0.28**	−0.26**	NS	NS	NS

* denotes a significant correlation $p<0.05$,

** denotes a significant correlation $p<0.01$, NS denotes a non-significant correlation

Table 4

Correlations between self report measures, demographics, BMI, rOA, and gait variables at the fast speed

	Age	Race	Sex	BMI	rOA	WOMAC Function	WOMAC Stiffness	WOMAC Pain	AIMS Physical	AIMS Pain	AIMS Psych
Velocity (m/s)	NS	0.18*	−0.21**	−0.23**	−0.16*	−0.28**	NS	−0.20*	−0.28**	−0.16*	−0.18*
Stride Length (statures)	−0.15*	NS	NS	−0.28**	−0.17*	−0.26**	NS	NS	−0.26**	NS	NS
KROM (degrees)	NS	NS	NS	−0.25**	−0.24**	NS	NS	NS	−0.26**	NS	NS
PVF (BW)	NS	NS	−0.21*	−0.42**	−0.23**	−0.31**	−0.22**	−0.27**	−0.24**	NS	NS

* denotes a significant correlation p<0.05,

** denotes a significant correlation p<0.01, NS denotes a non-significant correlation

Table 5

Contribution of self-report measures, BMI, and radiographic disease severity to variation in gait parameters

Normal				
Gait Speed	R^2	R^2 Change	β	p
AIMS Physical Disability	0.09	0.09	−0.328	<0.001
BMI	0.19	0.10	−0.253	0.001
Radiographic Disease Severity	0.22	0.03	−0.164	0.029
Stride Length				
BMI	0.09	0.09	−0.296	<0.001
AIMS Physical Disability	0.15	0.06	−0.239	0.002
Age	0.17	0.03	−0.163	0.034
KROM				
BMI	0.08	0.08	−0.204	0.013
Radiographic Disease Severity	0.13	0.05	−0.320	<0.001
AIMS Physical Disability	0.19	0.06	−0.248	0.002
PVF				
BMI	0.08	0.08	−0.264	0.002
Radiographic Disease Severity	0.13	0.05	−0.212	0.013
Fast				
Gait Speed				
WOMAC Function	0.10	0.10	−0.169	0.042
Age	0.15	0.05	−0.339	<0.001
BMI	0.20	0.05	−0.221	0.003
AIMS Physical Disability	0.24	0.04	−0.203	0.008
Race	0.27	0.03	−0.195	0.014
AIMS Psychological Disability	0.30	0.03	−0.175	0.028
Stride Length				
BMI	0.09	0.09	−0.263	0.001
AIMS Physical Disability	0.17	0.07	−0.212	0.006
Age	0.20	0.03	−0.235	0.002
WOMAC Function	0.24	0.04	−0.230	0.004
KROM				
AIMS Physical Disability	0.10	0.10	−0.220	0.007
Radiographic Disease Severity	0.18	0.09	−0.267	0.001
BMI	0.23	0.05	−0.326	<0.001
PVF				
BMI	0.20	0.20	−0.385	<0.001
Radiographic Disease Severity	0.23	0.03	−0.209	0.010
AIMS Physical Disability	0.26	0.04	−0.192	0.010