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Relationship between objectively measured lifestyle factors and health factors in patients with knee osteoarthritis

The STROBE Study

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Abstract

The purpose of this study was to investigate the association between objectively-measured lifestyle factors and health factors in patients with knee osteoarthritis (OA).

In this cross-sectional study, 52 patients with knee OA were examined. Lifestyle factors were measured using a wearable smartwatch (step counts, walking distance, calorie consumption, sleep hours) and by self-report (eating speed). Body mass index (BMI), waist circumference, blood pressure, muscle strength of knee extensor and hip abductor, knee pain, symptoms, daily living function, sports recreation function, quality of life by knee injury and OA outcome score (KOOS) were measured to obtain data on health factors. Correlations and regression analysis were used to analyze the relationship between lifestyle factors and health factors.

KOOS subscales (pain, symptom, daily living function) and hip abductor strength were positively correlated with daily step count, which was the only independently contributing lifestyle factor. Additionally, knee pain duration and diastolic blood pressure were negatively correlated with daily step count. BMI and waist circumference showed no correlation with physical activity data, but were negatively correlated with sleep duration and eating speed.

The findings of this study contribute to expanding the knowledge on how lifestyle habits of older patients with knee OA contribute to their health status. Daily step counts were associated with knee OA-related pain, symptom, function in daily living, duration of knee pain, blood pressure, and strength of hip abductor. BMI and waist circumference were associated with sleep duration and eating speed.

Abbreviations: BMI = body mass index, ICC = intraclass correlation coefficients, KOOS = knee injury and OA outcome score, OA = osteoarthritis.

Keywords: health, knee osteoarthritis, lifestyle, pain, wearable smartwatch

1. Introduction

A quarter of people >55 years experience at least 1 episode of knee pain every year, which is likely to develop into knee osteoarthritis (OA).[1] Knee OA is a major cause of pain, difficulty in walking, and physical inactivity, which is related with several adverse health factors such as increased body mass index (BMI), elevated blood pressure, higher cardiovascular risk, weakness of knee extensor and hip abductor, low functional level in physical activity, and low quality of life.[2–6]

A meta-analysis study demonstrated that obesity and excess weight are major risk factors of knee OA, and points to the need for education to improve, as well as a positive lifestyle change with an increase in physical activity.[7,8] Lifestyle is defined as the way an individual lives, including physical activity, diet, eating behavior, sleep pattern, social/leisure activity, alcohol consumption, and smoking.[9] Previous studies that relied on self-reported level of physical activity estimated that 23.8% to 57.8% of adults with OA are inactive.[10] Recently, wearable devices have been increasingly used, with functions like accelerometry, pedometry, heart rate monitoring, and global positioning system, which can objectively quantify the level of physical activity such as step counts and calorie consumption.[11] Patients with knee OA showed low level of physical activity using uniaxial accelerometer on the right hip, and a sedentary lifestyle exacerbated by knee OA/pain has been shown to increase the risk of obesity.[7,12,13] Other studies using uniaxial accelerometers attached on the waistband demonstrated that knee OA patients with a higher level of physical activity had better physical function, but this was not associated with knee pain intensity or obesity status.[14]

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Although sleep duration and eating behavior also are a part of lifestyle, previous studies on patients with OA focused on investigating the relationship between level of physical activity and OA-related health status.[7,11–14] Sleep duration is also part of the lifestyle factors which play a role in the prevention of chronic diseases, which can calculated in a day using wearable device in wrist.[15] Pain caused by OA contributes to sleep disturbance and is used as one of the indicator of pain intensity.[16] A recent study demonstrated that the shorter self-reported sleep duration has significant association with higher prevalence of knee or hip OA, especially the prevalence of OA was the lowest at 6 to 7 hours of daily sleep duration.[17] Previous meta-analysis demonstrated that faster self-reported eating speed is related with higher BMI, which is major risk factor of knee OA.[7,18,19] Because sleep duration or eating speed can impact high prevalence of OA or obesity,[7] it is necessary to quantify the relationship between lifestyle factors (such as sleep duration and eating speed) and OA-related health factors (BMI and waist circumference).

Understanding the relationship between lifestyle factors and health factors is important in designing a rehabilitation program focusing on habitual healthy lifestyle in older patients with knee OA. Therefore, the purpose of this study was to investigate the association between health factors (BMI, waist circumference, blood pressure, muscle strength, knee pain, symptom, daily living function, sports recreation function, quality of life) and lifestyle factors (objectively measured step count, walking distance, calorie consumption, sleep duration with wrist-worn wearable device including triaxial accelerometer and self-reported eating speed) in patients with knee OA. Additionally, we investigated which lifestyle factors independently contribute to each health factor. We hypothesized that less step counts, shorter sleep duration and faster-eating speed would be associated with worse knee OA-related pain, worse symptom, worse function, higher BMI, higher blood pressure and weak muscle strength.

Table 1

Characteristics and health factors of patients with knee osteoarthritis (N=52).

Variables	
Age, yr, mean ± SD	60.3±5.6
<55, N (%)	7 (13.5%)
55–64, N (%)	37 (71.1%)
65–74, N (%)	8 (15.4%)
Body mass index, kg/m^2, mean ± SD	24.3±3.2
<25 kg/m^2, N (%)	36 (69.2%)
25–29.9 kg/m^2, N (%)	14 (27.0%)
>30 kg/m^2 (%), N (%)	2 (3.8%)
Waist circumference, cm, mean ± SD	89.0±9.8
Blood pressure, mm Hg, mean ± SD	
Systolic blood pressure	131.5±15.6
Diastolic blood pressure	85.7±10.6
Elevated blood pressure (≥130/85 mm Hg), N (%)	30 (57.5%)
Grade of Kellgren–Lawrence score, No (%)	G1, 34 (65.3%), G2, 5 (9.6%), G3, 13 (25.0%), G4, 0 (0%)
Strength of knee extensor, N/kg	2.8±0.8
Strength of hip abductor, N/kg	0.7±0.3
Knee injury and osteoarthritis outcome score (range 0–100)	
Knee pain	53.0±13.2
Symptoms	51.6±13.1
Function in daily living	57.4±12.5
Function in sport and recreation	42.5±16.3
Knee-related quality of life	40.4±17.8
Duration of knee pain, mo, mean ± SD	39.9±28.5
Onset of knee pain, min, mean ± SD	34.4±24.7

SD=standard deviation.

2. Methods

This study was designed as a case-controlled, cross-sectional investigation. This study was approved by the Jeonju University Institutional Review Board. Before the study, the principal investigator explained all experimental procedures to the participants in detail. All participants provided written informed consent. All experimental procedures were conducted in the laboratory at Jeonju University.

2.1. Participants

A power analysis was performed to determine the sample size necessary to detect a significant relationship. To detect an association between lifestyle and health factor of $r=0.40$ (similar to previous studies), assuming $\alpha=0.05$ and power of 0.80, a minimum sample size of 46 patients was necessary.[20,21] We, therefore, recruited 54 participants with knee OA from the community welfare centers in Jeonju, South Korea (Table 1). All experimental procedures were conducted in the laboratory at Jeonju University. Inclusion criteria consisted of patients who were >50 years and who had a radiographic confirmation of their tibiofemoral OA clinical diagnosis using a standardized, semi-flexed, weight-bearing posterior-anterior knee radiograph by a rheumatologist specialized in OA.[22] Patients were excluded from the study if they had corticosteroid injections within the past 3 months, used oral corticosteroids within the past 4 weeks, a history of arthroplasty of the knee, regional pain syndromes, myocardial infarction, uncontrolled hypertension, symptomatic coronary artery disease, cognitive or neurological impairments that would prevent participation.[23,24]

2.2. Health factors

2.2.1. Demographic characteristic. Participants' age, sex, smoking and drinking habits, occupation, duration of knee pain and onset time of knee pain after walking were collected using a standardized questionnaire. Body weight and height were measured to calculate the BMI. Waist circumference was measured midway between the lowest rib and the iliac crest with an anthropometric tape.[25]

2.2.2. Blood pressure. Participants were asked to refrain from drinking caffeine or alcohol, engaging in vigorous physical activity, or smoking for 30 minutes before the measurement of blood pressure. Participants were asked to sit upright comfortably in a chair and rest for 5 minutes with legs and ankles uncrossed, their feet placed flat on the floor, and arm supported at heart level. Cuffs, sized according to the circumference of the upper arm, were used. The measurement of blood pressure was performed with a calibrated digital sphygmomanometer. Blood pressure was averaged from 3 readings taken at 30-second intervals.[26]

2.2.3. Knee pain, symptom, function, and quality of life.

Knee OA–related health status was assessed using self–reported knee injury and osteoarthritis outcome score (KOOS) questionnaire, consisting of 5 subscales: pain, symptoms, function in daily living, function in sport and recreation, and knee-related quality of life. Scores ranged from 0 to 100, with 0 indicating severe knee problems and 100 indicating no knee problems. KOOS is known for its high validity and reliability (intraclass correlation coefficients [ICC] = 0.78–0.97) in patients with OA.[27]

2.2.4. Muscle strength of knee extensor and hip abductor.

A hand-held dynamometer (Lafayette Instrument Company, Lafayette, IN) was used to measure muscle strength of knee extensor and hip abductor, which demonstrated excellent reliability (ICC = 0.92–0.97 and 0.86–0.97, respectively) in patients with knee OA.[5,28] The participants chose the most symptomatic knee as the target knee. Before measuring strength, we used 2 submaximal trials to familiarize the participants with each test position. After this, 2 trials with maximal isometric effort during 5 seconds were performed, with a 30-second rest between the 2 trials.[29] An average of the 2 trials was used for data analysis. Testing order for muscle groups was randomized. We normalized the average strength (Newtons [N]) to body mass (N/kg). In a pilot test, we confirmed excellent intratester reliability of examiner (ICC = 0.95 for knee extensor and 0.98 for hip abductor) who have 3 years of experience in assessment of physical therapy.

To measure the strength of the knee extensor, participants sat on an examination table with knees flexed to 90° and their feet off the ground. A hand-held dynamometer was placed on the anterior region of distal tibia, just on the superior aspect of malleoli. A nonelastic strap was secured around the examination table under the participant to hold the hand-held dynamometer in position, and the knee angle during strength measurement. Participants were asked to perform a knee extension "as hard as possible" into the hand-held dynamometer. Participants continued to exert force into the hand-held dynamometer for 5 seconds.[6,28]

The strength of the hip abductors was assessed in side-lying position on the examination table with a pillow between their legs. The hip and knee of the bottom leg (nontested leg) were slightly flexed. The hand-held dynamometer was placed just superior to the lateral epicondyle of the femur of the top leg (test leg). A hand-held dynamometer was held in place with a nonelastic strap that was secured around the examination table to maintain the hip position in neutral in the frontal plane (0° of abduction or adduction). The participants were instructed to slowly lift their leg and push against the dynamometer into hip abduction as strongly as possible for 5 seconds.[5]

2.3. Lifestyle factors

2.3.1. Physical activity and total sleep duration with wearable smartwatch.

Physical activity and total sleep duration were measured objectively using the wearable wireless smartwatch (Fitbit charge 2; Fitbit, Inc, San Francisco, CA) (Table 2). The wearable smartwatch is a small and wrist-worn activity tracker which uses a set of algorithms to detect steps by using a tri-axial accelerometer sensor and hear rate sensor. Previous studies demonstrated that Fitbit charge was one of the valid wearable activity trackers to record step count, energy expenditure, and sleep period time.[30] This smartwatch provided data of step count, distance covered, and calories burned, and heart rate/sleep mode was activated automatically. Participants secured the wearable smartwatch to their nondominant wrist in close contact with the skin, without excessive pressure. Participants were instructed to wear the wearable smartwatch for 7 consecutive days and not to remove the device for the entirety of the 7-day recording period, except of bathing, showering, or swimming. The smartwatch automatically connected via Bluetooth and transferred data to mobile platform via an application Fitbit Charge 2.

Table 2

Lifestyle factors of patients with knee osteoarthritis.

Variables	Mean ± standard deviation
Step count per d, steps	9907.6 ± 3641.8
Walking distance per d, km	6.8 ± 2.6
Calorie consumption per d, kcal	3113.1 ± 1220.1
Sleep duration per d, min	352.0 ± 66.7
Eating speed, min	10.7 ± 5.2

2.3.2. Self-reported speed of eating.

Participants were asked "How would you describe your usual time spent eating the main meal of the day?" and reported the approximate time (minute) spent eating (Table 2). The validity of this question demonstrated by the observed high level of agreement between self- and friend-reported speed of eating.[18,31] This question has demonstrated the repeatability by repeating the questionnaire survey after 1 year in participants (1062 men, 1816 women).[32]

2.4. Statistical analysis

Statistical analyses were performed using the SPSS software (ver. 18.0.1; SPSS, Inc, Chicago, IL). Descriptive data of lifestyle and health factors were examined for normality of distribution using the Kolmogorov–Smirnov test: all factors satisfied normal distribution except of grade of Kellgren–Lawrence score. Pearson or Spearman rank correlations were performed to identify the relationship between each health factor (BMI, waist circumference, blood pressure, muscle strength of knee extensor and hip abductor, knee pain intensity, symptoms, daily living function, sports recreation function, quality of life) and lifestyle factor (step count, walk distance, calorie consumption, sleep duration, and eating speed). A correlation coefficient ≥.75 was considered "good to excellent," .50 to .75 was "moderate to good," .25 to .50 was "fair," and .00 to .25 was "little or no relationship."[33] A stepwise multiple regression analysis or multinomial logistic regression was used to determine whether lifestyle factors could predict each health factor. The significance level was set at $P = .05$.

3. Results

Complete lifestyle data obtained via the wearable device were defined as a minimum of 10 hours of wear time daily and during sleeping for ≥4 days a week to determine participants' average level of physical activity.[14,34] Previous studies demonstrated that 3 or 4 days of pedometer data are sufficient to estimate adult pedometer-determined physical activity within a week.[34] Of the 54 patients recruited, data from 2 patients were excluded based on the definition of complete lifestyle data, leaving a total of 52 patients (47 female and 5 male) included in the analysis.

Table 3

Correlations between lifestyle factors and health factors in patients with knee OA.

Variables	Step count	Walking distance, km	Calorie consumption	Sleep time, min	Eating speed, min
Knee pain	0.45 (<0.01)	0.26 (0.07)	−0.15 (0.26)	0.02 (0.87)	−0.20 (0.15)
Symptoms	0.40 (<0.01)	0.32 (0.02)	−0.20 (0.15)	0.20 (0.16)	−0.21 (0.14)
Function in daily living	0.37 (<0.01)	0.28 (0.04)	−0.12 (0.38)	0.11 (0.44)	−0.03 (0.82)
Function in sport and recreation	0.21 (0.13)	0.18 (0.20)	−0.15 (0.29)	0.02 (0.90)	0.01 (0.95)
Knee-related quality of life	0.20 (0.15)	0.20 (0.15)	−0.37 (<0.01)	0.03 (0.84)	−0.28 (0.04)
Duration of knee pain, mo	−0.42 (<0.01)	−0.35 (0.01)	0.27 (0.06)	−0.14 (0.33)	0.11 (0.42)
Onset of knee pain after walking, min	−0.23 (0.10)	−0.17 (0.24)	−0.12 (0.40)	−0.26 (0.06)	0.27 (0.06)
Grade of Kellgren–Lawrence score	−0.30 (0.03)	−0.37 (<0.01)	0.05 (0.72)	−0.26 (0.06)	0.01 (0.98)
Body mass index, kg/m^2	−0.18 (0.21)	−0.01 (0.97)	−0.09 (0.54)	−0.34 (0.02)	−0.33 (0.02)
Waist circumference, cm	0.07 (0.60)	0.13 (0.35)	0.17 (0.23)	−0.39 (<0.01)	−0.52 (<0.01)
Systolic blood pressure, mm Hg	−0.04 (0.76)	0.13 (0.34)	−0.05 (0.71)	0.17 (0.22)	−0.07 (0.63)
Diastolic blood pressure, mm Hg	−0.29 (0.04)	−0.15 (0.28)	−0.03 (0.83)	0.02 (0.87)	−0.13 (0.36)
Strength of knee extensor, N/kg	0.09 (0.53)	0.07 (0.60)	−0.12 (0.40)	0.11 (0.46)	−0.01 (0.92)
Strength of hip abductor, N/kg	0.44 (<0.01)	0.43 (<0.01)	−0.12 (0.41)	0.20 (0.15)	−0.18 (0.21)

OA = osteoarthritis.

3.1. Correlation

Details of the correlation analysis are shown in Table 3. Correlation analysis demonstrated that knee pain in KOOS subscale was positively correlated with daily step count ($r=0.45$, $P<.01$). OA-related symptoms in KOOS subscale was also positively correlated with daily step count ($r=0.40$, $P<.01$) and daily walking distance ($r=0.32$, $P=.02$). Function in daily living in KOOS subscale was positively correlated with daily step count ($r=0.37$, $P<.01$) and daily walking distance ($r=0.28$, $P=.04$). Function in sport/recreation and knee-related did not show any correlation with all lifestyle factors.

Duration of knee pain (in months) was negatively correlated with daily step count ($r=-0.42$, $P<.01$) and daily walking distance ($r=-0.37$, $P<.01$). The onset of knee pain after walking (in minutes) showed no correlation with any lifestyle factors.

Grade of Kellgren–Lawrence score was negatively correlated with daily step count ($\rho=-0.30$, $P=.03$) and daily walking distance ($\rho=-0.37$, $P<.01$).

BMI was negatively correlated with daily sleep duration ($r=-0.34$, $P=.02$) and eating speed ($r=-0.33$, $P=.02$). Waist circumference was also negatively correlated with daily sleep duration ($r=-0.39$, $P<.01$) and eating speed ($r=-0.52$, $P<.01$).

Diastolic blood pressure (mm Hg) was negatively correlated with daily step count ($r=-0.29$, $P=.04$).

Knee extensor strength showed no correlation with any lifestyle factors. On the other hand, hip abductor strength was positively correlated with daily step count ($r=0.44$, $P<.01$) and daily walking distance ($r=0.43$, $P<.01$).

3.2. Regression

A stepwise regression analysis was used to determine the independent predictors of each health factor. The results showed that knee pain in KOOS subscale was significantly associated with daily step counts ($\beta=0.45$, $r^2=0.21$, $P<.01$). Symptoms in KOOS subscale were significantly associated with daily step counts ($\beta=0.40$, $r^2=0.15$, $P<.01$). Function in daily living in KOOS subscale was significantly associated with daily step counts ($\beta=0.38$, $r^2=0.12$, $P<.01$).

Longer duration of knee pain was significantly associated with lower daily step counts ($\beta=0.45$, $r^2=0.21$, $P<.01$). Grade of Kellgren–Lawrence score showed no association with lifestyle factors upon multinominal logistic regression.

More BMI was significantly associated with eating speed ($\beta=-0.37$, $r^2=0.34$, $P<.01$). and less sleep duration ($\beta=-0.26$, $r^2=0.34$, $P=.01$). Greater waist circumference was significantly associated with fast eating speed ($\beta=-0.48$, $r^2=0.35$, $P<.01$) and less sleep duration ($\beta=-0.33$, $r^2=0.35$, $P=.01$).

Greater diastolic blood pressure was significantly associated with a lower daily step counts ($\beta=-0.40$, $r^2=0.16$, $P<.01$) and fast eating speed ($\beta=-0.35$, $r^2=0.16$, $P=.01$).

Weak hip abductor strength was significantly associated with a lower daily step count ($\beta=0.40$, $r^2=0.16$, $P<.01$). Muscle strength of knee extensor showed no association with lifestyle factors.

4. Discussion

This study of patients with knee OA examined the association between health factors and lifestyle factors. While previous studies have demonstrated an association between the level of physical activity and OA related-knee pain and function, we were not aware of other studies which directly assessed the relationship between OA-related health and lifestyle factors, as well as physical activity in patients with knee OA. We confirmed that better scores in knee OA–related pain, symptom and function were significantly associated with higher daily step counts among lifestyle factors, which was measured objectively using a wearable smartwatch, but not associated with sleep and eating lifestyle factors. Additionally, greater BMI and waist circumference were significantly associated with less objectively-measured sleep duration, and self-reported fast eating speed among lifestyle factors. These findings show a wide variability of lifestyle data using a wearable device that is inversely related to health factors, providing the possibility for application of daily data to health management in patients with knee OA.

In people with knee OA, worse knee pain is likely to induce more physical inactivity and accumulating a lower daily step counts.[10,35] These previous results are in line with our study that a lower daily step counts causes worse scores in knee pain, symptom function of KOOS subscales and duration of knee pain. In this study, daily step counts were the only independently-contributing factor among lifestyle factors to KOOS scores. These findings, coupled with previous data using the same wearable smartwatch showing that preoperative daily step count of total knee arthroplasty has a positive correlation with KOOS pain scores (mean scores: 45.6; $r=0.280$) and KOOS function in daily activity (mean scores: 50.3; $r=0.282$) in patients with knee OA.[11] There is conflicting evidence as daily step count using accelerometer at the waist has no association with knee pain on the WOMAC scale (mean scores: 5.8, $r=-0.08$) in participants with knee OA who are not very physically active.[14] Such conflicting results may be due to a different intensity of physical activity. That is, worse knee pain can be associated with a less moderate level of physical activity, but no association with light physical activity.[36] Our participants were sanitation workers (54%), farmers (32%), licensed practical nurses (9%), and homemakers (5%), whose occupation implied a higher step count compared to a more sedentary occupation. Thus, mean daily step counts in our participants was 9907.6, significantly higher than the 6209 steps/d of the criterion used in previous studies for classifying the higher levels of physical activity group and 6000 to 8000 steps/d on average in healthy older adults.[14] Thus, our participants, who engaged in a moderate level of physical activity, showed significant association between daily step count and knee pain, symptom and function. Based on our results and previous literature, clinicians recommend that controlling daily step count may be necessary for people with knee OA, as increasing the overall daily step count may enable people to achieve moderate levels of physical activity, and prevent a more adverse sedentary lifestyle.[37]

Both longer and shorter sleep duration can induce increased sensitivity to noxious stimuli and a reduction in endogenous pain-inhibitory processes, so sleep duration has a significant impact on the prevalence of musculoskeletal pain.[38,39] Previous self-reported studies investigating older adults with painful knee OA demonstrated that shorter sleep duration is associated with a higher prevalence of OA and greater arthritis severity in WOMAC summary score.[17,40] Specifically, the prevalence of OA was lowest between 6 and 7 hours of sleep and greatest in patients who only slept for 0 to 3 hours.[17] However, in this study, sleep duration was not shown to be independently associated with OA related-knee pain, symptom and function scores of KOOS subscale. This study objectively measured sleep duration using a wearable smartwatch, 56% of our participants reported short sleep duration <6 hours, of which only 2 participants reported <3 hours daily. These differences in study design may have affected the conflict correlation outcomes. To know the cause and effect, a future longitudinal study is required to investigate the relationship between knee pain, symptom, and function versus objectively-measured sleep duration using accelerometer in participants with both knee OA and a short, moderate or long sleep duration.

Instead of knee pain and function, sleep duration and eating speed showed a negative association with BMI and waist circumference in our participants, which were predominantly female (90%). In line with our results, a recent cross-sectional study demonstrated that predominantly male (91%) individuals with knee OA had an association between a higher risk of obstructive sleep apnea and higher BMI, recommending that clinicians are necessary to screen for sleep disturbance among individuals with knee OA.[41] Pain and sleep have a bidirectional relationship: pain caused by OA can decrease sleep duration, and sleep deprivation can worse severity and sensitivity of pain.[42] Additionally, a faster eating habit showed an association with excess weight and a greater waist circumference, concurring with our results, which recommend eating slowly to prevent the development of cardiovascular diseases and diabetes mellitus.[43–45] However, 2 previous studies suggested contrary results.[46,47] Eating speed in mid-age women from 40 to 50 years may not significantly influence weight change, according to a 3-year longitudinal study.[46] Another study demonstrated that slow eating speed led to a significant decrease in energy intake in individuals in a normal-weight group, but not in the overweight/obese group.[47] Authors of previous studies offered a possible reason for the fact that the overweight/obese group might be consuming less food: overweight/obese participants were more self-conscious due to the measurement setting of stopwatch, so ate less during the study. Because our participants were over 50 years and eating speed was assessed by a self-report, contrary results might be observed. High BMI is demonstrated as a main risk factor in knee OA,[7] clinicians need to further explore the relationship between lifestyles factors (such as eating speed and sleep duration) and obesity health factors (such as BMI and waist circumference), and more education is required to transition into a positive lifestyle change.

A meta-regression analysis indicated that increasing daily steps by 2000 can decrease approximately 4 mm Hg of blood pressure.[48] Another meta-analysis of supervised walking data indicated that the change in diastolic blood pressure was approximately −1.5 mm Hg. Additionally, our results showed that a higher diastolic blood pressure was significantly associated with a lower daily step count and faster eating speeds in patients with knee OA. Previous studies also demonstrated higher blood pressure in patients with knee OA than without knee OA, and recommended that higher levels of daily physical activity and decreased sedentary behavior in the control of blood pressure in individuals with knee OA.[4,26]

Muscle strength of knee extensor showed no association with lifestyle factors. Previous data using accelerometer at the waist showing that steps/day showed no association with strength of knee extensor (measured with an isokinetic dynamometer) than those who engage in patients with knee OA.[14] Another study corroborated our results, showing hip abductor strength to be a significant predictor of performance, such as get-up and go test and stair climb and descent test, therefore, hip abductor strength was more important than the strength of knee extensor in individuals with knee OA.[5] Our results also showed that a higher daily step count was positively correlated with the strength of hip abductor. These results provide preliminary evidence suggesting that controlling daily step count may be beneficial to improve hip abductor strength, which is an important rehabilitation target muscle for maintaining function in patients with knee OA.[49]

There were several limitations to this study. First, it was difficult to identify cause-and-effect relationships between health and lifestyle factors, due to the cross-sectional design of the study, which is not suitable for revealing causal relationships whether a less active lifestyle leads to more pain or the more pain leads to a less active lifestyle. Thus, we should be cautious in interpreting the results of this study. Second, mean walking distance per day (6.8 km) was quite lot in this study. Previous studies found that the Fitbit gives average readings 400% too high in walking distance when comparing other 7 wearable activity trackers.[50] We used Fitbit for measurement of walking distance, so there was possible to overestimate walking distance. Another reason of high walking distance might be related with participant's occupation. 51% and 20% of participants worked as cleaner and farmer, respectively, which jobs need high level of step count. Third, this study did not measure sleep quality. Previous study assessed self-reported sleep quality in non-Hispanic whites older adults with knee OA, demonstrated that poor sleep quality has significant association related to greater knee pain.[51] Future study would be necessary to investigate the effects of objectively measured sleep quality on pain and function for patients with knee OA. Lastly, these participants who had radiographical evidence of knee OA did not exhibit severe OA (Grade 1: 65.3%; Grade 2: 9.6%; Grade 3: 25.0%; Grade 4: 0%), so these findings are only generalizable to older patients with mild to moderate knee OA. Previous long-term studies demonstrated that greater daily physical activity was associated with a 1-year period of worsening symptoms in patients with knee OA with Kellgren–Lawrence Grade 4.[52] Thus, future long–term research would be needed for patients with severe knee OA to investigate the cause and relationship between health factors and lifestyle factors, including eating and sleep patterns as well as daily step counts.

5. Conclusions

The findings of this study contribute to the knowledge of how lifestyle habits of older patients suffering from knee OA contribute to health status. Importantly, daily step count measured using wearable device is associated with knee OA-related pain, symptoms, function in daily activity, duration of knee pain, blood pressure, and strength of hip abductor. Additionally, objectively measured sleep duration and self-reported eating speed also are association with BMI and waist circumference. Therefore, level of physical activity, sleep duration and eating speed may be a component for management of patients with mild to moderate knee OA severity. This study shed lights on the application of wearable lifestyle data to knee OA-related health management.

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