Published in final edited form as:

Arch Phys Med Rehabil. 2013 February ; 94(2): . doi:10.1016/j.apmr.2012.09.026.

Association Between Chair Stand Strategy and Mobility Limitations in Older Adults with Symptomatic Knee Osteoarthritis

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Abstract

OBJECTIVE—To determine which lower limb strength and joint kinetic and kinematic parameters distinguish sit-to-stand (STS) performance of older adults with symptomatic knee osteoarthritis (OA) with higher and lower chair stand time.

DESIGN—Cross-sectional

SETTING—Motion analysis laboratory.

PARTICIPANTS—Age 50–79 years with radiographic knee OA and daily symptoms, stratified by chair stand times.

INTERVENTIONS—Not applicable.

MAIN OUTCOME MEASURE(S)—Lower limb strength and STS strategy.

RESULTS—Data were available for 49 participants (26M/23F) age 64.7±8.1 years. The respective mean±SD for chair stand times in the high, moderate and low functioning groups in men were 6.5±0.7, 8.6±0.7, and 11.5±1.3sec and in women were 7.6±1.2, 10.0±0.5, and 12.8±1.8sec. Chair stand time (p=0.0391) and all measures of lower limb strength (all p<0.0001) differed by sex. In men, no strength measure differed between groups, whereas in women hip abductor strength on the more affected side differed between groups. In men, sagittal hip ROM (p=0.0122) differed between groups and there was a trend towards a difference in sagittal knee power (p=0.0501) during STS, while, in women, only sagittal knee ROM (p=0.0392) differed between groups.

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Disclosure:

The authors have no conflict of interest with respect to any aspect of the study described in this manuscript.

Portions of this data were presented in 2009 at the American Geriatrics Society Annual Scientific Meeting (Chicago, IL).

SUPPLIERS

CONCLUSION(S)—Higher and lower functioning adults with symptomatic knee OA appear to use different strategies when standing from a chair. Higher functioning men flexed more at the hip and produced greater knee power than lower functioning men. Higher functioning women used less knee flexion than lower functioning women. As STS is an important mobility task, these parameters may serve as foci for rehabilitation aimed at reducing mobility limitations.

Keywords

aging; osteoarthritis; knee; functional limitations; mobility

INTRODUCTION

Rising from a chair or bed is a basic activity of daily living. It involves the recruitment of several lower limb muscle groups to perform the primarily concentric movement[1] and is considered more physically demanding than walking or stair climbing, due to the requirement for greater joint torques and range of motion.[2] To complete the sit-to-stand (STS) task, sufficient joint range of motion and lower limb power is necessary, based on strength contributing to joint torque at the velocity necessary to stand. In addition, joint torque requirements at the ankle, knee, and hip all increase when performing STS faster.[3] Therefore, any disease or injury that compromises strength, power, or range of motion of the lower limb may affect STS performance. All of these measures are negatively affected by knee osteoarthritis (OA).[4–9] As knee OA is the leading cause of physical disability in older adults,[10] there is a need to understand how STS performance varies between those with higher in comparison with lower mobility function.

Knee extensor weakness, commonly found in individuals with knee OA,[4–6, 8] to some extent, may account for the difficulty and increased time required to stand from a seated position experienced by older adults with knee OA and mobility limitations.[6, 11–13] Knee extensor weakness has been reported as the best independent predictor of age-related decline in performance of 10 m walk, stair climb, and chair-stand time, as well as home mobility.[12, 14, 15] Alternatively, the decreased range of motion that can occur with knee OA,[7, 11] manifested as a more extended knee on the affected side, could also limit rising, as a more anterior foot placement necessitates generation of greater joint moments at the hip.[16] With either of these possibilities, one may adopt various compensatory strategies to perform STS. For example, individuals may use greater trunk flexion, shifting their center of mass closer to their knee joint in order to decrease the amount of knee strength and power necessary to rise from a seated position.[17] This possibility is supported by evidence that the degree of trunk flexion used is inversely correlated with knee extensor strength.[18]

There is a wide range of physical function among older adults with knee OA, and interestingly, some research has demonstrated that pain and Kellgren-Lawrence OA severity grade do not predict knee extensor power,[9] one's functional level during gait[4] or STS performance.[9] Net joint power is the product of torque and angular velocity, representing energy from the muscles that is either being generated (positive power) to achieve an upright posture or absorbed (negative power) to slow segment motion or cushion directional changes during STS. Power differences across the lower limb joints reflect differences in energy demands that are placed on muscles crossing these joints and assessment may help to characterize differences in STS strategies used by older adults with symptomatic knee OA with higher in comparison with lower STS function.

It is currently unknown which kinematic and kinetic strategies characterize older adults with symptomatic knee OA with higher compared with lower levels of STS function. This knowledge gap leads to uncertainty regarding which modes of physical therapy would be most effective for improving mobility in older adults with knee OA.[19, 20] To enable rehabilitation interventions to transition those with mobility limitations to a higher functional level, the aim of this study was to identify lower limb strength as well as kinetic and kinematic parameters that distinguish lower functioning (slower chair stand time) from higher functioning (faster chair stand time) older adults with symptomatic knee OA. The anticipated outcomes are foci for rehabilitation therapies that will effectively improve physical function through clarifying how some older adults with knee OA attain a higher level of mobility function than others who have the same severity of symptoms.

METHODS

Participants

Sixty participants with symptomatic knee OA were recruited from one clinical site of the Multicenter Osteoarthritis Study (MOST), a longitudinal study of 3,026 men and women aged 50–79 years with risk factors for knee OA (overweight or obese, history of knee injury or surgery, or frequent knee pain).[4] Recruitment was stratified by decade, sex, and 20-meter walk time (completed as part of the MOST study) to ensure representation of a range of age (6th, 7th and 8th decades) and mobility level (high, moderate and low) among men and women. All participants completed an informed consent process and signed a consent form approved by the investigators' Institutional Review Board.

Knee osteoarthritis was determined through the examination of radiographs completed as part of the MOST study protocol and was defined by a Kellgren-Lawrence grade of II or greater on standardized fixed-flexed P-A radiographs.[21] Frequent knee symptoms were assessed by trained and certified interviewers, who asked participants: "During the past 30 days, have you had pain, aching or stiffness in or around your knee on most days?" Symptomatic knee OA was defined as the combination of radiographic tibiofemoral OA and frequent knee symptoms. No participants 1) limited their activities due to back pain during the preceding 30 days before enrollment in the study, 2) had neuromuscular disease, 3) required another person or an assistive device to walk, 4) were legally blind, 5) had an injury or illness other than knee OA that affected their walking ability, 6) had surgery in the past year requiring a recuperation period greater than 1 week, or 7) reported fainting spells or frequent falls in the prior year.

MEASURES

Characterization of Participants

To characterize knee pain and knee-related physical function, the modified Western Ontario McMasters Knee Osteoarthritis Index (WOMAC, University of Western Ontario, London, Canada), a valid and reliable instrument, was utilized.[22] Lower WOMAC scores indicate less pain and better physical function. Physical activity level was measured with the Physical Activity Scale for the Elderly (PASE), with higher scores indicating higher physical activity level.[a], 23–25

Functional Limitations

Self-reported functional limitations were measured using the Late Life Function and Disability Instrument: Function Component (LLFDI, Boston University, Boston, MA).[26–28] The advanced lower limb sub-score was the primary self-reported measure of mobility limitation, with higher scores indicating less mobility functional limitations. Objective functional limitations specific to STS were assessed with a timed chair-stand test, measured

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as the time (in seconds) required to stand from a seated position in a standardized chair five times without using their arms.[29] The sample was divided into tertiles of chair stand time to define higher, moderate, and lower functioning groups.

As a composite mobility and balance assessment, participants performed the Short Physical Performance Battery (SPPB, National Institutes of Health, Bethesda, Maryland), including side-by-side, semi-tandem, and tandem balance tests, 4 m walk tests, and the timed chair-stand test described above. The summary performance score (SPS) was calculated using the method of scaling described previously.[30] For the participants enrolled in this study, this was ((1− (4 m walk time/5.368)) + (1 − (chair stand time/16.22)) + (balance time/30), with all times expressed in seconds.

Knee Extensor and Flexor Strength Measurements

Peak isokinetic strength was measured with a Cybex 350 dynamometer.[b] Knee flexion and extension was evaluated at 60° per second and a chair back angle of 85° from 90° of flexion to each participant's full extension. A standardized protocol for measuring knee extensor strength was followed.[31] Participants were provided instructions using a standardized script and three practice trials using 50% effort. After the practice trials, four repetitions were completed for flexor and extensor torque. Participants' peak concentric knee extensor and flexor strength (Nm) was considered to be the maximal torque obtained over 4 trials for each of the respective motions. Examiners calibrated the isokinetic dynamometer position, angular velocity and torque (at 25 and 245 Nm) monthly. In a reliability study using the isokinetic dynamometer and protocol, conducted concurrently with the MOST study, the strength measurement had a day-to-day intraclass correlation coefficient of 0.94 (0.82–0.99), a coefficient of variation of 8% (6–12%) and a within participant variation of 6.3 Nm (4.71–9.63).

Hip Strength Measurements

Isometric hip strength testing was completed for hip extension, flexion, and abduction using a Spark Handheld Dynamometer Model 160.[c], 32 Hip abduction was measured with participants in a seated position and extension and flexion were measured in the prone and supine positions, respectively.[33] Each isometric contraction was held for 3 seconds and repeated for 3 total trials. The highest of the 3 isometric values was considered the peak force.[34] Good inter-rater and test-retest reliability of handheld dynamometry measurements has been reported in studies of older adults.[35]

Sit-to-Stand (STS) Task Motion Analysis

Kinetic and kinematic variables of interest were sagittal plane peak moments and power at the hip, knee and ankle as well as range of motion at the hip and knee. The initiation and end of the STS movement was identified by pelvic velocity in the vertical direction crossing the threshold of 0.01 m/s. Data for all trials were time-normalized at 2% intervals for the STS task and the magnitude of moments and powers were normalized to body mass. All reported motion capture variables are for the more affected limb.

Three-dimensional kinematic data[d] and ground reaction force data[e] were collected as participants stood from a standard chair (46 cm high) and returned to the seated position at their preferred speed, the STS task. Kinetic data for only the more symptomatic limb were

[b]Cybex International, Inc., 10 Trotter Drive, Medway, MA 02053 USA
[c]Spark Instruments & Academics Inc., Iowa City, IA USA
[d]Optotrak™, Northern Digital Inc., 103 Randall Drive, Waterloo, Ontario, Canada N2V 1C5
[e]Kistler, Model 9286, 75 John Glenn Dr., Amherst, NY 14228-2171 USA

obtained because only one force plate was used. Participants' foot position and seat depth were self-selected and arms were not used for the STS task. The average of five STS task trials at participants' self-selected speed was used to assess the kinematic and kinetic data. Three non-collinear infrared markers were used to track each of the eight segments: feet, legs, thighs, pelvis and trunk. Marker coordinate data and force plate data were collected at 60 Hz and 300 Hz, and filtered at 6 Hz and 10 Hz, respectively.

Data captured with the participant standing (participant calibration) were used to define the transformation matrices between the external marker reference system and the principal axes of each of the eight body segments used to represent the skeletal system. Segment principal axes were defined based on digitized bony landmarks used to represent the bilateral skeletal system: acromion, anterior and posterior superior iliac spines, lateral and medial epicondyles, lateral and medial malleoli, posterior heel and second toe. Marker position data were combined with anthropometric data and ground reaction forces in an eight-segment model.[f] A three-dimensional inverse dynamic solution was obtained to calculate internal net joint moments of force and powers, as well as range of motion (ROM) at the ankle, knee and hip, and a combined knee+hip moment.[36, 37]

STATISTICAL ANALYSIS

Three functional groups were formed by dividing subjects into tertiles based on the timed chair stand test. Scatter plots were generated to visually inspect for normality in the distribution of each motion analysis parameter with respect to chair stand time within the whole sample as well as within each functional group. Categorical variables (e.g. Kellgren-Lawrence grade) were summarized for men and women separately, using frequencies and percents. Continuous variables (e.g. age, BMI, PASE score, WOMAC scores, chair stand time in Tables 1A and 1B and measures of strength and motion analysis parameters in Tables 2A and 2B) were summarized with means±SD. In sex-specific analyses, ANOVA was used to assess for overall differences between the three functional groups. Tukey’s method of adjustment for multiple comparisons was used when making paired comparisons between the groups. Differences in peak sagittal moments and power at the ankle, knee and hip, combined sagittal knee+hip moment, and sagittal knee and hip ROM between function tertiles were analyzed in men (Table 2A) and women (Table 2B).

This study was conducted within a sub-cohort of an ongoing study. The selection of sample size for the sub-cohort was based on an a priori power calculation, conditioned on a 3-way ANOVA with factors being decade (3 levels: 50's, 60's, 70's), sex (2 levels), and function (2 levels: high/low with low based on the slowest quartile of 20m walk time in the MOST study). Based on data from prior reports,[38, 48] we estimated that a random effects model with 0.39 SD within and 0.32 SD contrast between groups would require 5 participants in each of the 12 sex-decade-function groups to provide 87.6% power at an alpha level of 0.05. Review of more recent publications during the period of the study led us to examine the differences between sexes and three functional levels (based on chair stand times), but not between decades.

RESULTS

Participants

Sit-to-stand task motion analysis data were available for 26 men (age 64.7±8.1 years, BMI 31.8±4.4 kg/m^2, and PASE 205.7±105.3) and 23 women (age 63.4±7.0 years, BMI 31.8±6.8 kg/m^2, and PASE 138.5±63.7). For the remaining 11 participants, missing data for motion

[f]Visual 3D, C-Motion, 20030 Century Blvd, Suite 104, Germantown, MD 20874 USA

analysis parameters was due to technical issues related to displaced motion analysis markers or error in force plate setup prior to participant data collection. All participants had a Kellgren-Lawrence grade greater than or equal to II in at least 1 knee, indicating knee OA. However, knee OA was bilateral in 24 participants (9 higher, 8 middle and 7 lower physical function participants). The more symptomatic knee (i.e. worse pain) had a Kellgren-Lawrence grade of: I in 2 participants (i.e. their contralateral knee met inclusion criteria for OA), II in 19 participants, III in 18 participants and IV in 10 participants. The more symptomatic knee was the right for 12 men and 17 women.

Age, WOMAC physical function score and WOMAC knee pain score did not significantly differ between timed chair stand function tertiles for men or women (all p>0.2)(Tables 1A and 1B). Physical activity level differed between functional groups in men (p=0.0027) (Table 1A) but did not significantly differ between functional groups in women (p=0.5669) (Table 1B). BMI significantly differed between groups in women (p=0.0335) (Table 1B), with a lower BMI in the low versus the moderate and high functioning groups. There were no statistically significant differences in age, BMI, activity level or functional measures comparing participants with unilateral vs. bilateral knee OA.

Timed Chair Stand Performance Test

The high functioning group performed the timed chair stand test (5 repetitions) in 6.5±0.7 sec in men and 7.6±1.2 in women, the moderate functioning group in 8.6±0.7 sec in men and 10.0±0.5 in women, and the low functioning group in 11.5±1.3 sec in men and 12.8±1.8 in women (Tables 1A and 1B). Men (8.8±2.2 sec) tended to have faster chair stand test times than women (10.1±2.4 sec) (p=0.0618).

Corroborative Mobility Function

In men, the LLFDI Advanced Lower Limb Function scores (p=0.0040) and summary performance scores (p=0.0008) significantly differed between functional groups (Tables 1A and 1B). Men in the higher functioning group reported higher Advanced Lower Limb scores than those in the moderate and lower functioning groups (Table 1A). In addition, men in the lower functioning group had significantly lower summary performance scores than those in the higher and moderate functioning groups (Table 1A). In women, the LLFDI advanced lower limb scores did not differ (p=0.9128), but the summary performance scores differed between functional groups (p=0.0004) (Table 1B).

Lower Limb Muscle Strength

All strength data significantly differed between men and women (all p≤0.002) supporting the decision to stratify analyses by sex. In men, strength was generally higher in those with higher function, but no strength measures significantly differed between groups (Table 2A, p>0.05). In women, hip abductor strength significantly differed between functional groups (p=0.0283), with the higher functioning group greater than the lower functioning group (Table 2B). No other strength measurements differed between groups in women (all p>0.05). However, there was a trend towards a difference for hip extension and knee flexion on the more affected side (p=0.0606 and p=0.0815, respectively) (Table 2B).

Sit-to-Stand (STS) Task Motion Analysis

Men in the higher (0.80±0.09 sec) and moderate (0.85±0.10) functioning groups required significantly less time than men in the lower functioning (1.06±0.20 sec) group to complete the STS task at self-selected velocity (p=0.0025). Similarly, higher functioning women (0.74±0.07 sec) stood more quickly than moderate (0.90±0.17 sec) or lower functioning (0.98±0.17 sec) women (p=0.0267).

For men, during the motion analysis STS task, sagittal hip ROM significantly differed between functional groups (p=0.0122), with the higher functioning group having 14.6° (95% CI 2.3°, 27.0°) greater ROM than the moderate group and 13.4° (95% CI 0.6°, 26.1°) greater than the lower group. There was a strong trend towards a difference in sagittal knee power (p=0.0501), with the higher functioning group generating more power than the lower group (effect size = 0.56). Sagittal ankle, knee, hip and combined hip+knee moments, sagittal knee ROM, and ankle and hip power did not differ between functional groups (all p>0.05).

For women, sagittal knee ROM significantly differed between functional groups (p=0.0392), with the higher functioning group demonstrating 12.0° (1.2°, 22.8°) less knee ROM compared to the lower functioning group (effect size = 0.59). As peak knee flexion angle occurred at the initiation of movement, this can also be interpreted as a difference in foot position since foot placement was self-selected. Sagittal ankle, knee, hip and combined hip +knee moments, sagittal hip ROM, and ankle and hip power did not differ between functional groups (all p>0.05).

DISCUSSION

The purpose of this study was to identify differences in STS strategy that distinguish lower and higher functioning older men and women with symptomatic knee OA. This characterization is clinically significant as it provides potential foci for rehabilitation interventions directed at improving mobility function in lower-functioning community-dwelling older adults with symptomatic knee OA. This study is the first to identify specific modifiable parameters that differentiate lower from higher STS mobility level. As this was an observational study, interventional studies are necessary to assess the effect of rehabilitation interventions targeted at increasing hip ROM and possibly sagittal knee power in men, or increasing hip abductor strength and possibly having the affected knee more extended (i.e., more anterior foot placement) in women. If intervening to correct these parameters were found to improve physical function during the STS task, it would foster delivery of effective physical therapy.

Of the strength variables, only hip abductor strength on the more affected side in women significantly differed between functional groups. The hip abductors play a role in stabilization of the femur,[38] which may explain their role in improving performance during sit-to-stand tests.[39] Knee extensor strength is the variable that others have found to be most important in performing STS.[12–14] We did not detect a significant difference in knee extensor strength between functional groups for either men or women. This may be because our participants with symptomatic knee OA had greater strength than participants with knee OA in prior reports.[8] Additionally, our study participants may have used a technique that relied more on their hip extensors (also acting as knee flexors due to the diarthrodial nature of the hamstrings) rather than knee extensors to extend their knee. This is supported by our knee OA participants having greater peak hip extension moments (men: 1.24±0.40 Nm/kg, women: 1.16±0.50 Nm/kg) than knee extension moments (men: 0.72±0.29 Nm/kg, women: 0.55±0.29 Nm/kg) during STS motion analysis compared to Pai,[11] who noted greater knee moments (1.2 Nm/kg) relative to hip moments (0.96 Nm/kg).

There are a number of logistical and performance factors that affect the hip and knee sagittal moments.[40] Chief among these are speed of performance[36, 37] and the position of the feet relative to the center-of-mass.[41] It has been shown that while individual strategies may vary, the magnitude of the sum of hip and knee moments was always greater than 1.53 Nm/kg, with this value increasing as the time to complete the motion decreased below 2.5 seconds.[37] An important methodological difference between that study and the current study was that initiation of the STS task was defined by vertical trunk motion in the former and by lift-off with vertical pelvic velocity exceeding 0.01 m/s in the current study. In the current study, the mean moment sum was always greater than the 1.53 Nm/kg prediction, but no association was demonstrated between this measure and the time to complete the task. However, the spectrum of timing was quite small compared to the data reported by Yoshioka et al.[37] An additional confounding factor was the potential for asymmetrical loading due to knee pathology or impairments.[42]

The finding of importance of knee power for STS concurs with past research.[43–47] Because men in the higher functioning group stood up faster than the lower two groups, knee power logically increased, and because knee moments did not differ between groups, angular velocity was the principle factor that increased knee power. It has previously been reported that knee extension moments increase as STS time becomes faster.[3] Therefore the lack of difference in knee joint moments between groups was unexpected. This may relate to the fact that the time for the self-selected pace STS task differed very little between functional groups in this study (≤0.26 sec), in comparison with the differences observed by Pai and Rogers of 0.4 sec between slow and normal, and 0.9 sec between normal and fast subjects.[3]

Among all variables measured during motion analysis, hip ROM during STS and, to a lesser extent, sagittal knee power best differentiated functional groups in men, while knee ROM during the STS task best explained functional level in women. However, the difference in knee ROM does not appear to indicate that the knees of lower functioning women had excess flexion. In fact, peak knee flexion was similar to both male groups, indicating that the higher functioning women were using less knee flexion. This explanation is consistent with the higher functioning women's ability to perform the task at a higher speed without utilizing increased hip and knee power in the affected limb like the higher functioning men.

In examining the peak ground reaction forces for the more affected limb, expressed as a percentage of ½ body weight, the average for higher functioning women was 121%, while the average for lower functioning women was 132%. This represents an 11% lower peak net acceleration acting through the lower limbs even though the higher functioning women stood up significantly faster. Greater loading of the more symptomatic limb in lower functioning women was unexpected. However, placed in the context of initial foot position and the bilateral power available, this finding is more intelligible. With the more flexed knee (posterior foot placement) of the symptomatic limb by lower functioning women, more force could be placed on that limb and greater knee moments generated.[48] Although not differing significantly between groups, the knee and hip moments corroborate the foot placement. Higher functioning women had a more extended knee (anterior foot placement) and they had greater hip moments than the lower functioning women. On the other hand, the lower functioning women had higher knee extension moments than the higher functioning women because of a more flexed knee (posterior foot placement). While we cannot compare symmetry of joint moments and power between limbs, due to lack of kinetic data for the less affected side, we found initial knee angle for the less affected side followed a similar pattern as for the more affected side: higher functioning women had a less flexed knee on the less affected side upon initiation (83.5°±10.3°) compared to the lower functioning women (91.8° ±8.4°).

The reasons that the two groups of women chose these strategies to rise from a chair may be explained further by available knee power. Knee extensor peak power was assessed at similar angular velocities in isokinetic testing (60°/sec) and the STS task (57.3°/sec), potentially enabling assessment of the percentage of peak knee extensor power used for the STS task. Expressed as a percentage of power available, on average, the higher functioning women used 76% while the lower functioning women used 89%. This difference may indicate that higher functioning women had the flexibility to place greater demands on the contralateral limb, whereas the lower functioning women did not, and therefore had to generate greater relative work with their involved limb. Alternatively, lower functioning women may have relied on the knee due to inability to generate a sufficient hip moment, although this difference was not statistically significant.

Data for men demonstrated the opposite trend— the peak ground reaction force for the more symptomatic limb, as a percentage of ½ body weight was 135% for the higher functioning men and 124% for the lower functioning men. The higher functioning men also used 93% of their isokinetic peak power, whereas the lower functioning men used 69%. These data suggest that to move at the higher speed the higher functioning men likely relied on their bilateral lower limbs whereas the lower functioning men relied more on the contralateral limb. Additional research is necessary to evaluate these observations, particularly because the speed of knee extension for the higher and lower functioning groups differed and at least one of these speeds would differ by a greater magnitude from the 60°/sec used in the isokinetic testing. In addition, the focus of this interpretation was on the knee; there are likely factors occurring at the hip, which may better elucidate the different strategies used by the higher and lower functioning groups.

STUDY LIMITATIONS

Limitations of the study include foot placement being self-selected for each trial performed. This may have resulted in different STS techniques between participants and between trials performed by the same participant, which may have affected muscle activation and joint moments of the knee and hip.[16] However, this freedom enabled assessment of participants' usual STS strategy. The standardization of seat height in the current study would affect torque production between individuals of different height, as lower seat heights require greater joint torques.[49] However, height did not significantly differ between functional groups, reducing the potential for this as a source of variation. Functional level was determined by chair stand performance time. This was specific to the aim of the study but does not represent the myriad tasks people with knee OA must complete in daily life. For example, one may be classified as high functioning during a gait test and low functioning during the STS test. Additionally, while functional level was determined by their five-repetition chair stand time, motion analysis was collected for the STS task at a self-selected velocity. With a difference of less than 0.3 sec between high and low functioning groups, few kinetic and kinematic variables were different between groups. More, or stronger, predictors may have been identified if participants stood as quickly as possible during the motion analysis test. Lastly, this was a cross-sectional study, so causality cannot be determined. Therefore, it is unclear whether differences relate to compensations by the higher functioning participants or excess impairments in the lower functioning participants.

CONCLUSIONS

In conclusion, knee power and hip flexion ROM during STS were greater in higher functioning men with symptomatic knee OA, while knee flexion angle was lower in higher functioning women than in lower functioning women. These data support the need to assess rehabilitation programs that may improve function in older adults with knee OA. When rising from a chair, men appear to rely on knee power and greater hip flexion and women appear to rely more on hip abductor strength and knee flexion angle. Differing STS strategies between men and women in this study support the need for sex-stratified rehabilitation strategies.

Acknowledgments

The authors would like to thank the American Geriatrics Society 2006 Dennis W. Jahnigen Career Development Scholars Award for funding this work and the participants and staff of the Multicenter Osteoarthritis (MOST) Study. Drs. Segal and Yack were involved in the study design, application for funding, data collection, data analysis, and manuscript preparation. Drs. Torner and Wallace were involved in the study design, application for funding and manuscript preparation. The sponsor for the study provided funding for the study but was not involved in the design, data collection, analysis, interpretation or decision to publish this work.

This research was supported by a 2006 Dennis W. Jahnigen Career Development Scholars Award through the American Geriatrics Society.

ABBREVIATIONS

STS	Sit-to-stand
ROM	range of motion
OA	osteoarthritis
MOST	Multicenter Osteoarthritis Study
WOMAC	Western Ontario McMasters Knee Osteoarthritis Index
LLFDI	Late Life Function and Disability Instrument: Function Component
SPPB	Short Physical Performance Battery
SPS	Summary Performance Score
BMI	body mass index

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Table 1

A: Participant Characteristics and Physical Function in Men				
MEN				
Function	**Higher N=8**	**Moderate N=10**	**Lower N=8**	**p-value**
Age (years)	62.4±5.2	65.0±10.3	66.6±7.7	0.590
BMI (kg/m^2)	29.5±3.8	32.3±2.7	33.5±6.0	0.181
PASE	296.3±119.6	192.7±72.9	131.5±50.4	<0.003*
SPS	2.1±0.2	1.9±0.1	1.7±0.3	<0.001**
WOMAC Pain	1.9±1.7	3.0±3.0	2.9±3.4	0.666
WOMAC Physical Function	8.6±7.4	11.3±11.0	14.1±9.7	0.527
Advanced Lower Limb	75.4±14.9	59.8±13.4	49.5±13.4	0.004‡
Chair Stand Time (sec.)	6.5±0.7	8.6±0.7	11.5±1.3	Differs by Definition

B: Participant Characteristics and Physical Function in Women				
WOMEN				
Function	**Higher N=7**	**Moderate N=9**	**Lower N=7**	**p-value**
Age (yrs)	63.6±8.5	60.6±4.5	66.9±7.5	0.210
BMI (kg/m^2)	32.4±6.2	35.3±6.8	26.8±4.4	0.034‡
PASE	160.1±52.7	138.9±59.2	116.4±79.6	0.459
SPS	2.0±0.1	1.8±0.1	1.7±0.1	<0.001*
WOMAC pain	2.0±1.9	3.2±2.3	3.0±3.3	0.619
WOMAC Physical Function	10.3±7.7	12.6±8.7	14.6±11.7	0.700
Advanced Lower Limb	50.7±11.4	51.0±11.4	53.2±13.1	0.913
Chair Stand Time (sec.)	7.6±1.2	10.0±0.5	12.8±1.8	Differs by Definition

Function grouping is based on tertile of sit-to-stand time. BMI (body mass index), PASE (Physical Activity Scale for the Elderly), SPS (Summary Performance Score), sec (seconds);

* Higher differs from others,

** Lower differs from others,

† Higher differs from Lower,

‡ Lower differs from Moderate

Function grouping is based on tertile of sit-to-stand time. BMI (body mass index), PASE (Physical Activity Scale for the Elderly), SPS (Summary Performance Score), sec (seconds);

* Higher differs from others

** Lower differs from others

† Higher differs from Lower

‡ Lower differs from Moderate

TABLE 2

A: Strength and Motion Analysis Parameters in Men

MEN		Higher	Moderate	Lower	p-value
Ankle moment (Nm/kg)		0.37±0.16	0.39±0.16	0.44±0.30	0.781
Ankle Power (W/kg)		0.34±0.19	0.29±0.16	0.27±0.14	0.657
Hip moment (Nm/kg)		1.37±0.44	1.09±0.40	1.31±0.35	0.310
Hip power (W/kg)		2.58±1.15	1.76±0.74	1.87±0.611	0.123
Hip ROM		111.4±8.6°	93.6±14.4°	98.0±10.6°	0.012††
Knee moment (Nm/kg)		0.79±0.31	0.78±0.32	0.58±0.22	0.259
Knee power (W/kg)		1.22±0.43	1.10±0.46	0.71±0.32	0.050†
Knee ROM		98.6±4.8°	93.2±8.9°	94.5±4.4°	0.224
Knee + Hip moment (Nm/kg)		2.16±0.35	1.87±0.40	1.88±0.28	0.188
Involved Side	Knee Extensor Strength (Nm)	118.48±34.82	123.58±47.67	103.81±51.36	0.692
	Knee Flexor Strength (Nm)	85.49±21.89	80.48±25.78	66.79±30.34	0.401
Uninvolved Side	Knee Extensor Strength (Nm)	128.10±31.32	115.33±50.60	109.53±49.57	0.727
	Knee Flexor Strength (Nm)	87.71±23.79	75.90±28.31	68.90±24.70	0.383
Involved side	Hip Extensor Strength (N)	166.96±30.34	172.52±27.31	170.12±28.33	0.942
	Hip Flexor Strength (N)	176.13±48.73	188.69±42.94	166.38±16.21	0.632
	Hip Abductor Strength (N)	191.23±43.39	181.48±42.99	161.74±39.20	0.460

B: Strength and Motion Analysis Parameters in Women

WOMEN		Higher	Moderate	Lower	p-value
Ankle moment (Nm/kg)		0.51±0.19	0.58±0.16	0.64±0.22	0.489
Ankle power (W/kg)		0.38±0.20	0.37±0.31	0.52±0.30	0.517
Hip moment (Nm/kg)		1.23±0.43	1.11±0.52	1.18±0.53	0.913
Hip power (W/kg)		2.29±1.10	1.79±1.27	2.01±1.22	0.719
Hip ROM		86.3±17.6°	87.0±16.0°	98.4±11.3°	0.314
Knee moment (Nm/kg)		0.52±0.26	0.48±0.18	0.63±0.35	0.537
Knee power (W/kg)		0.68±0.38	0.52±0.38	0.79±0.46	0.427
Knee ROM		82.7±7.9°	88.2±9.4°	94.3±5.1°	0.039†
Knee +Hip moment (Nm/kg)		1.75±0.47	1.57±0.44	1.82±0.57	0.660
Involved Side	Knee Extensor Strength (Nm)	74.68±28.67	80.73±27.53	58.98±25.36	0.311
	Knee Flexor Strength (Nm)	59.53±11.87	55.78±14.95	43.70±11.46	0.082
Uninvolved Side	Knee Extensor Strength (Nm)	80.74±23.65	82.95±30.71	57.09±31.70	0.199
	Knee Flexor Strength (Nm)	61.29±15.39	54.36±20.38	43.08±14.29	0.159
Involved Side	Hip Extensor Strength (N)	146.38±21.07	112.12±14.25	134.08±31.98	0.061
	Hip Flexor Strength (N)	143.30±31.72	136.09±25.26	135.37±22.63	0.849

B: Strength and Motion Analysis Parameters in Women					
WOMEN					
		Higher	**Moderate**	**Lower**	**p-value**
	Hip Abductor Strength (N)	156.76±20.71	139.12±36.84	107.53±24.63	0.028†

Function grouping is based on tertile of sit-to-stand time. ROM (range of motion), Nm (Newton meters), kg (kilogram), N (Newtons);

*Higher differs from others,

**Lower differs from others,

†Trend towards Higher differing from Lower,

††Higher differs from Moderate,

‡Lower differs from Moderate

Functional grouping is based on tertile of sit-to-stand time. ROM (range of motion), Nm (Newton meters), kg (kilogram), N (Newtons);

*Higher differs from others,

**Lower differs from others,

†Higher differs from Lower,

††Higher differs from Moderate,

‡Lower differs from Moderate