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Review Article

The Relationship Between Physical Activity and Fatty Acids Intake with Osteoarthritis Symptoms

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Abstract

Objective: There is limited knowledge on the level of dietary intake of Saturated Fatty Acids (SFA) and Trans Fatty Acids (TFA) and physical activity of patients with Knee Osteoarthritis (OA). In this study, we monitored and compared the level of SFA and TFA dietary intake, and physical activity in adults with and without knee OA. We also investigate the relationship between nutrient intake and physical activity with OA symptoms.

Design/Setting/Participants: Sixty patients diagnosed with knee OA and 50 healthy subjects were recruited in this cross-sectional study. Nutrient intakes were collected using a 3-day dietary record, and number of steps was monitored using Fitbit device. The clinical diagnosis was assessed using performance-based measures of 6-minute walk (6MWT) and stair test, and self-reported measures of pain, stiffness, and function.

Results: Patients had fewer steps/day ($p=0.04$) and spent less time in very active movements ($p=0.02$) than healthy controls. When nutrient intake was adjusted for sex, Body Mass Index (BMI), and age, patients with OA had significantly ($p<0.01$) higher intake of SFA, and TFA than healthy controls. Steps/day had a significant ($p<0.01$) association with all self-reported and performance-based measures. SFA was significantly ($p<0.05$) associated with pain, stiffness, and 6MWT, and TFA was significantly ($p<0.05$) associated with pain, function score, and 6MWT.

Conclusion: Walking more and consuming lower amount of SFA and TFA were associated with lower pain and higher physical function scores. Increasing walking, and reducing SFA and TFA should be explored as potential interventions for patients with knee OA.

Introduction

Osteoarthritis (OA) is a highly prevalent, costly, and disabling disease that affects 1 in 8 (13%) Canadians [1]. The prevalence of OA is expected to continue to rise due to the aging population and increased obesity and physical inactivity [2]. With the lack of disease modifying therapies, OA requires long-term management, which eventually leads to higher health care utilization and increases the medical costs in this population. Therefore, there is an urgent need for effective and accessible approaches to aid in the management of this common condition. The involvement of inflammatory pathways in OA pathogenesis is well known, and reducing inflammation is considered to be a key factor in the management of OA. In order to reduce inflammation in patients with OA, available international guidelines recommend targeting modifiable risk factors, including diet and physical activity/exercise [3]. Specific unfavorable dietary patterns may play an important role in the initiation and progression of many chronic diseases [4,5]. The association between a high-fat diet and early onset of OA in a mouse model has been known since 1950 [6]. Increased dietary fat has been shown to alter systemic levels of pro-inflammatory cytokines and trigger cartilage degradation in animal models [7,8]. For example, in a mouse study, a high-fat diet increased the levels of serum leptin, adiponectin, interleukin-8 (IL-8), and IL-1α, and also induced symptomatic characteristics of OA [9]. In humans, a recent cohort of participants with radiographic knee OA and baseline dietary data were followed yearly out to 48 months to study the association of dietary fat intake with radiographic progression of knee OA. They revealed that higher total fat or Saturated Fatty Acids (SFA) intakes were associated with increased radiographic progression of knee OA, while Higher Polyunsaturated Fatty Acids (PUFA) and Monounsaturated Fatty Acids (MUFA) intakes appeared to be associated with reduced progression [10]. Little is known regarding the relationship among dietary fat intake (including total fat, SFA, and TFA) and performance-based and self-reported pain and function in patients with OA.

Given the substantial body of evidence that has demonstrated the beneficial effects of exercise intervention, as another modifaiable risk factor, for patients with OA [11,12], exercise therapy is now regarded as a first-line intervention. However, patients with knee OA often do not comply with exercise regimens due to pain and limited function [12,13]. As walking is the most common form of physical activity that older adults with knee OA engage in daily, understanding the relationship between steps/day and health outcomes is useful for patients and arthritis health-related professionals [12]. The results regarding the association between steps/day and health outcomes in patients with OA are mixed from no association [14] to a positive association with function [15,16], and pain [17] measures. Several factors affect physical activity including age, sex, body composition, severity of knee OA, and comorbidities [10,17]. In the existing literature, researchers have not adjusted physical activity outcomes for confounding factors, have not reported the step/day count to compare with recommended guidelines, or have not used an adequate sample size [14,19-21]. Thus, our understanding of physical activity in terms of step count and its association with health outcomes is limited. In view of the above mentioned, the objectives of this study were to examine dietary intake of total fat, SFA, and TFA as well as the level of physical activity in participants with or without osteoarthritis. We also investigated the relationship between nutrient intake (including total fat and SFA) and physical activity measures with both performance-based and self-reported measures of function and pain, in adults with and without knee OA.

Methods

Study Design

A cross-sectional study was conducted.

Participants

Patients, age 45 to 75 years, with clinically and radiographically diagnosed moderate to severe unilateral knee OA who were referred to the Edmonton Hip and Knee Clinic were eligible to participate. Recruitment was initiated at the screening visit by the musculoskeletal specialist, or nurse, who asked patients whether they were interested/willing to participate in the study. If the patient was interested, then the healthcare provider introduced the researcher to the patient. Participants who had evidence of post-traumatic arthritis, neurological conditions that may impair their mobility or systemic inflammatory diseases (e.g., rheumatoid arthritis) were excluded from the study. Patients with uncontrolled diabetes and those with unstable angina or cardiac complications that may affect their level of activity (e.g., left ventricular ejection fraction <25%) and those who were undertaking weight loss or anabolic therapies (within the previous 3 months) were also excluded. The "healthy control" group was recruited from a population of healthy people with no history of injury in lower extremities (ankle, knee, and hip) or any symptoms related to osteoarthritis that affected their ability to walk or climb one flight of stairs (up and down). The recruitment for healthy participants was conducted using flyer advertisements, which was approved by the University of Alberta Research Ethics Board. All participants received an information sheet explaining the study and then met with the researcher who explained the study in detail, answered questions, and obtained written informed consent.

Procedure

Anthropometric measurements including weight (kg), height (cm), and waist girth circumference (WC; cm) were taken and rounded to the nearest 0.1 centimeters. BMI was calculated as weight (kg) divided by height squared (m^2). Performance-based and self-reported measures were used to evaluate symptoms in both groups. Performance-based measures including 6 Minute Walk Test (6MWT) and stair test were used to measure physical function and followed the Osteoarthritis Research Society International (OARSI) guidelines [22]. Western Ontario and McMaster University Osteoarthritis Index (WOMA) subscales of pain, function, stiffness and total scores, and the Lower Extremity Function Scale (LEFS) were used as self-reported measures. All measures have been shown to have high validity and reliability [23,24].

Nutrient intakes were collected using a 3-day diet record to determine the amount of food consumed for three consecutive days (two weekdays and one weekend day). Diet records provide reliable and detailed information on nutrient intake, and 3-day diet records, specifically, have been used to evaluate habitual dietary intakes in multiple populations including OA patients [25-28]. Participants received instructions, for completing the 3-day diet record. They were also instructed not to change their routine eating habits during the 3 days of food records. Each diet record was reviewed by one study investigator, who telephoned participants to collect missing details and clarify data entries where necessary. The recorded foods were inputted into the Food Processor Software (v. 10.11, 2012, Esha Research, Salem, Oregon, USA), using the Canadian Nutrient File when applicable. Daily food intake records with biologically implausible total calorie intake were removed from the analysis. The cut-offs used for implausible total calorie intake were based on previous studies, which were <800 or >4200 kcal/d for men and <500 or >3500 kcal/d for women [29]. Therefore, a total of 17 (5%) out of 294 daily observations were removed based on these criteria. From ESHA software output the amounts of energy intake (kcal/d), fat (kcal/d), fat (g/d), saturated fat (kcal/d), mono fat (g/d), poly fat (g/d), trans fat (g/d), cholesterol (mg/d), omega 3 fatty acids (g/d), omega 6 fatty acids (g/d), carbohydrates (g/d), protein (g/d), fiber (g/d) were included in the analysis.

To monitor participants' physical activity, a Fitbit Zip was used. Fitbit Zip is a low-cost wearable device regarded as convenient and comfortable to wear, which has an expanded battery life of almost 4 to 6 months. Fitbit Zip has been previously validated among older adults for measuring step count and has been shown to be a valid and reliable method to measure steps and distance [30]. Physical activity measures attainable from the Fitbit Zip include steps (count/day), distance (meter/day), sedentary (min/day), lightly active (min/day), fairly active (min/day; moderate intensity), and very active time (min/day; vigorous intensity) [31]. The device has a silicon clip that can be attached essentially anywhere on the body. Instructions were provided to participants regarding the appropriate wear and positioning of the accelerometer as follows. Participants were instructed to wear the accelerometer on their belt/waist, with the display facing outward, upon arising in the morning and continuing until going to bed at night for three consecutive days (two weekdays and one weekend day). When the Fitbit Zip was returned, the device was synced, and its data was uploaded to the fitbit.com dashboard. Participants' minute-by-minute step counts were downloaded through Fitbit's application program interface. To accurately represent participants' daily physical activity, the daily average of the total number of steps taken over three days was calculated and used in the analysis.

Statistical Analysis

Baseline characteristics were examined for normality of distribution using the Shapiro-Wilk test. In the descriptive analysis, all baseline characteristics of participants were compared between the group of patients with knee OA and that of the healthy controls using independent Student's t-tests or non-parametric tests when applicable. The primary analysis was done to compare the physical activity and nutrient intakes between the group of patients with knee OA and the healthy non-OA participant group. The primary outcomes were each of the nutrient intakes (e.g. total fat, SFA, TFA) and physical activity measures (i.e. steps/day and distance). The initial analysis compared means for each of the physical activity measures between the two groups using independent Student's t-test statistics. Since there was a high correlation between each of the nutrients with total energy intake, the means of each nutrient measure were adjusted for total energy intake [32] and compared between groups using linear regression modeling. Linear mixed-effect models were used to compare the physical activity and nutrient intake measures between two groups, adjusting for confounders (sex, age, and BMI). The association between each of the main dependent variables including steps/day for physical activity level and SFA for nutrient intake with independent variables (sex, age, BMI, and WC) were determined in univariate fashion using Pearson correlation and t-test when applicable. Independent variables of group, sex, age, BMI, and WC with $p<0.20$ were included in the full model. We examined for multicollinearity among the independent variable(s) using the variance-inflation factor (VIF). Variance-inflation factor of 4 [33] has been considered as the cut-off criterion to remove predictor variables that are highly correlated, which ensures stability and reliability of the model developed. Then, WC was removed from the full model due to collinearity with BMI. Nutrients were adjusted relative to total energy intake to examine their effect independent of the total amount of energy intake [32].

The secondary analysis involved examining the association between nutrient intake and physical activity with both performance-based (6MWT and stair test) and self-reported measures (WOMAC pain and LEFS). Dependent variables included each of the WOMAC subscales, LEFS, 6MWT, and stair test. Univariate regression analyses between each of the dependent variables with each of the independent variables (nutrient intakes and physical activity measures) were performed to find potential predictors. Predictors (independent variables) with a significant ($p<0.20$) regression coefficient were tested for multicollinearity using VIF measures, setting a VIF of 4 as the cut-off criterion [33]. Best linear subset regression modeling with minimization of Mallow's CP and maximizing R squared was used to select the best model. The selected model was used to quantify the relationship between each of the dependent variables and individual predictor variables. All statistical analyses were performed using the R software program Version 0.99.902.

Results

A total of 60 patients with knee OA and 50 healthy controls were recruited. One patient and one healthy participant dropped out of the study after the initial visit and thus their data were excluded. Thus, 59 patients with knee OA and 49 healthy controls were included in the analyses. Baseline characteristics of participants are shown in (Table 1). Overall, patients with knee OA were older and had higher BMI and waist circumference ($p<0.0001$) compared to healthy controls. As expected, patients with moderate to severe OA had worse LEFS, WOMAC pain, function, stiffness, and total WOMAC scores. Performance in the stair test and 6MWT were significantly ($p<.0001$) worse amongst the patients with OA when compared to healthy controls. Group differences in physical activity and nutrient intake measures are presented in (Table 2). Results of unadjusted means for physical activity revealed that patients performed significantly fewer steps per day ($p<0.0001$), walked shorter distances ($p<0.0001$), spent less time being fairly active ($p=0.009$) and very active ($p<0.0001$), and spent more time being sedentary than those in the healthy control group ($p=0.009$). However, after adjusting for confounding factors (i.e. sex, BMI, and age), only steps per day ($p=0.04$) and time spent in very active movements ($p=0.02$) were significantly different between the two groups. A significant ($p=0.02$) interaction between group and sex was observed for lightly active movements. Males in the OA group spent significantly more time ($p=0.03$) doing light activity compared to males in the healthy control group.

	Groups		
	OA¥	Healthy	p-Value
N	59	49	
Female N	41	32	
Baseline characteristics			
Age ±SD (year)	65.7±5.8	55.3±7.4	<.0001
BMI ±SD (kg/m^2)*	35.9±7.6	28.5±6.2	<.0001
Waist Circumference ±SD (cm)	118.2±22.1	93.4±14.7	<.0001
Performance-based outcomes			
6min-walk ±SD (meter)	290.0±98.6	588.0±63.8	<.0001
Stair Test ±SD (seconds)	25.7±13.0	6.7±1.2	<.0001
Self-reported outcomes			
LEFS ±SD (out of 80) €	30.5±13.8	78.3±4.3	<.0001
WOMAC (out of 100) §			
Pain ±SD	45.0±20.2	1.5±3.4	<.0001
Function ±SD	47.8±18.2	1.5±3.5	<.0001
Stiffness ±SD	57.7±19.1	6.2±11.2	<.0001
Total ±SD	48.1±17.8	1.9±3.6	<.0001

*BMI: Body Mass Index;

¥OA: Subjects who had moderate to severe osteoarthritis based on the Kellgren Lawrence Classification. €LEFS: Lower Extremity Function Scale, 80 being the best.

§WOMAC: Western Ontario and McMaster University Osteoarthritis Index, 100 being the worst.

Table 1: Baseline characteristics for original dataset and sex and BMI* matched groups.

	Unadjusted mean ± standard deviation			Adjusted mean ± standard error*		
	Group			Group		
	OA¥	Control	p-Value€	OA¥	Control	p-Value€
Physical activities‡ N	57	49		57	49	
Steps/day	4530±2105	7550±2937	<.0001	5319±432	6839.0±483	0.04
Distance (meters)	3130±1460	5060±2160	<.0001	3720±310	4500±350	NS
Sedentary (min)	1282±62.2	1248±68	0.009	1261±10.9	1127±12.2	NS
Light active (min)	149±59.0	165±66.4	NS	168±10.5	144±11.8	NS
Fairly activ (min)	4.8±6.9	10.4±12.9	0.009	6.7±1.8	9.1±2.0	NS
Very active (min)	3.76±6.2	17.3±20.3	<.0001	5.3±2.6	15.7±2.9	0.02
Nutrients† N	53	45		53	45	
Total energy (kcal/d) ‡	2110.8±408	1827.0±416	0.001	2049±69.1	1877±79.5	0.02

Total fat (kcal/d)	781.0±241	684.0±263	0.01	757±32.5	684±36.5	NS
Total fat (g/d)	87.0±26.9	76.2±29.3	0.01	84.4±3.6	76.1±4.1	NS
SFA (kcal/d) Φ	244.0±96.3	207.0±104.9	0.01	250.0±13.1	204.0±14.8	0.04
SFA (g/d) Φ	27.1±10.7	23.0±11.7	0.01	27.8±1.5	22.7±1.7	0.04
Mono fat (g/d)	30.3±13.7	27.5±15.0	NS	29.1±1.9	27.2±2.9	NS
Poly fat (g/d)	16.5±8.0	14.7±8.8	NS	14.8±1.0	15.5±1.2	NS
TFA (g/d) §	1.38±1.1	0.93±1.2	0.01	1.43±0.15	0.91±0.20	0.05
Cholesterol (mg/d)	344 ±236	279±258	NS	371.0±31.8	264.0±35.7	NS
Omega 3 (g/d)	1.98±1.47	1.72±1.59	NS	1.79±0.20	1.84±0.20	NS
Omega 6 (g/d)	13.5±7.1	12.5±7.7	NS	12.2±0.9	13.3±1.0	NS
Omega 3/ Omega 6	0.15±0.10	0.15±0.11	NS	0.14±0.01	0.15±0.01	NS
Mono fat /saturated fat	1.16±0.57	1.27±0.62	NS	1.07±0.07	1.28±0.08	NS
Poly fat/saturated fat	0.66±0.41	0.70±0.44	NS	0.57±0.05	0.75±0.06	NS
Carbohydrates (g/d)	214±69.2	246±75.4	0.004	216.0 ±9.4	246.0±10.6	NS
Protein (g/d)	85.0±24.6	81.5±26.9	NS	88.5±3.3	78.5±3.7	NS
Protein/bodyweight (g/kg)	0.88 ±0.42	1.07±0.45	0.005	0.97±0.05	0.94±0.05	NS

*The results are from the linear mixed models using the full model that includes sex, group, sex×group, body mass index, age, and total energy intake as independent variables.

¥OA: Subjects who had moderate to severe osteoarthritis.

ΦSFA: Saturated Fatty Acids;

§TFA: Trans Fatty Acids,

‡Variables are adjusted for all factors in the full model except total energy intake.

€ Significant P-values are bolded. P-values for other factors and adjusted mean for sex×group are presented in (Table S1).

†Vit C (mg/d), Vit D (mg/d), Calcium (mg/d), Phosphorus (mg/d), Water (g/d), Fiber (g/d), Sugar (g/d), Vit K (mg/d), Vit B1 (mg/d) , Vit B3 (mg/d), and Vit B12 (mg/d) were dropped from Table 2 since they were neither significantly different nor our main interest.

Table 2: Unadjusted means ± standard deviation and adjusted means ± standard error for physical activities and nutrients by group.

Based on unadjusted nutrient intake, OA patients had significantly higher intake of total energy (kcal/d), total fat (kcal/d and g/d), SFA (kcal/d and g/d), and TFA (g/d), and a lower intake of carbohydrates (g/day) and protein (g/d and g/kg body weight) than healthy controls. When nutrient intake was adjusted based on the sex, BMI, and age of participants, patients with OA had significantly higher intake of total energy, SFA, and TFA than healthy controls (Table 2).Results of separate multiple regression models for self-reported (WOMAC pain, stiffness, function, and total, as well as LEFS) and performance-based (6MWT, and stair test) measures are presented in (Table 3). Steps per day had a high association with all self-reported and performance-based measures. Increasing 1000 steps per day, independent of other variables (SFA, TFA, age, and BMI), was associated with a significant reduction (improvement) of 1.9 scores in WOMAC pain (p =0.03), 2.1 scores in WOMAC stiffness (p=0.03), 1.7 scores in WMOAC function (p=0.06), 1.7 score in WOMAC total (p=0.04), and 1.1 seconds in the stair test (p=0.003). Increasing 1000 steps per day was associated with a significant increase (improvement) of 1.8 scores in LEFS (p=0.02) and 14.7 meters in 6MWT (p=0.001). Saturated fatty acids intake was significantly associated with pain, stiffness, LEFS, and 6MWT, where increasing intake of 10 gram SFA, independent of other variables, was associated with a significant increase (worsening) of 3.7 scores in pain (p=0.13) and 3.5 scores in stiffness (p=0.15). Also, increasing 10 gr SFA intake was associated with a reduction (worsening) of 4.9 scores in LEFS (p=0.01) and 17.5 meters in 6MWT (p =0.15). Trans fat intake was significantly associated with WOMAC pain, function, and total score, as well as distance walked during the 6MWT, where increasing 1 gr TFA intake was associated with a significant increase (worsen) of 4.5 scores in pain (p=0.09), 5.8 scores in function (p=0.02), 5.6 in total score (p =0.02), and 18.8 meters in 6MWT (p=0.02). Non-demographic factors (age and BMI) accounted for 33%, 31%, 29%, 30%, 34%, 45%, and 32%, respectively, of WOMAC pain, stiffness, function, and total score as well as LEFS, 6MWT, and stair test.

Variable		Pain	Stiffness	Function	Total	LEFS	6MWT	Stair
Intercept	β*	-75.38	-99.1	-85.1	-83.6	169.4	1176	-25.2
	C.I¥	-120.8 to -29.8	-148 to -49	-130 to -39.8	-128 to -38	128 to 210	952 to 1400	-44.2 to -6.1
	p‡	0.001	0.0001	0.0001	0.0001	0.0001	0.0001	0.01
Non-Demographic Factors (NDF)								
Steps (1000)	β	-1.9	-2.1	-1.7	-1.75	1.82	14.7	-1.13
	C.I	-3.7 to -0.2.2	-4.1 to -0.18	-3.4 to 0.09	-3.5 to 0.01	0.21 to 3.42	6.03 to 23.4	-1.88 to -0.39
	p p.R2€	0.03	0.03	0.06	0.04	0.02	0.001	0.003
SFA (10 gr)	β	0.23	0.27	0.23	0.24	0.27	0.37	0.32
	C.I	3.7	3.5	---Ϯ	--- Ϯ	-4.9	-17.5	---
	P	1.1 to 8.6	-1.4 to 8.4			-9.1 to -8.0	-41.6 to 6.2	
	p.R2	0.07	0.04			0.07	0.06	
Trans (1 gr)	β	4.5	--- Ϯ	5.8	5.6	--- Ϯ	-18.8	
	C.I	-0.82 to 9.8		0.92 to 10.8	0.75 to 10.5		-45.1 to 7.52	
	p	.09		0.02	0.02		0.15	
	p.R2							
		0.03		0.06	0.06		0.02	
Demographic factors								

BMI(kg/m2)	β	0.47	0.98	0.55	0.58	-0.74	-5.29	0.46
	C.I	-0.14 to 1.09	0.31 to 1.65	-0.06 to 1.2	-0.02 to 1.2	-1.3 to -0.19	-8.34 to 2.24	0.20 to 0.72
	p p.R2	0.13	0.004	0.07	0.05	0.009	0.008	<.001
		0.01	0.04	0.02	0.02	0.03	0.04	0.07
Age (year)	β	1.35	1.7	1.59	1.56	-1.49	-9.7	0.53
	C.I	0.79 to 1.89	1.1 to 2.3	1.04 to 2.14	1.02 to 2.10	-1.9 to 0.98	-12.47 to -7.0	0.31 to 0.77
	p	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
	p.R2	0.13	0.17	0.19	0.18	0.17	0.19	0.12
R2 of NDF	0.33	0.31	0.29	0.3	0.34	0.45	0.32	
R2 for model		0.48	0.53	0.49	0.51	0.55	0.67	0.51
Adj. R2 for model		0.46	0.51	0.47	0.48	0.53	0.65	0.5

§ = The full model included Steps, SFA, TFA, BMI, and age.
*β = Beta; regression Coefficients
¥C.I= Confidence Interval
‡P= P-Value
€p.R2 = Partial R squared
Ϯ This covariate was not included in the best linear subset modeling with minimization of Mallow's CP and maximizing R squared.

Table 3: Regression correlation coefficients between self-reported and performance-based and each of physical activities and nutrients among the study population§.

Discussion

The current study reports physical activity and nutrient intake in a group of patients with moderate to severe primary unilateral knee OA and compares them with a group of healthy controls. Patients with knee OA were particularly inactive compared to healthy controls, as monitored using accelerometer-based devices. Knee OA patients spent less time performing very active movements (Vigorous) than healthy controls. The current study also demonstrated that patients with knee OA had significantly higher levels of total energy intake, SFA, and TFA intakes compared to healthy controls. Significant associations between steps per day or nutrient intake and health outcomes (performance-based and self-reported measures of pain and physical function) were observed. An increase in steps was associated with better WOMAC pain, stiffness, function, and LEFS as well as the stair test, and 6MWT. Conversely, an increase in SFA or TFA was associated with worse WOMAC pain, stiffness, function, LEFS, and 6MWT. These results may imply that increase in steps/day and reduction in SFA and TFA intake would be associated with better performance-based and self-reported outcomes. Walking is one of the most common types of unstructured physical activity that older adults with knee OA engage in daily, and that has the potential to improve overall health [15]. Step count is gaining widespread attention since it can be easily communicated to the public and directly translated into the clinical setting. It follows that quantifying and examining steps/day may be an important behavioral measure to monitor for patients with knee OA. The results of the current study showed that patients with knee OA were less active than non-OA controls (5319 vs. 6839 steps/day, respectively) after adjusting for putative confounders (age, sex, and BMI); these findings are in line with previous studies [14,19,21]. For example, a study by Verlaan, et al. [21] reported that patients with knee OA walked fewer steps per day (p=0.001, 4402 steps/day) compared to healthy subjects (6943 steps/day). Our results are also in line with a systematic review suggesting that older adults with chronic diseases accumulate 3500–5500 steps/day, and healthy older adults accumulate between 6000 to 8000 steps/day [34,35]. There are a few studies [21,36] that did not show a clear difference in steps/day between OA patients and healthy controls. There may be several reasons related to this discrepancy, such as the inclusion of patients who varied extensively with respect to the severity of disease (including patients at risk and from early-stage knee OA up to pre-TKA) and the healthy control groups from the general population who had different comorbidities. It is expected that patients at risk for and in the early stage of knee OA exhibit the same level of physical activity compared to the general population [36].

The benefits of regular exercise on reducing pain and improving physical function in patients with knee OA have been documented in a recent systematic overview of reviews [12] of 240 studies involving 24,583 participants. However, patients with knee OA often do not adhere to exercise regimens due to pain and limited function [12,13]. For people with symptoms of knee OA, even 10-min bouts of exercise can be challenging [12]. Since walking is the preferred form of activity for older patients, understanding the relationship between steps/day and health outcomes is useful for patients and arthritis health-related professionals [12]. Our findings quantified the association between physical activity and performance-based as well as between physical activity and self-reported function. Results of the current study indicate that increasing steps/day would be associated with improvement in WOMAC pain, stiffness, physical function scores, LEFS score, 6MWT distance, and the stair test. These results are in line with previous studies in the OA population demonstrating the positive independent association of physical activity with physical function [15,16,37] and pain [17]. Due to the lack of evidence quantifying SFA and TFA intake of OA patients and comparing those intakes with healthy controls, a direct comparison of our results is not possible. However, data from patients with other chronic diseases such as heart failure [38] and diabetes [39] demonstrated that a high fat intake was more prevalent in patient with chronic disease. Animal models have demonstrated an association between high-fat diet and early onset of OA since 1950 [40]. Since then, animal models have been used to test the hypothesis that high-fat diet induces and accelerates the progression of osteoarthritis [41]. A recent meta-analysis [42] of 14 publications on the effect of a high-fat diet on the onset or progression of Osteoarthritis (OA) in mice indicated that a high-fat diet induced or exacerbated the progression of OA in mice. It is difficult to establish the role of diet in the etiology of knee OA in humans due to the lack of sensitive markers of nutritional status, the human body's adaptability to the varying levels of nutrient intake, and the complexity and slow progression of OA [42]. Our results indicate that lower SFA and TFA intake, independent of other variables, would be associated with improving pain, stiffness, function, LEFS, and 6MWT.

Very few human studies have evaluated the role of fat intake in knee OA progression. A cohort study with 251 healthy participants indicated that increased SFA intake was associated with an increased incidence of bone marrow lesions, which may predict knee OA progression [43]. A large prospective study in OA patients also found that higher intakes of TFA and SFA were associated with increased knee joint space-width loss, whereas the higher intakes of MUFAs and PUFAs were associated with reduced radiographic progression of OA [10]. Of note, the Minimal Clinically Important Difference (MCID) values after rehabilitation programs for WOMAC pain, stiffness, and physical function (on the scale of 0-100), LEFS, and 6MWT were reported as 7.09, 16.2, 11.25, 12, and 50 meters, respectively [44,45]. The results indicate that adding 3730, 7710, 6620, 6666, and 3400 steps/day, independent of other factors, might improve pain, stiffness, function, LEFS, and 6MWT, respectively to be considered as beneficial. In terms of dietary intake of SFA, and TFA, guidelines recommended that adults should limit the SFA intake to no more than 10% of the total calories (22g/day for a person eating 2000 calorie/day) and eliminate TFA from the diet. Our results indicate that the OA group consumed 27.8 grams of SFA and 1.43 gram TFA. A reduction of 5.8 grams in SFA intake (from 27.8 to 22 gr/day), independent of other variables, would be associated with improving 2.3, 2.0, and 2.8 scores, respectively, in WOMAC pain, stiffness, and LEFS, as well as 10.2 meters in 6MWT. The results also show that eliminating TFA from OA patients' diets (from 1.43 to zero gr/d), independent of other factors, would be associated with 6.4 scores in pain, 8.3 scores in function, 8 scores in total, and 26.9 meters in 6MWT.

Limitations

There are limitations to this study that should be acknowledged. Accelerometers are known to miss certain activities such as water activities and cycling. It is possible that participation in non-stepping activities biased our study results. However, considering that these activities are generally not very common among patients with OA, we think that most of the activities were captured. It is also possible that wearing an accelerometer may be made individuals more aware of their activity level and may have encouraged participants to be more active. To minimize this effect, the accelerometer used in this study did not provide feedback to the participants. The reported steps/day in this study is a reasonable estimate since the values are similar to previously published reports [21] and are within the range reported by the Canadian Health Measure Survey [46]. This is a cross-sectional study, and thus it does not provide evidence that the observed associations are causal. A prospective longitudinal study with larger sample size is needed to establish the causal association of nutrient intake and physical activity with OA symptoms. Obesity may be a factor linking fat intake to OA symptoms. However, the association between fat intake and OA symptoms remained significant even after adjusting for BMI. Another limitation of this study is that OA were matched for sex, but not age and BMI. However, we attempt to account for potential confounders such as BMI and age that could affect our outcomes through the analyses. This has been suggested and recommended in previous research in the absence of matching [47-49].

Conclusion

The results of this study provide information about the steps/day and dietary intake of patients with knee OA and add to the literature showing that a higher intake of SFA and TFA is associated with worse self-reported and performance-based function measures, and a higher number of steps/day was associated with better self-reported and performance-based measures of physical function. These findings may suggest that following a healthy lifestyle, including walking, reducing SFA, and eliminating TFA may be an effective strategy for knee OA management. Lifestyle strategies are more attractive than medications in terms of risk/benefit and are more likely to be implementable. There is a need for further prospective cohort studies to determine whether there is a causal relationship between lifestyle factors, including high-fat diet and steps/day, and OA symptoms.

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