



Sex-stratified reference values for the life-space assessment in the Canadian longitudinal study on aging

Selina Malouka¹ · Alexandra Jean Mayhew^{2,3,4} · Hon Yiu So⁵ · Parminder Raina^{2,3,4} · Marla Beauchamp^{1,4} · Julie Richardson^{1,2} · Ayse Kuspinar^{1,4} 

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Abstract

Background The Life-Space Assessment (LSA) can compliment traditional physical performance measures of mobility by accounting for the interaction between individuals and their environment. However, there are no studies that have generated percentile curves showing sex-stratified reference values in a large population-based sample of community-dwelling adults, making its interpretation difficult. Therefore, this study **aimed** to establish sex-stratified reference values for the LSA in middle-aged and older Canadians.

Methods Baseline data for participants aged 45–84 years old from the Canadian Longitudinal Study on Aging (CLSA) were used ($n = 22,154$). Quantile regression was used to estimate specific percentiles, with age as the independent variable and LSA scores as the dependent variable. Models were run for the whole sample, then separately for males and females. The models were cross-validated to assess their reliability. CLSA inflation and analytic weights were applied.

Results On average, the sample was 62.5 ± 10.0 y.o. (51.1% males), with a weighted mean LSA score of 89.2 ± 17.0 . There was also a decrease in LSA scores with age, where scores were lower for older age groups compared to younger groups, and LSA scores were lower for females relative to males.

Discussion and conclusions Reference data will aid in interpreting, comparing, and making inferences related to LSA scores obtained in clinical and research settings for Canadian adults.

Keywords CLSA · Life-space mobility · Population data · Normative data

Introduction

A decline in mobility with age places a significant burden on older adults [1]. For example, impaired mobility is a predictor of falls, loss of independence, institutionalization, and

death [2–4]. The literature consistently demonstrates that mobility is strongly associated with health and quality of life [5–8]. However, there is a mismatch between the level of functioning that individuals report as being capable of and the level of functioning that they achieve in their day-to-day life [9].

In 1998, Glass proposed a model to distinguish between three “tenses” of functioning: the hypothetical (i.e., what a person can do), experimental (i.e., what a person could do), and enacted (i.e., what a person does do) [9]. First, the hypothetical tense of functioning refers to the individual’s perceived ability, traditionally captured through self-report measures. Second, the experimental tense refers to the individual’s capability, which is often assessed by asking individuals to demonstrate their physical function in experimental or clinical settings (i.e., performance-based measures). Lastly, the enacted tense refers to the individual’s functional performance within the context of their home. Enacted functioning acknowledges situational and ecological factors that

✉ Ayse Kuspinar
kuspinaa@mcmaster.ca

¹ School of Rehabilitation Science, McMaster University, IAHS, 1400 Main St. W. Room 435, Hamilton, ON L8S 1C7, Canada

² Department of Health Research Methods, Evidence, and Impact, McMaster University, Hamilton, ON, Canada

³ Labarge Centre for Mobility in Aging, McMaster University, Hamilton, ON, Canada

⁴ McMaster Institute for Research on Aging, McMaster University, Hamilton, ON, Canada

⁵ Department of Mathematics and Statistics, Oakland University, Rochester, MI, USA

shape functioning in the real world. Although each tense represents different perspectives and may be more optimal in one situation over the other, relying solely on instruments which measure the hypothetical tense may lead to inaccurate estimates of disability rates, and underrepresentation of the importance of psychosocial factors in shaping functioning [9].

Mobility is often assessed in defined settings using physical performance measures, such as gait speed [10] and the Timed Up and Go test [11], capturing the experimental tense of functioning. Such physical performance measures focus on specific aspects of physical functioning (i.e., what individuals can do in experimental settings), but do not acknowledge the interaction between the person and environment (i.e., what individuals actually do in their daily life, including their homes) [12, 13].

Life-spaces refer to areas visited in everyday life (i.e., room, home, outdoors, neighborhood, service community, surrounding area, and world), and life-space mobility refers to an estimate of “the magnitude or extent of travel into the environment, regardless of how one gets there” [14]. In other words, life-space mobility captures an individual’s mobility within and outside their home. Notably, the construct of life-space mobility that has emerged in the literature [15] aligns well with Glass’s enacted tense of functioning.

The Life-Space Assessment (LSA) is the most widely used measure of life-space mobility [16, 17] and is gaining increasing attention in the literature for reflecting the mobility of individuals in their daily life, acting as an informative measure of aging-related changes and functional ability. Further, the LSA has been shown to predict important health outcomes, such as morbidity and healthcare utilization [18–21]. Given its advantages and its emerging use in research, reference data for the LSA is required to interpret, compare, and make inferences on scores obtained in clinical and research settings. To our knowledge, there are no studies that have generated percentile curves, using robust regression analyses, showing sex-stratified reference data for the LSA in a large population-based sample of community-dwelling Canadian adults, making its interpretation difficult. Therefore, the current study aimed to establish such sex-stratified reference values for the LSA using data from the Canadian Longitudinal Study on Aging (CLSA) for adults with no underlying mobility limitations [22, 23].

The CLSA offers a comprehensive population-based dataset from across Canada that is ideal for establishing sex-stratified reference values. We hypothesized that LSA scores will decrease with age. Further, LSA scores for females will be lower than LSA scores for males, given that among older adults, females with any disease experience lower physical functioning relative to males [24, 25], and the LSA has been shown to reflect this sex-based difference [26].

Method

Study design

A cross-sectional secondary analysis of the CLSA baseline Comprehensive Cohort dataset (collected 2012–2015) was conducted.

Sample

The CLSA is a Canada-wide, 20 year longitudinal study of around 50,000 community-dwelling adults aged 45–85 years at baseline [22, 23]. All 50,000 participants were asked to provide a core set of information regarding multiple measures (e.g., lifestyle/behaviour, social, physical/clinical, psychological, economic, and health status measures). Additionally, 30,000 of the 50,000 participants were asked to supplement this core set with in-depth information (i.e., via interviews, physical examinations, and biospecimen collection), forming the CLSA Comprehensive Cohort. The CLSA Comprehensive Cohort was used for this study.

The CLSA’s eligibility criteria excluded individuals who were: residents in the three territories and some remote regions, living on federal First Nations reserves and other First Nations settlements in the provinces, full-time members of the Canadian Armed Forces, unable to respond in English or French, temporary visa holders or have transitional health coverage, and living in long-term care institutions. Further, individuals with cognitive impairments or participants judged by the CLSA interviewers as unable to understand the purpose of the study and/or provide reliable data were excluded.

The current study employed a subset of the CLSA Comprehensive Baseline Dataset to include all eligible participants ages 45–84 years. Participants with incomplete data on the LSA were excluded. Further, participants who: (i) had any injury over the last 12 months that limited normal activities, (ii) underwent surgery over the last three months, (iii) had chemotherapy in the last four weeks, and (iv) were currently receiving dialysis treatment were also excluded (participants with missing or incomplete values for these criteria were not excluded to avoid making assumptions about their health state). Lastly, individuals who reported one or more limitations in activities of daily living (ADL)/ instrumental activities of daily living (IADL) were considered to have ADL disability and were excluded (participants with missing or inconclusive values were excluded to ensure that the included sample did not have any functional limitations). This exclusion criterion is necessary to ensure that the reference sample

generated was representative of healthy aging and minimize the influence of underlying mobility limitations or serious chronic diseases.

Outcome measure

The LSA was completed using an in-home face-to-face interview and asks participants about the life-spaces they visited (i.e., 1 = rooms in the house outside of the bedroom, 2 = yard or immediate outdoor area, 3 = their neighbourhood, 4 = neighbourhoods outside their own, and 5 = outside of their city or town) [17]. Specifically, the LSA asks if an individual went to a certain life-space in the past 4 weeks (“Yes” or “No” for each level), with a “No” option scoring a 0, a level 1 life-space scoring 1 point for “Yes,” incrementally increasing until the 5th life-space level which is given a score of 5 points for “Yes” [17]. Participants are then asked about the frequency of their movement within each life-space (i.e., 1 = < 1/week, 2 = 1–3 times/week, 3 = 4–6 times/week, and 4 = daily), and if assistance was required (i.e., 1 = personal assistance, 1.5 = assistive devices, 2 = no assistance) [17]. The method of scoring which accounts for all of this information is called the composite score (LS-C) and is calculated by multiplying the values across each level, and then the 5 level scores are added together. This scoring produces a value that can range from 0 to 120, with a change of 5 or more points considered clinically meaningful [17, 27]. The LSA scores presented in this paper are the calculated composite scores (i.e., LS-C scores).

Ethical considerations

This study received approval from the Hamilton Integrated Research Ethics Board (HiREB application #8131).

Analysis

Descriptive summary statistics are presented as means and standard deviations (SD) for continuous variables. Counts and percentages are presented for categorical data. As the data did not meet the assumptions of a linear regression, quantile regression was used to estimate specific percentiles (i.e., 5th, 10th, 25th, 50th, 75th, 90th, and 95th percentiles), with age measured continuously as the independent variable and LSA scores as the dependent variable [28, 29]. Quantile regression was also used as it allows for the exploration of the relationship between variables at different percentiles. Cross-validation was used to compare between linear, quadratic, and cubic polynomials for age. To cross-validate the models, from each year of age and sex strata, 70% of the included sample was randomly selected by the software as the “training” sample, while the remaining 30% was selected as the “testing” sample. The model fitted in the training

sample was applied to the “testing” sample. The observed versus expected count of participants with measurements within each percentile range were determined. This process was repeated one hundred times using a seed of 1234. The cross-validation suggested that the quadratic model was satisfactory, compared to the linear or cubic models, as assessed by the proportion of the population covered by each percentile range (e.g., whether the 5th percentile covered 5% of the population) (Supplementary File 1: Table 2). Models were run for the sample, and then separately for males and females. Mean percentile values of the resulting model are presented by sex and age group (45–49, 50–54, 55–59, 60–64, 65–69, 70–74, 75–79, and 80–84 years).

To generalize the results to the Canadian population and account for the complex survey design of the CLSA, sampling weights were incorporated into the analyses. As recommended and provided by the CLSA [22, 23], inflation weights were applied to the descriptive summary statistics (i.e., means and standard deviations), while analytic weights were applied to the quantile regression analyses. The appropriateness of the sampling weights was then assessed after removal of participants as per the exclusion criteria. Significance levels for all statistical tests were set at the 0.05 level, and statistical analyses were conducted using STATA version 16.0 or R version 4.1.1. for Macintosh software.

Results

As per the eligibility criteria, participants were excluded if they had incomplete data on the required questions of the LSA, which comprised 0.2% ($n = 53$) of the whole sample. Furthermore, participants with any injury over the last 12 months that limited normal activities ($n = 4,362$), underwent surgery over the last three months ($n = 1,243$), had chemotherapy in the last 4 weeks ($n = 95$), were currently receiving dialysis treatment ($n = 14$), and reported having ADL/IADL limitations ($n = 2,931$) or had an inconclusive ADL/IADL classification due to missing values ($n = 108$) were excluded.

Table 1 outlines the unweighted characteristics of the whole sample ($n = 22,154$), for males ($n = 11,330$) and females ($n = 10,824$). Around 50% of the participants were males (51.1%) and the mean age of the sample was 62.5 years (SD = 10.0). Majority of the sample had a post-secondary degree/diploma (78.1%), had at least one chronic condition (90.5%), and lived in an urban environment (90.5%).

Table 2 outlines the weighted LSA scores for the whole sample, as well as for males and females separately, after the incorporation of the sampling weights. The weighted LSA scores ranged from 0 to 120 for both males and females, with a mean LSA score of 89.2 (SD = 17.0) for

Table 1 Unweighted sample characteristics for the whole sample ($n=22,154$), males and females

Characteristic	N (%)		
	Whole sample	Males	Females
Sex			
Males	11,330 (51.1)	–	–
Females	10,824 (48.9)	–	–
Age (years)			
45–49	2,177 (9.8)	1,052 (9.3)	1,125 (10.4)
50–54	3,633 (16.4)	1,797 (15.9)	1,836 (17.0)
55–59	3,515 (15.9)	1,683 (14.9)	1,832 (16.9)
60–64	3,874 (17.5)	2,010 (17.7)	1,864 (17.2)
65–69	3,245 (14.7)	1,664 (14.7)	1,581 (14.6)
70–74	2,253 (10.2)	1,207 (10.7)	1,046 (9.7)
75–79	2,256 (10.2)	1,254 (11.1)	1,002 (9.3)
80–84	1,201 (5.4)	663 (5.9)	538 (5.0)
Education			
< Secondary school graduation	1,137 (5.1)	541 (4.8)	596 (5.5)
Secondary school graduation	2,114 (9.5)	956 (8.4)	1,158 (10.7)
Some post-secondary education	1,570 (7.1)	799 (7.1)	771 (7.1)
Post-secondary degree/diploma	17,297 (78.1)	9,010 (79.5)	8,287 (76.6)
Chronic disease			
Present	20,056 (90.5)	10,055 (88.8)	10,001 (92.4)
Absent	1,926 (8.7)	1,168 (10.3)	758 (7.0)
Geographical location			
Rural	2,105 (9.5)	1,034 (9.1)	1,071 (9.9)
Urban	20,049 (90.5)	10,296 (90.9)	9,753 (90.1)

Table 2 Weighted LSA scores for the whole sample, males and females

Variable	Mean (standard deviation)		
	Whole sample	Males	Females
Sex			
Male	91.0 (16.6)	–	–
Female	87.4 (17.3)	–	–
Age (years)			
45–49	92.6 (16.2)	92.1 (16.1)	93.1 (16.3)
50–54	93.8 (16.5)	95.3 (16.0)	92.3 (16.8)
55–59	90.6 (16.5)	93.1 (16.7)	88.3 (16.1)
60–64	88.0 (16.6)	89.7 (16.5)	86.3 (16.6)
65–69	85.3 (16.5)	87.8 (16.0)	82.9 (16.7)
70–74	84.1 (16.8)	87.3 (16.6)	81.1 (16.5)
75–79	82.7 (16.1)	86.1 (15.3)	79.6 (16.3)
80–84	78.6 (17.0)	83.2 (17.0)	74.5 (15.8)

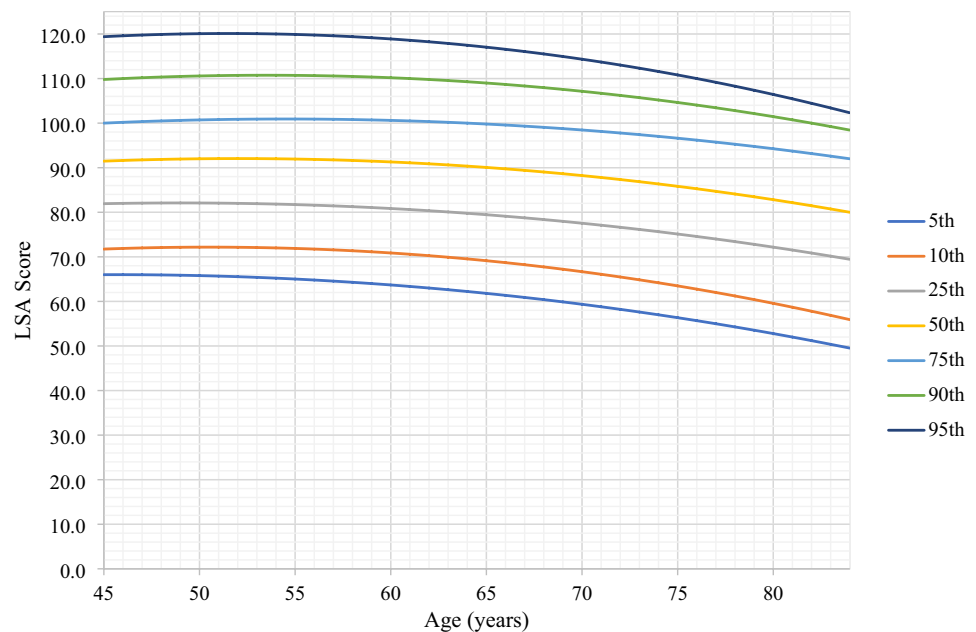
the whole sample, 91.0 (SD = 16.6) for males, and 87.4 (SD = 17.3) for females, suggesting that, on average, the sample was able to move independently outside their neighborhood (i.e., LSA score > 60) [30]. Weighted mean LSA scores were typically lower for females compared to males. There was also a decrease in LSA scores with age,

where scores were lower for older age groups compared to younger groups.

Table 3 presents a summary of results of the quantile regression, outlining the percentile mean values for the weighted sex-stratified reference values for the LSA scores (i.e., 5th to 95th percentiles) by age group (see Supplementary File 1: Table 1 for the reference values of the whole sample, and Supplementary File 2 for quantile regression raw percentile scores). The cross-validation suggested that the quadratic model was satisfactory, compared to the linear or cubic models, as assessed by the proportion of the population covered by each percentile range (e.g., whether the 5th percentile covered 5% of the population) (Supplementary File 1: Table 2). Choice of the quadratic model was also supported by the visual inspection of the data. LSA scores were lower for the higher age groups and lower for females relative to males. These age-specific percentile trends are further illustrated in Figs. 1 and 2 (see Supplementary File 1: Fig. 1 for age-specific percentile trends of the whole sample). The greatest decline in LSA scores generally occurred in the sixties, with an earlier decline occurring in the early fifties for those in the bottom percentiles (i.e., 5th and 10th). In addition to identifying trends, these graphs can be used to compare an individual’s score relative to others of the same age and sex.

Table 3 Weighted sex-stratified reference values for the LSA scores: mean percentile values

Age (years)	Mean percentile values						
	5th	10th	25th	50th	75th	90th	95th
Males							
45–49	66.0	72.0	82.0	91.7	100.3	110.2	119.7
50–54	65.5	72.1	82.0	92.0	100.8	110.7	120.1
55–59	64.5	71.5	81.4	91.7	100.8	110.6	119.6
60–64	63.0	70.2	80.3	90.9	100.3	109.8	118.2
65–69	60.9	68.2	78.7	89.4	99.3	108.3	116.0
70–74	58.2	65.5	76.6	87.3	97.8	106.2	113.0
75–79	55.0	62.0	74.0	84.7	95.7	103.4	109.1
80–84	51.2	57.8	70.8	81.4	93.2	100.0	104.4
Females							
45–49	64.4	72.0	80.9	90.0	100.0	110.1	120.0
50–54	63.2	69.8	79.7	90.0	100.2	110.1	119.7
55–59	61.6	67.5	78.1	89.3	99.7	109.2	118.5
60–64	59.6	65.0	76.0	87.8	98.4	107.7	116.3
65–69	57.2	62.4	73.4	85.7	96.3	105.4	113.2
70–74	54.3	59.6	70.5	82.8	93.5	102.3	109.1
75–79	50.9	56.6	67.1	79.2	90.0	98.5	104.0
80–84	47.2	53.5	63.2	74.9	85.6	94.0	98.0

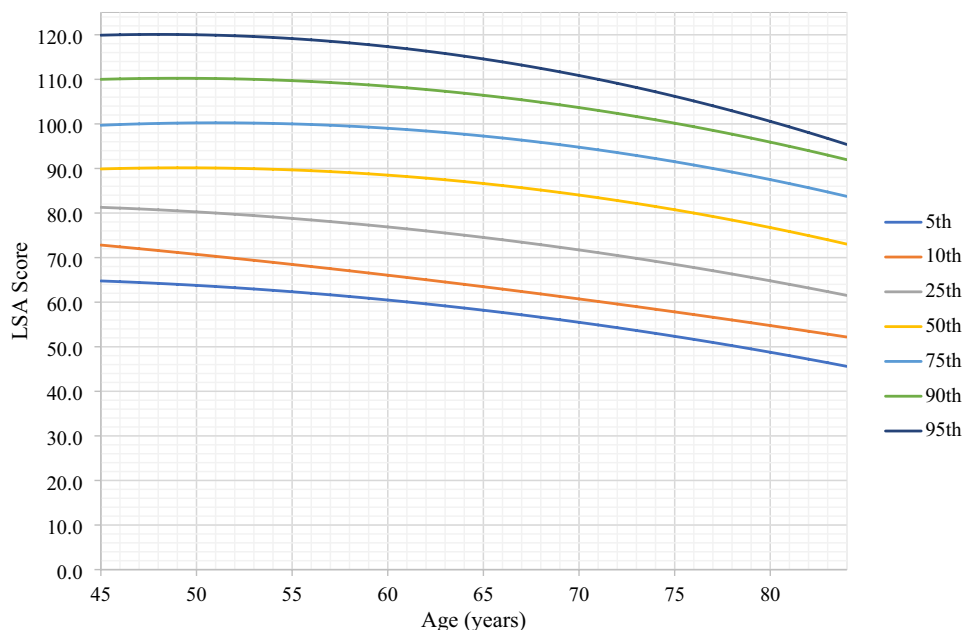
Fig. 1 Weighted percentile curves for the LSA scores in males

Discussion

To our knowledge, this is the first study to use a population-based dataset and robust regression-based analyses to establish sex-stratified reference values for the LSA and present corresponding percentile graphs in community-dwelling Canadian adults aged 45–84 years. Overall, LSA scores were lower for older individuals and for females. By

generating reference values using quantile regression, the current study provided an opportunity to investigate the effect of age on LSA scores at the different percentiles of the population, as stratified by sex. Although the greatest decline in LSA scores occurred around 60 years of age, earlier declines (i.e., in the early fifties) were observed in the lower percentiles (i.e., 5th and 10th), suggesting that those individuals could be more at risk of experiencing earlier functional limitations.

Fig. 2 Weighted percentile curves for the LSA scores in females



The trends in reference values from the current study are comparable to those obtained from Australia ($n = 3032$) using data from the South Australian Health Omnibus Survey. Australian reference values show that LSA scores were lower for older age groups, and that females have lower LSA scores than males [26]. More specifically, after 55 years, LSA scores in Australia were lower in females relative to males [26]. Similarly, in the current study, LSA scores were lower with increasing age in Canada, and were lower for females relative to males. Also, the greatest decreases in LSA scores by age occurred in the late fifties, with females showing larger decreases than males. Previous research provides an explanation for these sex-based differences: it has demonstrated that, among older adults, females with any disease/condition experience lower physical functioning relative to males [24, 25], and the LSA has been shown to reflect this sex-based difference [26].

In the literature, LSA scores < 60 typically indicate “restricted” life-space mobility (i.e., that individuals are confined to their neighborhood) [30]. On the other hand, LSA scores > 60 have been associated with an individual’s ability to get out of their neighborhood independently (i.e., “un-restricted life-space”) [30]. It is important to note that various factors can contribute to having a restricted life-space mobility besides physical function (e.g., reduced social participation). Our results show that the age at which individuals’ LSA scores drop below 60 varies by sex. For the whole sample, restricted LSA scores are observed after 65 years in the 5th percentile, and after 75 years at the 10th percentile. For males, restricted LSA scores are observed after 70 years for the 5th percentile and after 80 years for the 10th percentile. For females, restricted LSA scores are

observed earlier than men, with the 5th percentile showing restricted LSA scores after 60 years and the 10th percentile after 70 years. Scores at other percentiles were not less than 60 points within this sample, suggesting that individuals at lower percentiles are most at risk for having restricted life-space mobility. This is critical as restricted LSA scores have been associated with negative health outcomes, such as a greater risk (4.4 times) of admissions to a nursing home after six years, relative to those with unrestricted life-space mobility [31], and individuals performing at these lower percentiles should be addressed to mitigate the effect of negative health outcomes. The LSA can track declines in individuals’ community mobility, often preceding IADL/ADL limitations [31], and can provide an opportunity for early multidisciplinary intervention, specifically for those performing at lower percentiles of the population.

Restrictions in LSA scores can result from a variety of different factors. For example, Peel et al. [16] demonstrated that ADL, IADL, and the Short Physical Performance Battery (SPPB) only explained 45.5% of LSA score variability, suggesting that elements of social participation could also be reflected within this variability in scores. Furthermore, Kuspinar et al. [12] suggested that driving, social support, and walking speed were most associated with LSA scores in the CLSA. Together, these studies show that the LSA could be capturing aspects of daily mobility that are not reflected in traditional physical performance measures. The variables mentioned (e.g., physical function, driving, and social support) tend to decrease with age and could be contributing to the overall LSA trends observed in this study (e.g., restrictions were observed around the age at which people tend to retire and stop commuting). Moreover, environmental

barriers play a critical role in influencing life-space mobility: individuals experiencing high curbs or a lack of sidewalks have higher odds of restricted life-space mobility [15]. This further highlights the utility of the LSA in assessing a wholistic view of mobility, providing an opportunity for the exploration of the different factors that influence mobility from the home to the outside world.

The three tenses of functioning (i.e., the hypothetical, experimental, and enacted), defined by Glass, represent different yet complimentary perspectives on functioning [9]. Assessing one tense over another is likely to have different applications; however, relying solely on measuring the hypothetical tense may lead to an inaccurate estimation of disability rates and mobility in everyday life [9]. It is, therefore, important to consider the use of the LSA to compliment the use of other mobility measures [9]. Furthermore, since the LSA predicts morbidity, mortality, and healthcare utilization [18–21], declines in life-space mobility could indicate an early decline in functioning, providing an opportunity to intervene early during a period when interventions are more likely to result in improvement [16]. Having population-specific, sex-stratified reference values of the LSA then becomes essential to clinicians and researchers in Canada when assessing patients' performance relative to the general population and, if needed, determining appropriate courses of action/treatment.

A strength of this study is the use of robust, regression-based methods and the use of a large population-based dataset and sampling weights. However, given that the data collection sites of the CLSA are located in urban regions and given the CLSA's exclusion criteria, results of this study may not apply to those living in remote regions and the three territories, federal First Nations reserves and other First Nations settlements in the provinces. The sample may also not be representative of those who are not English- or French-speaking. Further, the percentile scores are limited to providing information about LSA score distribution and do not provide information about which scores are indicative of risk. Lastly, the data was collected between 2012 and 2015, prior to the COVID-19 pandemic, and may not reflect any changes in life-space mobility that were a consequence of it. Future research could determine LSA scores that are indicative of risk of negative health outcomes, as well as investigate the effect of the COVID-19 pandemic on LSA scores.

Conclusions

In conclusion, this study determined sex-stratified reference values for the LSA in community-dwelling middle-aged and older Canadians aged 45–84 years. The results suggest that LSA scores are lower for females and decline with age, with earlier declines observed among those scoring in the

lowest percentiles. Consideration of life-space mobility is important for a comprehensive assessment of mobility and these population-based reference values will aid clinicians and researchers in interpreting LSA scores of individuals in Canada.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s40520-023-02382-2>.

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Author contributions Conceptualization: AK. Methodology: SM, AM, AK, MB, JR, PR. Analysis: SM, AM, HYS, AK. Writing, original draft preparation: SM. Writing, review, and editing: SM, AM, AK, MB, JR, PR. Supervision: AK. All authors read and approved the final manuscript for submission.

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Data availability All relevant data are presented in the manuscript and supplementary materials.

Declarations

Conflict of interest None reported.

Informed Consent As per the CLSA protocol.

Human and animal rights As per the CLSA protocol.

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