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Reliability and Validity of the IPAQ-L in a Sample of Hong Kong Urban Older Adults: Does Neighborhood of Residence Matter?

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This study examined reliability and validity of the Chinese version of the International Physical Activity Questionnaire–Long Form (IPAQ-LC) in Chinese seniors, including moderating effects of neighborhood walkability and socioeconomic status (SES) on reliability and validity. The IPAQ-LC was interviewer-administered (n = 96), accelerometer and 7-day walk-diary data were collected (n = 94), and the IPAC-LC was readministered (N = 92). Acceptable reliability was found for all measures of physical activity (PA) overall and across different types of neighborhood. Participants from highly walkable neighborhoods were more reliable at estimating walking for transport. Participants from low-SES areas were less reliable at estimating leisure-time PA and sitting but more reliable at estimating transport-related walking. IPAQ-LC walking was significantly related to light- but not moderate-intensity accelerometry-based PA. It was moderately to strongly related to a 7-day diary of walking. The data imply slow-paced walking, probably due to age, climate, and terrain. The findings suggest that the IPAQ-LC's reliability and validity are acceptable in Chinese seniors.

Keywords: physical activity, self-report measure, elders, walkability

The importance of physical activity for healthy aging is well documented (Nelson et al., 2007). To accurately assess physical activity, and hence formulate public health physical activity recommendations for older adults, it is crucial to develop and identify valid and reliable physical activity measures. Due to their relatively low administrative cost, self-report measures are commonly used to assess physical activity patterns in large-scale studies and for population-surveillance purposes. They are also useful for gathering qualitative information on physical activity, such as domain (e.g., leisure and occupational) and type (e.g., swimming, walking; Welk, 2002). In addition, compared with objective physical activity measures such as pedometers and accelerometers, they may more accurately capture variations in intensity levels of physical activity attributable to environmental features such as hills, heat, and humidity.

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A recent review on physical activity questionnaires found the Chinese version of the International Physical Activity Questionnaire–Short Form (IPAQ-SC; Deng et al., 2008) to be one of the most reliable self-report measures for elders (Forsen et al., 2010), with intraclass correlation coefficients (ICCs) ranging from .81 to .89 (Deng et al., 2008). The IPAQ-SC has been validated in Chinese elders using pedometry-measured activity as the objective criterion (Deng et al., 2008). Low to moderate positive associations were found between weekly pedometer counts and IPAQ-SC estimates of energy expenditure from total physical activity and walking. No significant associations were found between pedometer counts and energy expenditure from other moderate- and vigorous-intensity physical activity, likely due to the inability of pedometers to quantify physical activity intensity and walking being the main activity among Chinese elders.

While the IPAQ-SC is a convenient tool for assessing overall physical activity and various activity intensities, it does not collect information on activity domains. In contrast, the long version of the IPAQ (IPAQ-L) covers the major physical activity domains of work, transportation, household, and leisure (Craig et al., 2003). The Chinese version of the IPAQ-L (hereafter, IPAQ-LC) showed levels of reliability and validity comparable to those of other commonly used self-report measures of physical activity in adults (Macfarlane, Chan, & Cerin, 2011). Yet, to our best knowledge, no studies have examined the appropriateness of the IPAQ-LC for Chinese elders. In light of the growing interest in the application of socioecological models of health to the study of physical activity patterns (Giles-Corti, Timperio, Bull, & Pikora, 2005), emphasizing the value of studying settings and context in which physical activity occurs, it is important to establish the metric properties of the IPAQ-LC in this population segment. The IPAQ-L has been successfully used to assess physical activity in adults globally (Craig et al., 2003). It is also being used in international initiatives aimed at examining the effect of environmental factors on physical activity in adults (www.ipenproject.org). To better understand how the environment affects physical activity and devise effective environmental interventions advantageous to the population at large, it is important to identify age-group differences in effects. This requires the use of common physical activity measures across age groups.

To address the research gaps we have outlined, the main aim of this study was to estimate the reliability and validity of the interviewer-administered IPAQ-LC in a community sample of Chinese elders. Validity evidence for the IPAQ-LC was assessed against accelerometry-based estimates of physical activity and diary-based estimates of walking for different purposes. While waist-mounted accelerometers can objectively capture intensity and duration of ambulatory activities (Welk, 2005), activity diaries allow the assessment of activity type and domain (Matthews, 2002). We limited the activity diary to walking to minimize participants' burden and because walking is by far the most common type of physical activity in Chinese elders (Deng et al., 2008).

Secondary aims of the study were to establish whether test–retest reliability and validity of the IPAQ-LC differed across participants living in neighborhoods varying in transport-related walkability and socioeconomic status (SES). Residents living in more walkable neighborhoods might show higher levels of reliability for transportation-related activities because they are more likely to engage in such activities (Cerin, Leslie, Owen, & Bauman, 2007; Owen et al., 2007). Residents of lower SES areas are likely to have lower levels of education and hence find it more challenging to understand questionnaire items, which may increase the error of measurement when compared with their higher SES counterparts (Galobardes, Shaw, Lawlor, Lynch, & Davey Smith, 2006; Turrell et al., 2011). Different levels of error of measurement may result in spurious differences in environment–physical activity relationships across population subgroups. Thus, it is important to identify environmental sources of measurement unreliability (Brownson, Hoehner, Day, Forsyth, & Sallis, 2009; Turrell et al., 2011).

Methods

This study used data from a subsample of participants (subsample n = 94, total N = 484) who consented to take part in a project aimed at developing measures to study the associations between environment and physical activity in Chinese older adults (Cerin et al., 2010). The study was awarded ethical clearance by the ethics committees of the participating institutions.

Participants and Procedure

Participants were Chinese-speaking people age 65 years or above, with no diagnosis of cognitive impairment, able to walk without assistance from others or an assistive device and communicate verbally, and residing in one of 32 preselected street blocks of Hong Kong. They were recruited from membership lists of four Hong Kong Elderly Health Centres (EHCs) representing catchment areas of low and high transport-related walkability stratified by low and high SES. Members of the EHCs are generally representative of the elderly population of Hong Kong (Schooling et al., 2006).

The SES level of a catchment area (district) was established using data on median household income and percentage of owner-occupiers obtained from the Census and Statistics Department of the Hong Kong Special Administrative Region. Area walkability was determined using data from Centamap (www.centamap.com) and the Census and Statistics Department on household, intersection, and commercial/service destination densities expressed as units per km^2. Details about the characteristics of sampling areas are given elsewhere (Cerin et al., 2010).

Participants were recruited using a two-stage sampling strategy. Eight street blocks with at least 25 residing EHC members were randomly selected without replacement in each of the four catchment areas. Approximately 15 EHC members were recruited from each block by mailing invitation letters followed up by a phone call (total N = 484; 78% response rate). After we had obtained written informed consent, a set of questionnaires, including the IPAQ-LC (Macfarlane et al., 2011), was interviewer-administered to the whole study sample. In administering the IPAQ-LC, particular attention was given to clearly explaining the meaning of activities (e.g., walking for transportation) and activity intensities (light vs. moderate activity) by providing examples relevant to this population segment, as suggested by Heesch, van Uffelen, Hill, and Brown (2010). Examples of leisure-time vigorous physical activity included badminton, running, fast swimming, and brisk uphill hiking, while examples of leisure-time moderate physical activity were Tai Chi, uphill hiking, and swimming at regular pace. The importance of reporting activities lasting for at least 10 min was also emphasized.

All participants were asked if they would be willing to wear an accelerometer for a week, keep a diary of walks, and be reassessed on the questionnaires 2 weeks after the first assessment. Based on power calculations, 3 participants per street block (n = 96) were randomly selected from those who consented to take part in this component of the study (73% of the original sample). The sociodemographic characteristics of the sample are presented in Table 1.

An accelerometer and a 7-day diary of walks (including a log to record accelerometer nonwear time) were delivered to the participants 8 days before the first administration of the IPAQ-LC. Participants were required to wear the accelerometer for 7 consecutive days for at least 10 hr/day, keep a daily diary of walks, and record accelerometer nonwear periods. They received a daily phone call to motivate and verify compliance. On the eighth day of the study, the accelerometer and diary were collected and the IPAQ-LC was interviewer-administered to those with at least 5 valid days of data, including a weekend day. Ninety-two of 96 participants attended both interviews, while 94 participants provided valid accelerometry (average 13.5 valid hr/day; SD = 1.3 hr/day) and diary data. The interval between the two administrations of the IPAQ-LC ranged from 14 to 20 days (average of 17 days). Both interviews were conducted by the same person. Grocery vouchers were offered as incentives for participation after successful completion of each study component.

Table 1 Participant Characteristics, *N* = 94

Characteristic	%
Gender	
male	42
female	58
Age	
65–74 years	62
75–84 years	36
≥85 years	2
Educational attainment	
secondary/high school or above	44
primary	50
no formal education but can read and write	7
Area of residence	
high walkability, high socioeconomic status	26
high walkability, low socioeconomic status	24
low walkability, high socioeconomic status	24
low walkability, low socioeconomic status	26

Measures

Sociodemographic data on gender, age, and educational attainment were collected during the first interview. Area-level SES and walkability were measured as outlined in the previous section and dichotomized into *high* and *low*. Physical activity was measured using the IPAQ-LC, a 7-day diary of walks, and the uniaxial accelerometer MTI-ActiGraph model GT1M (Fort Walton Beach, FL).

IPAQ-LC. The IPAQ-LC (Craig et al., 2003) was interviewer-administered on two occasions. Participants were asked questions on the frequency and duration of activities undertaken in the last 7 days. These were classified into the domains of occupation, transportation, household, and leisure and encompassed sections on walking, moderate-intensity physical activity, vigorous-intensity physical activity, and sedentary behaviors. For comparison purposes, the IPAQ-LC data were presented as weekly minutes, as well as metabolic equivalent task (MET) minutes per week, and were computed according to the IPAQ scoring protocol (www.ipaq.ki.se/scoring.pdf). Data were presented as total activity, activity by domain, activity by intensity level, and activity by domain and intensity levels.

MTI-ActiGraph Accelerometer. This MTI-ActiGraph Accelerometer Model GT1M is a uniaxial accelerometer that provides an objective measure of physical activity by recording the number and magnitude of vertical accelerations generated by human movement (Welk, 2005). It was programmed to record activity in 1-min epochs (Davis & Fox, 2007), producing both count and step-count data. The participants were instructed to firmly secure it to the right hip in the midaxillary line, wear it during waking hours, remove it for water activities and sleep, and keep a concurrent log to record the periods of monitor wearing and nonwearing. Nonwear periods were identified using the log information, as well as 100 min of consecutive zero counts, a criterion appropriate for an older population (Davis & Fox, 2007). A valid day was defined as having at least 10 hr of recorded activity. Previously published cut points that were employed in earlier studies with older adults (Davis & Fox, 2007; Davis et al., 2011) were used to classify activity counts into sedentary (<100 counts/min), light (100–1,951 counts/min), moderate (1,952–5,724 counts/min) and vigorous (>5,724 counts/min; Craig et al., 2003; Freedson, Melanson, & Sirard, 1998). To allow detailed comparison with the IPAQ-LC, data were summarized as weekly minutes of the following activities: sedentary; light; moderate; vigorous; at least light (light to vigorous physical activity; LVPA); at least moderate (moderate to vigorous physical activity; MVPA); ≥10-min bouts of light physical activity, moderate physical activity, vigorous physical activity, LVPA, and MVPA, respectively; and sum of ≥10-min bouts of light, moderate, and vigorous physical activity. Total weekly step counts and average counts per minute were also computed.

Seven-Day Diary of Walks. Participants had to keep a pilot-tested diary of walks outside their homes. For each walk, participants recorded the starting and finishing time and location (street), whether the location was in or outside their neighborhood of residence (defined as a 15-min walk from home), and the purpose of the walk: errands (e.g., shopping, banking, visit to the doctor), visiting friends, going to other places (e.g., cinema, community center, park, restaurant, schools), recreation, exercise, work, or accompanying or picking up others. For walks consisting of multiple destinations/stops (>5-min stops), participants were instructed to report each walk section as a separate entry. Stops at public-transit points for the purpose of using public transportation were considered destinations/stops. Walking for work and recreation were coded as work- and recreation-related walking, respectively, while all the remaining purposes for walking were coded as walking for transport. Diary data were summarized as weekly minutes of walking for transportation, leisure, and work and total walking.

Data Analysis

Means, standard deviations, medians, interquartile ranges, skewness, and kurtosis were computed for all physical activity variables. Positively skewed variables were log-transformed. Test–retest reliability of the IPAQ-LC was assessed for each physical activity variable using ICCs based on three-level linear mixed models allowing for area clustering effects (i.e., variations in physical activity measures due to differences between the 32 sampling areas; Cerin, 2011) and using the restricted-maximum-likelihood estimation method. These are equivalent to ICCs based on two-way random-effect models for single measures—ICC(2,1) (McGraw & Wong, 1996)—but with an additional neighborhood-level random effect. This type of model permits estimation of the proportion of total outcome variance attributable to differences between individuals (an index of measure repeatability), where the total variance is defined as the sum of the within-individual (across time points), between-individuals, and between-areas variations. Ignoring between-areas variations caused by multistage sampling usually results in an overestimation of reliability (Turrell et al., 2011). ICCs were computed for the whole sample, by area SES, and by area walkability. The significance of the between-areas differences in ICCs was established using Fisher's *Z* test (Donner & Zou, 2002). Between-areas differences in physical activity were also examined to explore the possibility that differences in reliability (if any) were attributable to varying levels of physical activity participation.

The validity of the IPAQ-LC was assessed by estimating its associations with corresponding accelerometry- and walk-diary-based physical activity variables using mixed models accounting for area clustering effects, whereby the IPAQ-LC variables were treated as outcomes and the accelerometry- and walk-diary-based variables as predictors. Given that there are no widely accepted accelerometer cut points specifically appropriate for older adults (Pruitt et al., 2008), we investigated the level of correspondence between various activity-intensity combinations of IPAQ-LC- and accelerometry-based variables. Differences in validity estimates between high- versus low-SES and walkability areas were evaluated by including appropriate interaction terms (physical activity predictor by area SES, physical activity predictor by area walkability) in the regression models. A probability level of 5% was adopted. Associations between IPAQ-LC and other physical activity variables were expressed in the form of correlation coefficients computed by estimating the outcome variance explained by a specific physical activity predictor (Snijders & Bosker, 1999). Finally, mixed models were used to estimate the mean differences between selected pairs of IPAQ-LC- vs. accelerometry- and walk-diary-based variables with high conceptual correspondence. The validity analyses were complemented by Bland–Altman difference plots (Altman & Bland, 1983).

Results

Table 2 reports the descriptive statistics for all physical activity variables. No participants reported any occupational physical activity, cycling for transportation, domestic yard work, or vigorous-intensity physical activity in any of the four domains. The lack of vigorous-intensity physical activity was also observed for the accelerometry-based estimates of physical activity. Transportation-related walking was the most prevalent activity, followed by walking for leisure. Compared with diary data, IPAQ-LC measures of walking were slightly higher. In addition, the IPAQ-LC mean weekly minutes of total physical activity (M = 1,160, SD = 544) were substantially higher than the total weekly minutes of accelerometry-based MVPA (M = 161, SD = 145) and ≥10-min bouts of MVPA (M = 70, SD = 126). However, they were very similar to the average accelerometry-based weekly minutes of ≥10-min bouts of LVPA (M = 1,196, SD = 741). Here, we note that participants reported an average of 5.12 weekly minutes (SD = 15.30) of moderate-intensity water activities (swimming), during which they did not wear the accelerometer.

Table 3 shows the test–retest reliability of the IPAQ-LC by domain and type of activity for the overall sample and for areas differing in SES and walkability. The level of reliability was acceptable for all variables in the whole sample and four area-based subsamples (Forsen et al., 2010). Residents of highly walkable areas showed higher levels of reliability in transport-related walking than their counterparts. Residents of highly walkable areas also tended to report more walking for transport (631 min/wk) than their counterparts (513 min/wk; p = .063). Differences in reliability were also found between low- and high-SES areas, with the former showing greater reliability for walking for transport and the latter yielding higher reliability estimates for leisure-time physical activity and sitting. However, no statistically significant differences in physical activity participation were found between the two types of area (all p > .153).

Validity analyses reporting the associations of IPAQ-LC variables with conceptually linked accelerometry- and walk-diary-based variables are summarized in Table 4. Weekly minutes of walking were significantly and substantially positively related to all walk-diary variables. However, they were only weakly associated with some accelerometry-based physical activity estimates. Moderate-intensity physical activity as measured by the IPAQ-LC was unrelated to all accelerometry-based variables with the exception of mean activity level (counts/min). Total physical activity from the IPAQ-LC was related to all accelerometry-based variables. The strongest association was observed between the IPAQ-LC measure of total physical activity and accelerometry-determined total weekly minutes of ≥10-min bouts of LVPA.

Compared with the walk diaries, the IPAQ-LC yielded higher mean values of total walking and transportation walking but not of leisure walking (Table 5). Large differences were found between the mean total weekly minutes of physical activity from the IPAQ-LC and accelerometry-based estimates of MVPA, with the IPAQ-LC providing much higher values (Table 5). The opposite was true when comparing total physical activity from the IPAQ-LC with total weekly minutes of LVPA from the accelerometer and sitting with accelerometry-based sedentary behavior. No significant differences were observed between the mean values of total physical activity from the IPAQ-LC and accumulated ≥10-min bouts of LVPA from the accelerometer (36 min/wk or 5.1 min/day). The Bland–Altman plot of this pair

Table 2 IPAQ-LC-, Walk-Diary-, and Accelerometry-Based Estimates of Physical Activity in a Sample of Hong Kong Elders

Physical activity measure	Assessment 1 *M (SD)*	Assessment 1 Median (IQR)	Assessment 2 *M (SD)*	Assessment 2 Median (IQR)
IPAQ-LC by domain and type (min/week)				
transportation—walking	565 (337)	420 (420)	580 (332)	420 (420)
domestic (inside)—moderate	134 (247)	0 (150)	141 (304)	0 (120)
leisure—walking	384 (290)	420 (367)	393 (301)	420 (451)
leisure—moderate	77 (173)	0 (70)	78 (176)	0 (25)
leisure—vigorous	0 (0)	0 (0)	0 (0)	0 (0)
IPAQ-LC by domain (min/week)				
transportation	565 (337)	420 (420)	580 (332)	420 (420)
domestic	134 (247)	0 (150)	141 (304)	0 (120)
leisure	461 (322)	420 (368)	471 (352)	420 (360)
IPAQ-LC by domain (MET min/week)				
transportation	1,866 (1,113)	1,386 (1,386)	1,913 (1,096)	1,386 (1,386)
domestic	402 (740)	0 (450)	423 (913)	0 (360)
leisure	1,575 (1,121)	1,386 (1,204)	1,608 (1,229)	1,386 (1,151)
IPAQ-LC by type (min/week)				
all walking	949 (460)	840 (630)	972 (458)	840 (630)
all moderate	211 (307)	80 (220)	219 (366)	5 (295)
sitting (weekday + weekend)	1,938 (621)	2,100 (720)	1,938 (621)	2,100 (875)
all MVPA	211 (307)	80 (220)	219 (366)	5 (295)
all (walking + MVPA)	1,160 (544)	1,050 (716)	1,191 (572)	1,050 (818)
IPAQ-LC by type (MET min/week)				
all walking	3,132 (1,517)	2,772 (2,079)	3,209 (1,513)	2,772 (2,079)
all moderate	712 (1,035)	240 (1,200)	734 (1,207)	20 (1,193)

(continued)

Table 2 *(continued)*

Physical activity measure	Assessment 1 *M* (*SD*)	Assessment 1 Median (IQR)	Assessment 2 *M* (*SD*)	Assessment 2 Median (IQR)
all vigorous	0 (0)	0 (0)	0 (0)	0 (0)
sitting (weekday + weekend)	1,968 (621)	2,100 (720)	1,938 (621)	2,100 (875)
all MVPA	712 (1,035)	240 (1,200)	734 (1,207)	20 (1,193)
all (walking + MVPA)	3,843 (1,784)	3,492 (2,327)	3,944 (1,877)	3,465 (2,597)
7-day diary of walks (min/week)				
transportation walking	509 (285)	414 (289)	—	—
leisure walking	345 (209)	368 (270)	—	—
total walking	854 (381)	813 (443)	—	—
Accelerometry-based estimates (min/week, except for step counts)				
step counts (total)	60,018 (24,240)	58,767 (35,221)	—	—
light	1,852 (580)	1,806 (777)	—	—
light (≥10-min bouts)	930 (600)	751 (722)		
moderate	160 (144)	129 (186)	—	—
moderate (≥10-min bouts)	70 (126)	13 (103)		
vigorous	1 (2)	0 (0)	—	—
vigorous (≥10-min bouts)	0 (0)	0 (0)	—	—
MVPA	161 (145)	129 (187)	—	—
MVPA (≥10-min bouts)	70 (126)	13 (103)		
LVPA	2,013 (622)	2,001 (769)	—	—
LVPA (≥10-min bouts)	1,196 (741)	1,080 (1,017)	—	—
sum of light, moderate, and vigorous ≥10-min bouts	1,000 (633)	818 (847)	—	—
sedentary	3,585 (792)	3,642 (762)	—	—
mean activity level (counts/min)	254 (107)	238 (130)		

Note. IQR = interquartile range; IPAQ-LC = Chinese version of the International Physical Activity Questionnaire–long form; MET = metabolic equivalent task; MVPA = moderate to vigorous physical activity; LVPA = light to vigorous physical activity. No occupational physical activity, cycling for transportation, domestic yard physical activity, or vigorous physical activity was self-reported on the IPAQ-LC.

Table 3 Test–Retest Reliability of the IPAQ-LC and Differences Between High- and Low-SES Areas and Between High- and Low-Walkability Areas, ICC (95% CI)

Physical activity measure	Overall	High SES	Low SES	High walkability	Low walkability
Transportation walking (min/week) and total transportation (min/week and MET min/week)[a]	.88 (.83, .92)	.84 (.73, .91)	.93** (.88, .96)	.93 (.88, .96)	.79*** (.64, .88)
Domestic (inside)—moderate (min/week) and total domestic (min/week and MET min/week)[b]	.82 (.74, .88)	.83 (.71, .90)	.80 (.66, .88)	.81 (.68, .89)	.81 (.68, .89)
Leisure walking (min/week)	.83 (.75, .88)	.95 (.91, .97)	.71*** (.53, .82)	.82 (.69, .90)	.84 (.73, .91)
Leisure—moderate (min/week)	.93 (.89, .95)	.99 (.99, 1.00)	.87*** (.79, .93)	.92 (.87, .96)	.94 (.89, .97)
Total leisure (min/week)	.88 (.83, .92)	.98 (.97, .99)	.80*** (.67, .88)	.87 (.79, .93)	.89 (.81, .94)
Total leisure (MET min/week)	.88 (.82, .92)	.99 (.97, .99)	.79*** (.65, .88)	.87 (.79, .93)	.89 (.81, .94)
All walking (min/week and MET min/week)	.85 (.78, .90)	.87 (.78, .93)	.82 (.70, .89)	.81 (.68, .89)	.87 (.78, .93)
All moderate (min/week)	.87 (.80, .91)	.89 (.81, .94)	.84 (.73, .91)	.85 (.74, .91)	.89 (.81, .94)
All moderate (MET min/week)	.86 (.79, .91)	.89 (.81, .94)	.83 (.71, .90)	.84 (.73, .91)	.89 (.80, .94)
Sitting (weekday + weekend; min/week and MET min/week)	.77 (.66, .83)	.83 (.71, .90)	.71* (.54, .83)	.76 (.60, .86)	.79 (.65, .88)
All (walking + MVPA; min/week)	.86 (.80, .91)	.85 (.75, .92)	.88 (.79, .93)	.88 (.80, .93)	.84 (.72, .90)
All (walking MVPA; MET min/week)	.86 (.80, .91)	.85 (.75, .91)	.88 (.79, .93)	.88 (.80, .93)	.84 (.72, .91)

Note. IPAQ-LC = Chinese version of the International Physical Activity Questionnaire–long form; SES = socioeconomic status; ICC = intraclass correlation coefficient; MET = metabolic equivalent task; MVPA = moderate to vigorous physical activity. Before computing the ICCs and testing between-area differences in levels of physical activity, positively skewed variables (all but sitting) were log-transformed. Differences in ICCs were tested between low- and high-SES area, and high and low walkability areas.

[a]Total transportation was equivalent to transportation walking because all participants reported 0 min of cycling for transportation. The ICCs of min/week were equivalent to those of MET min/week because all participants reported only transport-related walking (i.e., total min/week of transportation physical activity was multiplied by the constant 3.3). [b]Total domestic work was equivalent to domestic work (inside) because all participants reported 0 min of yard work. The ICCs of min/week were equivalent to those of MET min/week because all participants reported only moderate-intensity activity.

*$p < .05$. **$p < .01$. ***$p < .001$.

Table 4 Associations of IPAQ-LC (min/Week) with Accelerometry and Walk Diary Estimates of Physical Activity

Comparison	r_p
IPAQ-LC- vs. accelerometry-based variable	
walking vs. step counts	.28**
moderate vs. step counts	.17
total vs. step counts	.35***
walking vs. light	.36***
moderate vs. light	.03
total vs. light	.37***
walking vs. light (≥10-min bouts)	.35***
moderate vs. light (≥10-min bouts)	.04
total vs. light (≥10-min bouts)	.31**
walking vs. moderate	.11
moderate vs. moderate	.17
total vs. moderate	.25*
walking vs. MVPA	.11
total vs. MVPA	.25*
walking vs. MVPA (≥10-min bouts)	.03
moderate vs. MVPA	.17
moderate vs. MVPA (≥10-min bouts)	.12
total vs. MVPA (≥10-min bouts)	.28**
walking vs. LVPA	.37***
moderate vs. LVPA	.07
total vs. LVPA	.39***
walking vs. LVPA (≥10-min bouts)	.30**
moderate vs. LVPA (≥10-min bouts)	.08
total vs. LVPA (≥10-min bouts)	.51***
walking vs. sum of light, moderate and vigorous ≥10-min bouts	.30**
moderate vs. sum of light, moderate and vigorous ≥10-min bouts	.05
total vs. sum of light, moderate and vigorous ≥10-min bouts	.47***
walking vs. mean activity level (counts/min)	.25*
moderate vs. mean activity level (counts/min)	.22*
total vs. mean activity level (counts/min)	.41***
sitting vs. sedentary	.16
IPAQ-LC- vs. walk-diary-based variable	
transportation walking vs. transportation walking	.70***
total walking vs. total walking	.69***
leisure walking vs. leisure walking	.48***

Note. IPAQ-LC = Chinese version of the International Physical Activity Questionnaire–long form; r_p = partial correlation coefficient; MVPA = moderate to vigorous physical activity; LVPA = light to vigorous physical activity. Positively skewed variables (all but sitting) were log-transformed. Accelerometer counts/min were classified as follows: sedentary <100, light 100–1,951, moderate 1,952–5,724 and vigorous >5,724 (Freedson et al., 1998).

*$p < .05$. **$p < .01$. ***$p < .001$.

Table 5 Differences Between IPAQ-LC-Based and Accelerometry- and Walk-Diary-Based Estimates of Physical Activity (min/Week)

Comparison	Difference, *M* (95% CI)
IPAQ-LC vs. accelerometry-based variable	
total vs. MVPA	999*** (892, 1,106)
total vs. LVPA	–853*** (–984, –722)
total vs. MVPA (≥10-min bouts)	1,090*** (980, 1,200)
total vs. LVPA (≥10-min bouts)	–36 (–174, 102)
total vs. sum of light, moderate, and vigorous ≥10-min bouts	160* (19, 301)
sitting vs. sedentary	–1,646*** (–1,854, –1,439)
IPAQ-LC vs. walk-diary-based variable	
transportation walking vs. transportation walking	56* (6, 106)
leisure walking vs. leisure walking	38 (–14, 92)
total walking vs. total walking	95** (26, 169)

Note. IPAQ-LC = Chinese version of the International Physical Activity Questionnaire–long form; MVPA = moderate to vigorous physical activity; LVPA = light to vigorous physical activity.
$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

of physical activity variables indicated that the mean difference between the two estimates of physical activity was independent of the average estimate of physical activity (Figure 1). The correlation of the difference between the two estimates and the average estimate was not significant ($r = –.16$, $p = .134$). However, a certain degree of heteroscedasticity in the variability of the differences across levels of physical activity was present. Moreover, the 95% limits of agreement were rather large (–1,341 and 1,269 min/week, or –192 and 181 min/day).

Discussion

This study examined the reliability and criterion validity of the IPAQ-LC in a sample of Hong Kong elders residing in communities varying in SES and transport-related walkability. To our knowledge, this was the first study to investigate the extent to which the reliability and validity of the IPAQ-L vary by the environmental characteristics of where people live. It is also the first study to provide a detailed analysis of the correspondence between accelerometry-based estimates of physical activity of varying intensity and duration and IPAQ-L estimates of various forms of physical activity in older adults. This is particularly important in the absence of accelerometer cut points specifically developed for elders. Extant cut points for moderate- and vigorous-intensity physical activity for adults are likely to be too high for an elderly population, producing downward-biased estimates of physical activity and, thus, substantial mismatch between self-reported and accelerometry-based measures of physical activity (Hurtig-Wennlof, Hagstromer, & Olsson, 2010; Pruitt et al., 2008). This mismatch can be exacerbated by environmental characteristics of the study location—namely, unusual hilliness and a subtropical climate typified by hot

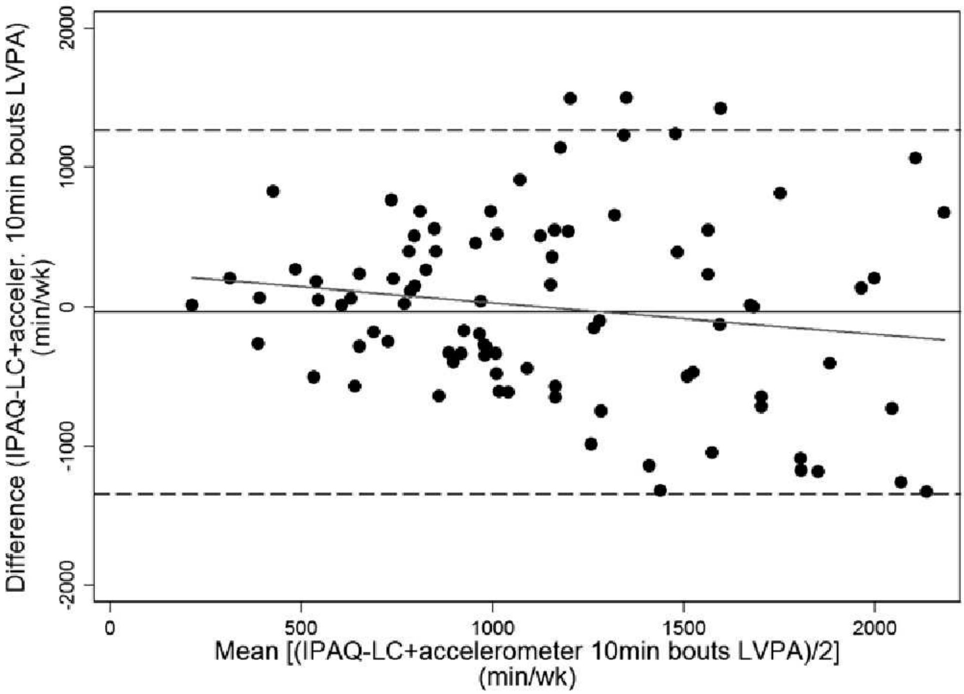

Figure 1 — Bland–Altman plot for total physical activity as measured by the Chinese version of the International Physical Activity Questionnaire (IPAQ-LC) and light to vigorous physical activity (LVPA) as measured by the accelerometer ActiGraph GT1M in a sample of Hong Kong elders (N = 94). The full horizontal black line at y = –36 indicates the min/wk difference between the two estimates of physical activity (mean bias). The two dashed lines denote 95% limits of agreement (–1,341 and 1,269). The gray line represents the line of best fit between the mean estimate of physical activity (x axis) and the difference in estimates of physical activity (y axis).

and humid conditions. Accelerometers cannot quantify changes in physical activity intensity due to fluctuations in terrain grade (Welk, 2002), nor can they quantify increments in relative intensity due to heat and humidity. All these factors (hilliness, climate, and cut points not suited to the elderly) can contribute to a high level of discrepancy between self-report- and accelerometry-based measures of physical activity. A detailed analysis of the relationships between accelerometry-based and IPAQ-LC estimates of physical activity of varying intensity can provide a more appropriate assessment of the criterion validity of the IPAQ-LC.

The first aim of this study was to examine the reliability of the IPAQ-LC. Acceptable levels of reliability, defined as ICC values greater than .70 for self-report physical activity questionnaires (Forsen et al., 2010), were observed for all domains and types of physical activity (Table 3). The level of reliability was similar to that observed in previous studies among adults (Craig et al., 2003; Macfarlane et al., 2011; Vandelanotte, de Bourdeaudhuij, Philippaerts, Sjostrom, & Sallis, 2005; van der Ploeg et al., 2010) and elders (Deng et al., 2008). We could not formally establish the reliability of vigorous-intensity physical activity and yard work because none of the participants reported such activities. The lack of yard work is not surprising as most Hong Kong residents live in multistory apartments. With regard to vigorous-intensity physical activity, other studies using the IPAQ-S (Deng et al., 2008; Hurtig-Wennlof et al., 2010) and accelerometry (Davis & Fox, 2007) have noted that very few elders engage in such types of activity. Thus, if low prevalence of vigorous physical activity is confirmed among elders living in other geographical locations and settings (e.g., rural areas), it would be appropriate to omit vigorous physical activity items from IPAQ-L versions for seniors.

The reliability of some of the IPAQ-LC variables differed across walkability and SES areas. Estimates of walking for transportation were found to be more reliable among participants who lived in highly walkable areas characterized by mixed land use. It is possible that these residents tended to walk more regularly for transportation than their counterparts due to better availability of and access to various services (Cerin et al., 2007; Owen et al., 2007). Besides having an effect on the regularity of walking patterns, walkable neighborhoods may contribute to higher reliability in estimates of walking by affecting the actual amount of walking residents do. People who walk more frequently may be more aware of the time they spend walking and, thus, be more capable of evaluating their total amount of walking (Kang, Herr, & Page, 2003).

Compared with high-SES areas, low-SES areas were associated with lower reliability estimates in leisure-time physical activity and sitting but higher reliability of walking for transport. Although we did not find significant differences in these types of activities between high- and low-SES areas, previous studies have reported higher levels of utilitarian walking (Badland & Schofield, 2006) and lower levels of leisure-time physical activity (e.g., Cerin & Leslie, 2008; Kavanagh et al., 2005) and sitting (Proper, Cerin, Brown, & Owen, 2007) in lower SES groups. The extent to which the observed differences in reliability between SES groups were due to disparities in ability to understand the survey questions or reflected differences in regularity and amount of participation in different forms of physical activity remains unknown. Nevertheless, the fact that no significant SES-area differences in validity estimates were observed somewhat supports the notion that differences in reliability might have been due to variability in participation rather than differential measurement error caused by disparities in understanding; otherwise, the validity estimated would have likely been lower among low-SES respondents (Reis & Judd, 2000).

The results of validity analyses of the IPAQ-LC somewhat mirrored those of previous studies on the IPAQ-S in similar age groups (Deng et al., 2008; Hurtig-Wennlof et al., 2010) and those on the IPAQ-L in other populations (e.g., Craig et al., 2003; Macfarlane et al., 2011) but also showed some peculiarities. Walking was significantly but weakly related to accelerometry-based step counts, light-intensity physical activity, LVPA, and mean activity level but unrelated to moderate-intensity physical activity and MVPA. It was also moderately to strongly associated with walking from the 7-day diary (Table 4), although it yielded higher average levels than the diary (~95 min/week; Table 5). These findings suggest that the examined sample tended to walk at a slow pace, likely due to their age (Hurtig-Wennlof et al., 2010), as well as the climate and terrain of the study location. Pruitt et al. (2008) reported ActiGraph readings as low as 149 counts/min during a self-paced walk in a group of older adults. Another recent study observed mean 131–236 ActiGraph counts/min in a relatively large sample of older urban UK adults (Davis et al., 2011), while an average of 387 mean counts/min had been reported in younger adults (Davis & Fox, 2007). Altogether, these findings emphasize the importance of establishing more appropriate accelerometer cut points for an aging population but, at the same time, provide support for the validity of the walking items of the IPAQ-LC in the examined population.

It is interesting that while Hurtig-Wennlof et al. (2010) found a significant association between walking and accelerometry-based moderate-intensity physical activity, our study did not. As noted earlier, this might be due to the subtropical climate and hilly terrain of Hong Kong, which are not conducive to brisk walking outdoors, but also due to cultural differences. The median average activity counts per minute observed in this study were lower than that reported in the Swedish study (medians 238 vs. 317 counts/min), while the overall minutes of accelerometry-based LVPA were similar (2,013 vs. ~2,000 min/week), indicating that the Hong Kong sample engaged in lower intensity physical activity. Yet, when compared with a recent study conducted in the UK (Davis et al., 2011), Hong Kong elders had mean activity levels and MVPA similar to those of UK older adults classified as engaging in high levels of walking for transportation (>11.6 journeys/week). Moreover, they had substantially lower sedentary time (2 fewer hr/day) and more light-intensity activity (1 more hr/day) than their "active" UK counterparts. This suggests that the high level of density, land-use mix, and availability of public transportation in Hong Kong may play a significant role in replacing sedentary time with light forms of physical activity in elders, despite Hong Kong's unfavorable climate and terrain. This sample reported very high levels of walking for transportation, more than 1.5 and 2.4 times higher than those observed in Australian (Cerin & Leslie, 2008) and American adults (Cerin, Saelens, Sallis, & Frank, 2006), respectively. Even if these walking activities were of low intensity, the fact that they replace sedentary behaviors has important public health implications in light of the emerging evidence of the harmful effects of prolonged sitting on health (Healy et al., 2007). It appears that creating environments that facilitate easy access to services and destinations may be a valuable investment for the long-term health of our aging populations.

In this study, IPAQ-LC–assessed moderate-intensity physical activity was not as prevalent as walking and was mainly accumulated through domestic rather than leisure activities. Although showing sufficient test–retest reliability, moderate-intensity physical activity from the IPAQ-LC was not associated with accelerometry-based variables, with the exception of mean activity level (ActiGraph counts/min). Apart from the notorious difficulties in reporting such activities (Collins, Marshall, & Miller, 2007), another reason for the lack of correlation could be the presence of compensatory processes whereby engagement in leisure or domestic moderate activity sometimes and in some individuals is accompanied by a reduction in time spent in other more common types of physical activity such as walking. These issues represent another interesting and important avenue for future research.

While the reliability of sitting data was acceptable, its association with the accelerometry-based measure of sedentary behavior was low. This is not an uncommon observation (Deng et al., 2008), which has been recently attributed in part to the sequence in which the questions are presented (sitting questions are the last in the IPAQ-LC; Hurtig-Wennlof et al., 2010).

Total physical activity from the IPAQ-LC was moderately associated with most accelerometry-based variables. The lowest associations were observed with variables excluding light-intensity activity, which is understandable as most activity was accumulated through (likely slow-pace) walking. Total physical activity showed the highest associations with accelerometry-based weekly minutes of ≥10-min bouts of LVPA (r = .51). The Bland–Altman plot comparing total physical activity from the IPAQ-LC with the ≥10-min bouts of LVPA from the accelerometer showed that the two measures yielded similar estimates of physical activity and that the differences between the two measures did not depend on the participants' levels of physical activity (Figure 1).

Strengths and Limitations

This study is novel in that it is the first to validate the IPAQ-LC in a community sample of Chinese urban elders. It is also the first study to report reliability and validity differences across neighborhoods varying in SES and walkability. This is particularly important for the currently blooming research area of environmental influences on physical activity (Sallis, Owen, & Fisher, 2008). Another strength is the use of both accelerometer and walk diary as validation instruments. In fact, as noted earlier, walking is by far the most prevalent activity in Hong Kong older adults, but most of this walking is likely to be at slow pace and, hence, fall within the light-intensity physical activity band of accelerometer readings for adults that is commonly taken to be associated with nonambulatory activities (Matthews, 2005). It was thus important to also use daily diaries of walks to validate the IPAQ-LC.

Limitations of this study include the use of accelerometer cut points developed for a younger population (adults). It would have been better to estimate cut points derived from individual calibration protocols (Barnett & Cerin, 2006; Pruitt et al., 2008). However, resource constraints precluded this course of action. Another limitation pertains to the actual use of accelerometry. Although accelerometers are appropriate tools to estimate ambulatory activities, they cannot pick up changes in activity intensity due to the terrain gradient. Since many parts of Hong Kong are hilly, we believe that the accelerometers might have substantially underestimated the level of activity in this age group. This problem could be overcome by the combined use of accelerometers and heart-rate monitors (Brage et al., 2004).

Conclusion and Recommendations

This study indicates that the interviewer-administered IPAQ-LC is a reliable and acceptably valid physical activity measure for Chinese elders living in an urban environment. Future studies need to investigate whether a less resource-intensive, self-completed version of the IPAQ-LC would be equally reliable and valid.

No evidence of differential validity of the IPAQ-LC across different SES and walkability areas was found. Reliability sometimes differed across areas. However, given that these differences did not affect validity estimates, they are likely to be due to the volatility of the examined behaviors rather than interpretational biases of the items. Clearly, this remains an issue to be disentangled in future studies. Future studies also need to investigate whether the measurement properties of the IPAQ for seniors depend on age, use of assistive devices, and physical functioning. More work remains to be done on the adaptation of the IPAQ to various populations of seniors, including the provision of relevant and appropriate examples of activities for each physical activity domain and intensity and the possible omission of items measuring vigorous physical activity, given its low prevalence in this age group.

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