Received: 13 September 2022 | Revised: 27 April 2023 | Accepted: 1 May 2023

DOI: 10.1002/osp4.687

ORIGINAL ARTICLE

Obesity Science and Practice Open Access WILEY

An intervention to decrease sedentary behavior in older adults: A secondary analysis of a randomized controlled trial

Nikita Abraham[1] | Kate Lyden[2,3] | Robert Boucher[1] | Guo Wei[1,4] | Victoria Gonce[1] | Judy Carle[1] | Katalin Fornadi[1] | Mark A. Supiano[5] | Jesse Christensen[6] | Srinivasan Beddhu[1,7]

[1]Division of Nephrology & Hypertension, University of Utah Health Sciences, Salt Lake City, Utah, USA

[2]Department of Kinesiology, University of Massachusetts, Amherst, Massachusetts, USA

[3]Department of Health and Exercise Science, Colorado State University, Fort Collins, Colorado, USA

[4]Study Design and Biostatistics Center, University of Utah Health Sciences, Salt Lake City, Utah, USA

[5]Division of Geriatrics, University of Utah Health Sciences, Salt Lake City, Utah, USA

[6]Department of Physical Medicine and Rehabilitation, Veterans Affairs Salt Lake City Health Care System, Salt Lake City, Utah, USA

[7]Medical Service, Veterans Affairs Salt Lake City Health Care System, Salt Lake City, Utah, USA

Correspondence
Srinivasan Beddhu, University of Utah Health Sciences, 421 Wakara Way Suite 360, Salt Lake City, UT 84108, USA.
Email: Srinivasan.beddhu@hsc.utah.edu

Funding information
National Heart, Lung, and Blood Institute, Grant/Award Number: R21HL145494; National Institute of Diabetes and Digestive and Kidney Diseases, Grant/Award Numbers: R01 DK091437, R01DK128640, R21DK106574; National Institute on Aging, Grant/Award Number: R01 AG074592; University of Utah, Grant/Award Numbers: C06-RR11234, UL1-RR025764

Abstract

Background: Sedentary behaviors are associated with adverse health outcomes in older adults. The feasibility of behavioral interventions in this population is unclear.

Methods: In the Sit Less, Interact, Move More (SLIMM) trial of 106 participants who had obesity, those randomized to the SLIMM intervention ($N = 54$) were instructed to replace sedentary activities with stepping. An accelerometer was used to measure physical activity. In this secondary analysis, mixed effect models were used to examine the effects of the SLIMM intervention on sedentary and stepping durations and steps/day by age (<70 and ≥ 70 years).

Results: Mean ages in the <70 years ($N = 47$) and ≥70 years ($N = 59$) groups were 58 ± 11 and 78 ± 5. In the older subgroup, compared to standard-of-care ($N = 29$), the SLIMM intervention ($N = 30$) significantly increased stepping duration (13, 95%CI 1–24 min/d, $p = 0.038$) and steps per day (1330, 95% CI 322–2338, $p = 0.01$) and non-significantly decreased sedentary duration by (28,95% CI −61–5 min/d, $p = 0.09$). In the age <70 subgroup, there was no separation between the standard of care ($N = 23$) and SLIMM ($N = 24$) groups.

Discussion: In older adults who had obesity, SLIMM intervention significantly increased stepping duration and steps per day. Interventions targeting sedentary behaviors by promoting low intensity physical activity may be feasible in this population.

KEYWORDS
chronic kidney disease, physical activity, sedentary behavior

1 | INTRODUCTION

There were ~36.5 million US adults ≥70 years of age in 2019[1] and they represent an important and rapidly growing segment of the US population.[2] Prominent public health concerns in this population are related to physical impairment, cognitive decline, and other chronic non-communicable illnesses. In persons aged 70 to <80, 80 to <90 and ≥ 90 years, the prevalence of dementia is 5%, 24% and 37%, respectively while the proportion of individuals needing assistance with activities of daily living like personal care in those aged 65–74, 75–84 and ≥ 85 years are 3.9%, 8.0% and 21.1% respectively.[3,4] Physical impairment and cognitive decline are major drivers of impaired quality of life,[5,6] nursing home admissions,[7,8] increased health care costs[9,10] and mortality[11] in older adults; hence, improving independence, quality of life, physical function, and cognitive function in older adults is an imperative public health concern.

Sedentary behaviors are spending most of the awake time in activities in seated or lying postures that are characterized by a metabolic equivalent of task (MET) of 1.0–1.5.[12] The term "exercise" is typically applied to moderate or vigorous intensity physical activities (MVPA; ≥3 METs). Adults aged 65 or older need at least 150 min/week of moderate intensity activity or 75 min/week of vigorous-intensity activity.[13] Physical inactivity (the lack of achieving weekly MVPA goals) and sedentary behaviors (spending most of the awake time in sitting/recumbent posture) are not synonymous. They represent distinct domains as one could be physically active (achieve the weekly goal of 150 min/week of MVPA) but still spend the rest of the awake hours sedentary.[14]

Evidence from epidemiological studies and small pilot interventional studies suggest that sedentary behavior is associated with obesity, frailty, cognitive impairment, chronic kidney disease (CKD) and diabetes in older adults.[15–18] There is consensus that sedentary activities must be decreased[19]; however, it is unlikely that MVPA could be an effective replacement for sedentary activities as achieving the currently recommended levels of 2.5 h/week of MVPA would account only for 2% of the total awake time (112 h/week). In the general US population, most US adults do not reach the current MVPA goals[20,21] and achieving the weekly MVPA goal might be even more difficult in older adults with decreased physical function. Therefore, lowering sedentary duration in older adult populations by replacing sedentary behaviors with non-sedentary light intensity physical activities (1.6–2.9 METs) may be more feasible than increasing MVPA.

However, there are conflicting data on whether sedentary behavior in older adults could be replaced with light intensity activities.[22,23] Therefore, the current analysis was conducted to test the hypothesis that an intervention seeking to replace sedentary duration with stepping duration is potentially feasible in older adults using the data from the Sit Less, Interact, Move More (SLIMM) Study,[24] a 24-week randomized controlled trial of a sedentary behavior intervention in 106 participants with chronic kidney disease (NCT02924298).

2 | METHODS

Details of the SLIMM Study has previously been published.[24] This 24-week, pilot, single center, open-labeled, randomized controlled trial was conducted at The University of Utah and recruited participants from 23 March 2017 to 15 December 2018. The study was sponsored by the National Institute of Diabetes and Digestive Kidney Diseases and was approved by the University of Utah Institutional Review Board and conforms to the provisions of the Declaration of Helsinki. The study is listed at clinicaltrials.gov (NCT02970123). Informed consent was obtained from trained staff members.

2.1 | Study population

In brief, 106 participants with CKD stages 2–5 (or on maintenance hemodialysis or kidney transplant recipient), BMI between 25.0 and 39.9 kg/m^2, gait speed of at least 0.7 m/s, and the ability to walk at least 250 m in a six-minute walk test were randomly assigned to the SLIMM intervention or standard of care. Pregnancy, incarceration, life expectancy <1 year, unlikely compliance to the protocol per primary provider opinion, the inability to obtain accelerometer data before randomization, enrollment in other interventional trials using drugs or devices, and inability to ambulate were exclusion criteria. Block randomization was performed by the Research Electronic Data Capture system with a 1:1 allocation sequence generated at the beginning of the study.

2.2 | Intervention

Details of the SLIMM intervention have previously been published.[24] Physical activity was measured using a validated[25,26] activPAL™ activity monitor worn on mid-thigh for 7 days before the baseline and every 4 weeks in the SLIMM group ($N = 54$) and baseline and every 8 weeks in the standard of care group ($N = 52$). The additional follow-up visits in the SLIMM group are part of the intervention. Based on the activity monitor data, the SLIMM group was provided individualized instructions on reducing sedentary duration and increasing stepping duration. Participants were provided a graphic display that outlined the times that they were most sedentary. They completed a worksheet outlining their current physical activity goals and weekly measures of physical activity. Participants were provided with detailed guidance on times during the day that they should get up from sedentary postures and perform low intensity activities. The standard of care arm provided national guidelines on physical activity.

2.3 | Outcomes

The primary outcomes for the SLIMM Study were sedentary and stepping durations, which were defined as the time spent sedentary or stepping during awake hours as determined from the activPAL output. In this post-hoc analysis, sedentary duration, stepping duration, and steps per day were compared between participants age <70 years and those age ≥70 years.

2.4 | Statistical methods

Demographic characteristics, comorbid conditions, clinical features, and physical activity measurements were compared between groups with age <70 and ≥70 years. Categorical variables were summarized as counts (%) and analyzed using a chi-squared or Fisher's exact test if any expected counts were less than five. Continuous variables were summarized as mean and standard deviation or median and interquartile range (IQR) and analyzed using a *t*-test or Wilcoxon rank sum test as appropriate. Variables were compared between the standard of care and SLIMM intervention within age <70 and ≥70 groups.

Mixed effect models were used to conduct randomized comparisons of the effects of the intervention in participant age ≥70 years and those <70 years. Unstructured covariance models were applied to account for serial correlation in each outcome over time. Utilizing the intention to treat principle, treatment effects of age subgroup on the mean levels of sedentary and stepping durations and the number of steps/day were estimated across the follow-up assessments at week 8, 16, and 24 for both subgroups.

Primary conclusions were derived from comparisons between age subgroups and randomized groups. Between age subgroups and treatments, the adjusted mean follow-up levels were compared to baseline levels to summarize changes within the individual randomized groups, recognizing that these changes are subject to bias from regression to the mean and other sources.

In sensitivity analyses, the average of the adjusted mean levels of outcomes in both age subgroups were compared across the 8, 12, 16, 20 and 24-week assessments in the SLIMM arm to the average adjusted mean level across the 8, 16 and 24-week assessments in the standard of care arm (all time-points analyses).

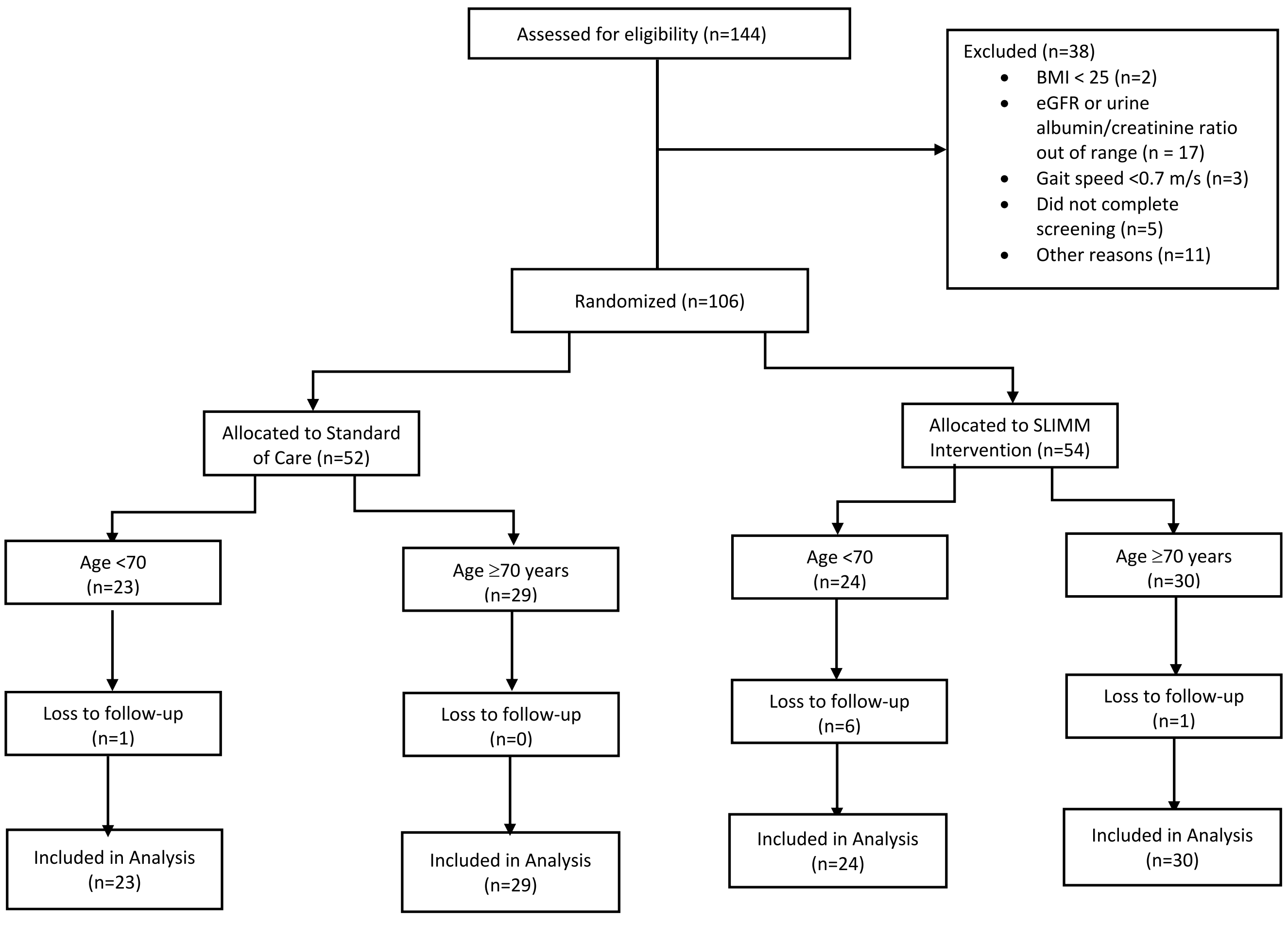

FIGURE 1 CONSORT flow diagram of study participants.

All data were analyzed using STATA version MP 15.0 or SAS version 9.4. In this study, hypothesis testing was conducted using 2-sided $\alpha = 0.05$ without adjustment for multiple comparisons.

3 | RESULTS

Of the 106 SLIMM Study participants, 59 (56%) were age ≥70 years and 54 (51%) were randomized to the SLIMM intervention (Figure 1). The mean ages of <70 and ≥70 years subgroups were 58 ± 11 and 78 ± 5 years, respectively (Table 1). Compared to the younger subgroup, in the older subgroup, there was a higher proportion of women (30% vs. 53%, $p = 0.02$) and Caucasians (79% vs. 98%, $p = 0.001$). The eGFR levels were similar in those without ESRD (46 ± 13 vs. 44 ± 13 mL/min/1.73 m^2). However, CKD stages 4/5 were more prevalent in the younger age group (32% vs. 12%, $p = 0.02$). There was a higher proportion lost to follow-up in the younger group compared to the older group (15% vs. 2%, $p = 0.001$) (Figure 1).

Baseline sedentary duration (641 ± 151 vs. 653 ± 107 min/d) and steps/d (6228, interquartile range 3146–8446 vs. 4910, interquartile range 4026 to 6470 steps/d) were not statistically different between age groups. However, stepping duration (98 ± 61 vs. 75 ± 26 min/d, $p = 0.01$) and physical function measured by gait speed (1.1 ± 0.2 vs. 1.0 ± 0.2 m/s, $p = 0.03$) and six-minute walk distance (402 ± 69 vs. 373 ± 61 m) were significantly lower in the older age subgroup. Baseline characteristics were balanced across the standard of care and SLIMM arms within the age subgroups (Table 2).

3.1 | Randomized comparisons between treatment arms of the SLIMM intervention effects on sedentary and stepping durations and steps per day by age subgroups

In the younger subgroup, there was no separation between the treatment arms in sedentary and stepping durations and the number

TABLE 1 Baseline characteristics[a] of study participants by age subgroups.

	Age <70 years N = 47	Age ≥70 years N = 59	p-value
Demographics			
Age, years	58 ± 11	78 ± 5	
Female, n (%)	14 (30)	31 (53)	0.02
White race, n (%)	37 (79)	58 (98)	0.001
Comorbid conditions			
Type 2 diabetes, n (%)	16 (34)	20 (34)	0.99
Cardiovascular disease[b] n (%)	13 (28)	15 (25)	0.80
Stroke, n (%)	5 (11)	7 (12)	0.84
Clinical features			
Baseline eGFR of those not on dialysis/kidney transplant	46 ± 13	44 ± 13	0.46
CKD stages, n (%)			0.02
Stage 2/3a	20 (43)	25 (42)	
Stage 3b	12 (26)	27 (46)	
Stage 4/5	15 (32)	7 (12)	
Baseline body fat, %	30 (23, 36)	34 (26, 41)	0.06
Physical activity measurements			
Sedentary duration, min/d	641 ± 151	653 ± 107	0.62
Stepping duration, min/d	98 ± 61	75 ± 26	0.01
Number of steps/d	6228 (3146, 8446)	4910 (4026, 6470)	0.26
Gait speed m/s	1.1 ± 0.2	1.0 ± 0.2	0.03
Six-minute walk distance, m	402 ± 69	373 ± 61	0.02

[a]Mean ± standard deviation or median (interquartile range) are presented for continuous variables.
[b]Coronary artery disease, congestive heart failure, or peripheral vascular disease.

TABLE 2 Baseline characteristics[a] by intervention arms in age subgroups.

	Age <70		Age ≥70	
	Standard of care $n = 23$	SLIMM intervention $n = 24$	Standard of care $n = 29$	SLIMM intervention $n = 30$
Demographics				
Age, years	58 ± 10	57 ± 13	78 ± 5	78 ± 6
Female, *n* (%)	9 (39)	5 (21)	16 (55)	15 (50)
White race, *n* (%)	16 (70)	14 (88)	28 (97)	30 (100)
Comorbid conditions				
Type 2 diabetes, *n* (%)	6 (26)	10 (42)	11 (38)	9 (30)
Cardiovascular disease[b] *n* (%)	9 (39)	4 (17)	9 (31)	6 (20)
Stroke, *n* (%)	2 (9)	3 (13)	4 (14)	3 (10)
Ever smoked, *n* (%)	15 (65)	12 (50)	8 (28)	6 (20)
Past or current alcohol, *n* (%)	18 (78)	17 (71)	11 (38)	14 (47)
Clinical features				
Baseline eGFR[b]	43 ± 13	48 ± 13	45 ± 11	43 ± 14
CKD stages, n (%)				
Stage 2/3a	7 (30)	13 (54)	12 (41)	13 (43)
Stage 3b	7 (30)	5 (21)	15 (52)	12 (40)
Stage 4/5	9 (39)	6 (25)	2 (7)	5 (17)
Baseline systolic BP, mmHg	134 ± 20	123 ± 16	133 ± 21	133 ± 16
Baseline diastolic BP, mmHg	83 ± 14	77 ± 14	70 ± 9	70 ± 9
Baseline body fat, %	29 (22, 36)	31 (27, 37)	35 (30, 40)	30 (25, 41)
Physical activity measurements				
Standardized sedentary duration, minutes per day	622 ± 168	659 ± 134	662 ± 90	645 ± 122
Standardized stepping duration, minutes per day	105 ± 60	92 ± 63	78 ± 27	72 ± 25
Steps per day	6432 (3826, 8834)	5564 (2998, 7224)	4882 (4158, 6654)	4922 (3876, 6138)
Screening gait speed, m/s	1.1 ± 0.2	1.1 ± 0.2	1.0 ± 0.2	1.0 ± 0.2
Screening six-minute walk distance, m	403 ± 60	402 ± 78	370 ± 59	376 ± 64
Screening body mass index, kg/m^2	30.4 ± 3.6	32.2 ± 4.6	30.6 ± 3.8	29.3 ± 2.7

Note: For comparison of Standard of Care versus SLIMM groups in participants age <70 years, $p = 0.047$ for systolic BP. Other *p*-values were not significant.

[a]Mean ± standard deviation or median (interquartile range) are presented for continuous variables.

[b]Coronary artery disease, congestive heart failure, or peripheral vascular disease.

of steps (Figure 2, Panel A-C). In the older subgroup, there was a clear separation. In the SLIMM arm of the older subgroup, compared to baseline, sedentary duration decreased by 58 (95% CI 24–91) min/d at week 20 but this attenuated to 35 min/d (95% CI −1 to 71) at week 24 (Figure 2, Panel D). The maximum increase in stepping duration (21, 95% CI 10–32 min/d at week 20) and the number of steps (1900, 95% CI 829–2970 at week 16) in the SLIMM arm in the older subgroup also attenuated at week 24 (Figure 2, Panels E and F)

The changes from baseline to the average of weeks 8, 16 and 24 in sedentary and stepping durations and steps per day within each of the treatment arms and between arms differences by age subgroups in mixed effects models are summarized in Table 3. In the younger

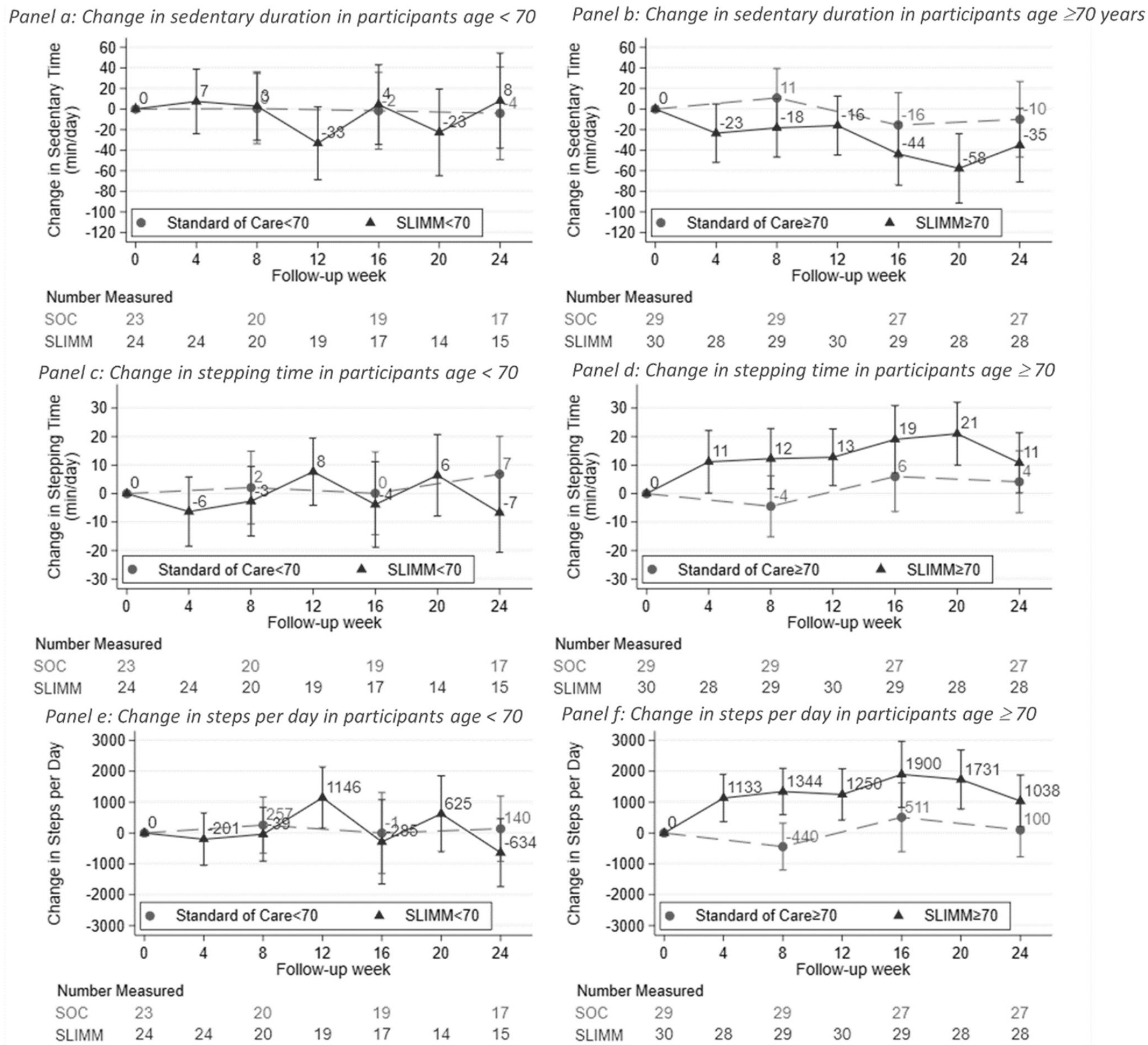

FIGURE 2 Changes in sedentary and stepping durations and steps/day by age subgroups and study arms.

subgroup, between SLIMM and standard of care arms, treatment effects on sedentary duration (1, 95% −39 to 42 min/d), stepping duration (−4, 95% −18 to 11 min/d) and the number of steps/day (−424, 95% −1669 to 820) were not different. In the older subgroup, the SLIMM intervention decreased sedentary duration by 28 (95% CI −61 to 5) min/d but this did not reach statistical significance ($p = 0.09$). However, in the older subgroup, the SLIMM intervention resulted in significant increases in stepping duration (13, 95%CI 1–24 min/d, $p = 0.038$) and number of steps per day (1330, 95% CI 322–2338, $p = 0.01$).

Differences between arm differences (SLIMM arm difference—the standard of care arm difference) in age <70 and age ≥70-year groups for sedentary and stepping durations were non-significant (30, 95% CI −22 to 81 min/d, $p = 0.26$ and −16, 95% CI −35 to 2 min/d, $p = 0.088$, respectively). However, the differences in the number of steps/d were significant (−1754, 95% −3356 to −153, $p = 0.032$). Thus, there was evidence that age modified the effects of the SLIMM intervention on the number of steps/d.

The comparisons between the treatment arm and age groups were similar in sensitivity analyses of all time points (Supplementary Table S1).

4 | DISCUSSION

The results of the current analysis show that the SLIMM intervention resulted in increased stepping duration and the number of steps per day and decreased sedentary duration in adults >70 years of age with CKD. Thus, these results suggest that it is feasible to reduce sedentary behavior in this population.

TABLE 3 Changes in sedentary and stepping durations and number of steps per day between SLIMM and standard of care arms by age subgroups.

Change in endpoints	Within SLIMM arm Difference[a], (95% CI)	Within standard of care arm Difference[b], (95% CI)	Between arms Difference[c], (95% CI)
Age <70			
Sedentary duration, min/d	0 (−30, 30)	−2 (−30, 27)	1 (−39, 42)
Stepping duration, min/d	−1 (−12, 10)	3 (−8, 13)	−4 (−18, 11)
Number of steps/d	−371 (−1342, 599)	53 (−880, 987)	−424 (−1669, 820)
Age ≥70			
Sedentary duration, min/d	−33 (−57, −10)	−5 (−29, 19)	−28 (−61, 5)
Stepping duration, min/d	14 (6, 23)	2 (−7, 10)	13 (1, 24)
Number of steps/d	1410 (639, 2181)	80 (−714, 875)	1330 (322, 2338)

[a]Within SLIMM arm difference represents the change from baseline to the follow-up average at weeks 8, 16 and 24 in the SLIMM arm.

[b]Within standard of care arm difference represents the change from baseline to the follow-up average at weeks 8, 16 and 24 in the standard of care arm.

[c]Between arm difference is the above SLIMM arm difference—the standard of care arm difference.

Previous studies have shown that sedentary duration increases with age and older adults spend >75% of the awake time in sedentary activities.[27–30] In a cross-sectional study, prolonged sedentary duration was associated with lower scores on the Montreal Cognitive Assessment.[31] In 8002 middle-aged and older adults in the Reasons for Geographic and Racial Differences in Stroke (REGARDS) study,[29] greater total sedentary time was associated with a greater risk of cancer mortality and the observational "trade-off" of sedentary duration for light intensity physical activities was associated with lower cancer mortality. These findings were consistent with earlier observation from a National Health And Nutrition Survey (NHANES) analysis that 'trade-off" of sedentary duration for light intensity activities was associated with lower mortality in the general and CKD populations.[32]

There have been few interventional trials that tested replacing sedentary duration with light intensity activity duration. In a randomized crossover study of 19 patients with type 2 diabetes, insulin sensitivity measures improved with a Sit Less sedentary behavior intervention.[15] In the SLIMM pilot study, the SLIMM intervention decreased sedentary duration and increased stepping duration but these effects were not sustained at 24 weeks[24] In contrast, the Italian Diabetes and Exercise Study (IDES) 2, a randomized controlled trial of 300 participants with type 2 diabetes, demonstrated that a behavioral intervention decreased sedentary duration and increased light-intensity activity duration over 3-year of follow-up.[22]

The above raises the question of whether these findings are applicable in older adults. A 12-week sedentary behavior intervention in a randomized controlled trial of 38 older adults did not observe an effect on sedentary behavior.[23] However, in the subgroup of adults aged 70 or older ($N = 59$), in the current analysis, compared to the standard of care, the SLIMM intervention resulted in a significant increase in stepping duration and number of steps/day showing a trend toward decreased sedentary duration. These findings are consistent with the subgroup analysis of adults aged 65 or older in the IDES 2 trial ($N = 119$), in which the behavioral intervention significantly increased light intensity activity duration and decreased sedentary duration.[22]

Taken together, these data suggest that it is feasible to decrease sedentary duration by engaging in light intensity activities in older adults. Both patients and providers need to be educated on the distinction between sedentary behavior (spending awake time in seated/recumbent posture) and physical inactivity (not achieving weekly MVPA goal target) as older adults who are not physically able to do MVPA may remain sedentary because they are unaware of the potential benefits of light intensity physical activities.

Of note, the SLIMM intervention was not effective in reducing sedentary duration or increasing stepping duration in those age <70 years in the current study. While this is surprising, a potential explanation is selection bias regarding advanced CKD in the younger and older subgroups. More advanced stage 4 or 5 CKD stages were less common in the older group perhaps because older participants with more advanced CKD were more hesitant to participate.

There are several limitations to our analysis. First, this is a post-hoc subgroup analysis of a randomized trial. Nonetheless, the findings in the older adults in the current analysis are consistent with previous post-hoc subgroup analysis of older adults in the IDES 2 trial.[22] Second, as all participants in the current study had CKD and patients with CKD are frailer than those without CKD,[33,34] these results might underestimate the potential effects of the SLIMM intervention on sedentary behavior in older adults without CKD. Third, the duration of the trial was only 24 weeks. Fourth, the younger age group had markedly higher loss to follow up than the older group. Finally, in this feasibility trial, the effects of the SLIMM intervention on clinical outcomes such as cognitive function decline, frailty, nursing admissions, or mortality were not studied.

5 | CONCLUSIONS

In summary, the results of this post-hoc subgroup analysis of a randomized controlled trial suggest that a sedentary behavior intervention could decrease sedentary duration and increase stepping duration and the number of steps/day in adults ≥70 years of age with CKD. A larger trial of longer duration with a sedentary behavior intervention on endpoints of cognitive function decline, frailty, nursing home admissions and mortality in older adults with and without CKD is warranted.

AUTHOR CONTRIBUTIONS

NA, KL, and SB interpreted data and were major contributors to writing the manuscript. RB and GW performed analysis. VG, JC, KF, MS, and JC substantively revised the manuscript. SB and KL contributed to the conception and design of the manuscript. All authors have contributed significantly and are in agreement with the content of the manuscript. All authors have read and approved the final manuscript.

ACKNOWLEDGMENTS

This work was supported by the National Institute of Diabetes and Digestive and Kidney Diseases (R21DK106574). Statistical analyses and preparation of this manuscript were also supported by grants from National Institute of Diabetes and Digestive and Kidney Diseases (R01 DK091437 and R01DK128640) and the National Heart, Lung and Blood Institute (R21HL145494), the National Institute of Aging (R01 AG074592) and the University of Utah Study Design and Biostatistics Center (funded in part from the Public Health Services research grant numbers UL1-RR025764 and C06-RR11234 from the National Center for Research Resources).

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

CONSENT TO PARTICIPATE

Informed consent for each participant was obtained by trained staff. Patient anonymity should be preserved.

ORCID

Srinivasan Beddhu https://orcid.org/0000-0002-3312-315X

REFERENCES

1. 2019: ACS 1-Year Estimates Subject Table. *Age and Sex*. United States Census Bureau; 2019. at. Accessed July 22, 2021, 2021. https://data.census.gov/cedsci/table?q=PEPAGE&t=Age%20and%20Sex&tid=ACSST1Y2019.S0101&hidePreview=false
2. *65 and Older Population Grows Rapidly as Baby Boomers Age*. United States Census Bureau 2020. (Accessed July 22, 2021, 2021, at. https://www.census.gov/newsroom/press-releases/2020/65-older-population-grows.html.)
3. Dohrn IM, Kwak L, Oja P, Sjöström M, Hagströmer M. Replacing sedentary time with physical activity: a 15-year follow-up of mortality in a national cohort. *Clin Epidemiol*. 2018;10:179-186. https://doi.org/10.2147/clep.s151613
4. Plassman BL, Langa KM, Fisher GG, et al. Prevalence of dementia in the United States: the aging, demographics, and memory study. *Neuroepidemiology*. 2007;29(1-2):125-132. https://doi.org/10.1159/000109998
5. Fusco O, Ferrini A, Santoro M, Lo Monaco MR, Gambassi G, Cesari M. Physical function and perceived quality of life in older persons. *Aging Clin Exp Res*. 2012;24(1):68-73. https://doi.org/10.1007/bf03325356
6. Lee S, Ho Chung J. The association between subjective cognitive decline and quality of life: a population-based study. *J Clin Neurosci*. 2022;98:60-65. https://doi.org/10.1016/j.jocn.2022.01.037
7. Han L, Gill TM, Jones BL, Allore HG. Cognitive aging trajectories and burdens of disability, hospitalization and nursing home admission among community-living older persons. *Journals Gerontology Series A*. 2015;71(6):766-771. https://doi.org/10.1093/gerona/glv159
8. Kojima G. Frailty as a predictor of nursing home placement among community-dwelling older adults: a systematic review and meta-analysis. *J Geriatr Phys Ther*. 2018;41(1):42-48. https://doi.org/10.1519/jpt.0000000000000097
9. Bock J.-O, König H.-H, Brenner H, et al. Associations of frailty with health care costs – results of the ESTHER cohort study. *BMC Health Serv Res*. 2016;16(1):128. https://doi.org/10.1186/s12913-016-1360-3
10. Deardorff WJ, Liu PL, Sloane R, et al. Association of sensory and cognitive impairment with healthcare utilization and cost in older adults. *J Am Geriatr Soc*. 2019;67(8):1617-1624. https://doi.org/10.1111/jgs.15891
11. Jacobs JM, Cohen A, Ein-Mor E, Maaravi Y, Stessman J. Frailty, cognitive impairment and mortality among the oldest old. *J Nutr health & aging*. 2011;15(8):678-682. https://doi.org/10.1007/s12603-011-0096-3
12. Ainsworth BE, Haskell WL, Herrmann SD, et al. 2011 Compendium of Physical Activities: a second update of codes and MET values. *Med Sci Sports Exerc*. 2011;43(8):1575-1581. https://doi.org/10.1249/mss.0b013e31821ece12
13. Piercy KL, Troiano RP, Ballard RM, et al. The physical activity guidelines for Americans. *JAMA*. 2018;320(19):2020-2028. https://doi.org/10.1001/jama.2018.14854
14. Craft LL, Zderic TW, Gapstur SM, et al. Evidence that women meeting physical activity guidelines do not sit less: an observational inclinometry study. *Int J Behav Nutr Phys Activ*. 2012;9(1):122. https://doi.org/10.1186/1479-5868-9-122
15. Duvivier BMFM, Schaper NC, Hesselink MKC, et al. Breaking sitting with light activities vs structured exercise: a randomised crossover study demonstrating benefits for glycaemic control and insulin sensitivity in type 2 diabetes. *Diabetologia*. 2017;60(3):490-498. https://doi.org/10.1007/s00125-016-4161-7
16. Hartman YAW, Karssemeijer EGA, van Diepen LAM, Olde Rikkert MGM, Thijssen DHJ. Dementia patients are more sedentary and less physically active than age- and sex-matched cognitively healthy older adults. *Dementia Geriatric Cognitive Disord*. 2018;46(1-2):81-89. https://doi.org/10.1159/000491995
17. Harvey J, Chastin S, Skelton D. Breaking sedentary behaviour has the potential to increase/maintain function in frail older adults. *Journal of Frailty, Sarcopenia and Falls*. 2018;03(01):26-34. https://doi.org/10.22540/jfsf-03-026
18. Lee J, Walker ME, Gabriel KP, Vasan RS, Xanthakis V. Associations of accelerometer-measured physical activity and sedentary time with chronic kidney disease: the Framingham Heart Study. *PLoS One*. 2020;15(6):e0234825. https://doi.org/10.1371/journal.pone.0234825
19. The Department of Health. The Sedentary Behaviour and Obesity Expert Working Group: Sedentary Behaviour and Obesity: Review of the Current Scientific Evidence; 2010. at. Accessed 23 June 2021. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/213745/dh_128225.pdf.)

20. Troiano RP, Berrigan D, Dodd KW, Mâsse LC, Tilert T, McDowell M. Physical activity in the United States measured by accelerometer. *Med Sci Sports Exerc*. 2008;40(1):181-188. https://doi.org/10.1249/mss.0b013e31815a51b3
21. Tucker JM, Welk GJ, Beyler NK. Physical activity in U.S. Adults: compliance with the physical activity guidelines for Americans. *Am J Prev Med*. 2011;40(4):454-461. https://doi.org/10.1016/j.amepre.2010.12.016
22. Balducci S, D'Errico V, Haxhi J, et al. Effect of a behavioral intervention strategy on sustained change in physical activity and sedentary behavior in patients with type 2 diabetes: the IDES_2 randomized clinical trial. *JAMA*. 2019;321(9):880-890. https://doi.org/10.1001/jama.2019.0922
23. Barone Gibbs B, Brach JS, Byard T, et al. Reducing sedentary behavior versus increasing moderate-to-vigorous intensity physical activity in older adults:A 12-week randomized, clinical trial. *J Aging Health*. 2017;29(2):247-267. https://doi.org/10.1177/0898264316635564
24. Lyden K, Boucher R, Wei G, et al. Targeting sedentary behavior in CKD. *A Pilot and Feasibility Randomized Controlled Trial*. 2021;16(5):717-726. https://doi.org/10.2215/cjn.12300720
25. Kozey-Keadle S, Libertine A, Lyden K, Staudenmayer J, Freedson PS. Validation of wearable monitors for assessing sedentary behavior. *Med Sci Sports Exerc*. 2011;43(8):1561-1567. https://doi.org/10.1249/mss.0b013e31820ce174
26. Lyden K, Kozey Keadle SL, Staudenmayer JW, Freedson PS. Validity of two wearable monitors to estimate breaks from sedentary time. *Med Sci Sports Exerc*. 2012;44(11):2243-2252. https://doi.org/10.1249/mss.0b013e318260c477
27. Arnardottir NY, Koster A, Van Domelen DR, et al. Objective measurements of daily physical activity patterns and sedentary behaviour in older adults: age, Gene/Environment Susceptibility-Reykjavik Study. *Age Ageing*. 2012;42(2):222-229. https://doi.org/10.1093/ageing/afs160
28. Cabanas-Sánchez V, Esteban-Cornejo I, Migueles JH, et al. Twenty four-hour activity cycle in older adults using wrist-worn accelerometers: the seniors-ENRICA-2 study. *Scand J Med Sci Sports*. 2020;30(4):700-708. https://doi.org/10.1111/sms.13612
29. Gilchrist SC, Howard VJ, Akinyemiju T, et al. Association of sedentary behavior with cancer mortality in middle-aged and older US adults. *JAMA Oncol*. 2020;6(8):1210-1217. https://doi.org/10.1001/jamaoncol.2020.2045
30. Giné-Garriga M, Sansano-Nadal O, Tully MA, et al. Accelerometer-measured sedentary and physical activity time and their correlates in European older adults: the SITLESS study. *Journals Gerontology Series A*. 2020;75(9):1754-1762. https://doi.org/10.1093/gerona/glaa016
31. Wu Z.-j, Wang Z.-y, Hu B.-q, et al. Relationships of accelerometer-based measured objective physical activity and sedentary behaviour with cognitive function: a comparative cross-sectional study of China's elderly population. *BMC Geriatr*. 2020;20(1):149. https://doi.org/10.1186/s12877-020-01521-y
32. Beddhu S, Wei G, Marcus RL, Chonchol M, Greene T. Light-intensity physical activities and mortality in the United States general population and CKD subpopulation. *Clin J Am Soc Nephrol*. 2015;10(7):1145-1153. https://doi.org/10.2215/cjn.08410814
33. Bao Y, Dalrymple L, Chertow GM, Kaysen GA, Johansen KL. Frailty, dialysis initiation, and mortality in end-stage renal disease. *Arch Intern Med*. 2012;172(14):1071-1077. https://doi.org/10.1001/archinternmed.2012.3020
34. Collard RM, Boter H, Schoevers RA, Oude Voshaar RC. Prevalence of frailty in community-dwelling older persons: a systematic review. *J Am Geriatr Soc*. 2012;60(8):1487-1492. https://doi.org/10.1111/j.1532-5415.2012.04054.x

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Abraham N, Lyden K, Boucher R, et al. An intervention to decrease sedentary behavior in older adults: a secondary analysis of a randomized controlled trial. *Obes Sci Pract*. 2023;9(5):529-537. https://doi.org/10.1002/osp4.687