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Validity of a Physical Activity Questionnaire in Shanghai

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Abstract

Purpose—In large epidemiologic studies, physical activity is often assessed using physical activity questionnaires (PAQs). As available PAQs may not capture the full range of physical activities in which urban Chinese adults engage, a PAQ was developed for this purpose. We examined the validity of this PAQ and the one-year stability of physical activity in 545 urban Shanghai adults.

Methods—The PAQ was interview-administered twice, approximately one year apart, and participants also wore an accelerometer and completed a physical activity log (PA-log) for seven consecutive days every three months over this same year. The intra-class correlation coefficient (ICC) was used to evaluate stability of physical activity across questionnaire administrations, and Spearman correlation coefficients (ρ) and mean differences and 95% limits of agreement were used to examine validity of the questionnaire compared against accelerometery and the PA-log.

Results—When measured by accelerometry, estimates of time spent in moderate-to-vigorous physical activity were lower and of time spent sedentary were higher than when self-reported on the PAQ ($p<0.001$). Total physical activity (ICC=0.65) and physical activity domains (ICC=0.45–0.85) showed moderate to high stability across PAQ administrations. Total physical activity ($\rho=0.30$), moderate-to-vigorous activity ($\rho=0.17$), light activity ($\rho=0.36$), and sedentary behavior ($\rho=0.16$) assessed by PAQ and by accelerometry were significantly and positively correlated, and correlations of the PAQ with the PA-log ($\rho=0.36$–0.85) were stronger than those observed with accelerometry.

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Conclusion—The PAQ significantly overestimated time spent in moderate-to-vigorous activity and underestimated time spent in light activity and sedentary behaviour compared with accelerometry, but performed well at ranking participants according to physical activity level.

Keywords

China; motor activity; self-report methods; reproducibility of results

Introduction

Paragraph Number 1

Reduced daily energy expenditure from non-recreational physical activities including occupational and transport activities following urbanization and mechanization (28–30) may have profound consequences on the increasing prevalence of non-communicable disease in China (40). This transition is particularly important since participation in activities of daily life is less easily altered than leisure-time activity (4), and the prevalence of leisure-time physical activity is low in China (14,16,19).

Paragraph Number 2

Physical activity is a complex, multi-dimensional behavior that is difficult to accurately assess in epidemiologic studies. Physical activity questionnaires (PAQs) are the method of choice for low-cost assessment of physical activity in large etiologic studies, and are capable of capturing the type and context of activity. However, current self-report methods often focus on specific domains of physical activity such as occupational or recreational activity as opposed to total physical activity, and may not assess all parameters of activity, including intensity, frequency, and duration. Furthermore, available PAQs may not sufficiently capture the full range of physical activities in which urban Chinese adults engage. For example, the International Physical Activity Questionnaire (IPAQ) provides a brief assessment of physical activity levels for surveillance purposes, but has shown low validity in a Chinese population (20). These considerations highlight the importance of culturally-relevant instruments (21) and support the need to examine the validity of an instrument in a population representative of that in which it will be used.

Paragraph Number 3

Accordingly, we developed a comprehensive PAQ inquiring about physical activity across domains (household, transportation, occupation, caring for others, leisure and recreation, stair climbing), incorporating activities common in urban Shanghai. We herein examined the validity of this PAQ using objective monitoring of physical activity by accelerometry as our criterion validation method, and we compared the PAQ with a 7-day physical activity log (PA-log). Due to differences in the time frame of the PAQ (past year) and the accelerometer measurement, we also assessed the stability of physical activity over time by re-administering the instrument one year later.

Methods

Shanghai Cohort Studies

Paragraph Number 4—The Shanghai Women's Health Study (SWHS) and Shanghai Men's Health Study (SMHS) are population-based prospective cohort studies of 74,943 adult women (aged 40–70 years at baseline) and 61,582 adult men (aged 40–75 years at baseline). Study participants were permanently residing in one of seven (SWHS) or eight (SMHS) communities in Shanghai, China, and were recruited to the studies between 1997 and 2006 (1997–2000 for

the SWHS and 2001–2006 for the SMHS). All participants provided written informed consent, and the study protocol was approved by the Institutional Review Boards (IRB) of all participating institutions.

Shanghai Physical Activity Study

Paragraph Number 5—The Shanghai Physical Activity Study was conducted in a subset of participants from the SWHS and the SMHS, with potential study members randomly selected from 2 communities of the parent studies. Participant enrollment began in December 2005, and data collection was completed in September 2008. Of the 1,101 participants contacted, 619 (56%) participated in the Physical Activity Study, including 310 women and 309 men.

Paragraph Number 6—Participants were enrolled in the study for one year. At the beginning of the study, participants completed a questionnaire (PAQ1, described below) that assessed physical activity patterns during the past year. They were also asked to wear an Actigraph accelerometer and to complete a PA-log for 7 consecutive days, four times during the study (*i.e*., at baseline [month 1], and in months 4–5, months 9–10, and in month 12). In addition, the physical activity questionnaire was re-administered during the final Actigraph wear period (PAQ2, month 12).

Past Year Physical Activity Questionnaire

Paragraph Number 7—To capture the full-range of activity behaviors in which adults in Shanghai typically engage, we adapted the Typical Week Physical Activity Survey that was developed by Ainsworth, *et al*., in the Cross-Cultural Activity Participation Study (2). Specifically, we developed a physical activity questionnaire that assessed participation during the past year in physical activities common to residents of Shanghai. As compared with the Typical Week Physical Activity Survey (2), our questionnaire inquired in greater depth about walking and cycling, which are typically considered major modes of transportation in the Shanghai general population, and provided culturally appropriate examples for questions about exercise participation (*e.g*. traditional Chinese exercises such as Tai Chi, or sword and fan dancing). Cultural input was obtained by collecting comprehensive information on physical activities common among both the SWHS and SMHS cohorts, which was used to tailor the PAQ to the study population. Following development of an initial draft of the instrument, small-scale pilot testing among cohort members was conducted to revise the questionnaire's instructions and word choices by checking the translation from English and by obtaining feedback regarding the comprehension of the questions by study participants.

The instrument was composed of 26 items divided into the following categories of physical activity: household; transportation; occupation and volunteer work; caring for others; leisure, recreation and exercise; stair climbing. For each questionnaire item, participants were asked to report in an open-ended format the number of months per year, the days per month, and the hours and minutes per day spent in each activity on days when they engaged in that particular behavior. Summary measures were calculated using reported frequency (months/yr and days/month), duration (converted to min/day), and intensity (metabolic equivalents [METs]) of physical activities using standard methods (1). For activities unique to the Shanghai population, MET-values were assigned using analogous activities from the Compendium of physical activities (1), *e.g.*, "Mind/body exercise and light effort: slow run, Tai Chi, Mulan, sword dancing and fan dancing" was assigned a value of 4.3 METs since Compendium values for similar activities range from 4.0–4.5 METs. Time (min/day) spent sedentary (<1.5 METs) and in light (2.0–3.0 METs) and moderate-to-vigorous (>3.0 METs) activity was calculated, as was total physical activity (MET-hrs/day, ≥2.0 METs).

Objective measurement of physical activity

Paragraph Number 8—Participants wore an Actigraph accelerometer (MTI Actigraph,model 7164; Fort Walton, FL) for seven consecutive days up to four times during the study. Participants were instructed to wear the monitor on the left hip (attached by an elastic belt) at all times except when sleeping, showering, and swimming. Study personnel distributed and collected the monitors in-person, recorded the dates of Actigraph distribution and collection, checked monitor calibration status, and recalibrated monitors as required.

Paragraph Number 9—The Actigraph measures vertical acceleration 10 times per second, which is integrated over a pre-specified epoch (1 min for this study) and converted to activity counts per minute (ct/min). We estimated monitor wear time using an automated scoring algorithm based on that developed by Troiano, *et al*. (38), employing a threshold of ≥60 minutes for determination of non-wear periods and a modified activity count threshold of ≥50 ct/min for determination of wear periods (compared with ≥100 ct/min as per Troiano, *et al*. (38)). We considered a valid day of observation to have ≥10 hours of monitor wear time (38), and we excluded all non-valid days and all measurement weeks with less than 2 valid days. In terms of summary measures, we calculated average values over valid days for total physical activity (ct/min/day ≥100 ct/min), for sedentary time (min/day <100 ct/min) and for time (min/day) spent in light (100–759 ct/min) and moderate-to-vigorous activity (≥760 ct/min) using previously described cut-points for sedentary behavior, light activity, and moderate-to-vigorous activity (23–25). We did not evaluate bouts of physical activity measured by the accelerometer since the PAQ questions did not assess bouts of activity.

Seven-day physical activity log (PA-log)

Paragraph Number 10—As the accelerometer does not capture information on the domain or context of physical activity, we also included the PA-log as a reference instrument in our validation study. Participants completed a PA-log on each of seven days on four separate occasions, concurrent with accelerometer wear periods. The seven-day PA-log was similar to instruments previously employed at baseline in the Shanghai cohorts (17,26). Participants were instructed to complete the PA-log at the end of each day, reviewing a list of physical activities in which individuals may have engaged during the previous 24 hours (self-care and housework; caring for others; transportation; occupational activity; sports, exercise, or recreational activity). The PA-log evaluated the duration of each type of activity (hours and minutes per day), and we estimated physical activity intensity (METs) using standard methods (1). Time (min/day) spent sedentary (<1.5 METs) and in light (2.0–3.0 METs) and moderate-to-vigorous (>3.0 METs) activity was calculated, as was total physical activity (MET-hrs/day, ≥2.0 METs), by averaging across all days of PA-log completion.

Participant characteristics at baseline

Paragraph Number 11—Exposure assessments were essentially identical in each cohort, except for the collection of reproductive and medical information that was gender-specific. For men, demographic (age, education, occupation) and lifestyle (alcohol intake, cigarette smoking) data were collected during in-person interviews at baseline (2001–2006), whereas women reported this information at baseline on a self-administered questionnaire (1997–2000). For both men and women, anthropometric variables (height, weight, waist and hip circumferences) were measured in-person by trained interviewers following a standard protocol (35,39).

Analytic population

Paragraph Number 12—Of 619 potential participants, we excluded 62 individuals without data from both PAQ administrations and 12 persons who did not meet the criteria for sufficient accelerometer data, leaving 545 participants (271 men and 274 women) for analyses.

Statistical Analysis

Paragraph Number 13—Examination of the distribution of total physical activity, moderate-to-vigorous activity, light activity, and sedentary time by quantile-quantile plots revealed departure from normality. Therefore, all data were analyzed using non-parametric methods, and we report participation in physical activity and sedentary behavior by medians and inter-quartile ranges (IQR). Differences in participation in physical activity subcomponents by gender and by method of assessing physical activity were investigated using the Kruskal-Wallis test and the Wilcoxon sign-rank test, respectively.

Paragraph Number 14—Although reliability of the PAQ could not be appropriately assessed given the study design, the stability of self-reported total physical activity, various intensities of physical activity, sedentary behavior, and domains of physical activity was assessed by the intra-class correlation coefficient (ICC) of log-transformed physical activity data from each of the two PAQ administrations, estimated by one-way ANOVA.

Paragraph Number 15—The validity analysis included only data from PAQ2 so that the criterion measurement period was included within the time frame of reference of the questionnaire (past year). For this same reason, we did not combine data from PAQ1 and PAQ2 to calculate de-attenuated correlation coefficients (33). The Spearman correlation coefficient (ρ) was used to estimate the association of accelerometer-measured physical activity with total physical activity, moderate-to-vigorous and light activity, sedentary behavior, and various domains of physical activity assessed by PAQ2. Correlations between PAQ2 and the PA-log were also evaluated to further examine domains of physical activity. We examined heterogeneity in the relationships of physical activity and sedentary behavior from PAQ2 with log-transformed estimates from accelerometry and the PA-log by age, gender, BMI, and educational attainment by testing the statistical significance of the corresponding interaction term in linear regression models using the Wald test.

Paragraph Number 16—For the absolute validity analysis, we calculated the mean difference (PAQ2-accelerometer), 95% confidence intervals (CI) and 95% limits of agreement (LOA) of time (min/day) spent in moderate-to-vigorous activity, light activity, and sedentary behavior between PAQ2 and accelerometry. The ability of the questionnaire to rank participants' activity levels was assessed by calculating: the mean counts/min/day from the accelerometer by quartile of total physical activity from PAQ2; mean sedentary time from the accelerometer (min/day) by quartile of sedentary time from PAQ2. Additional analyses were conducted to compare PAQ2 with the PA-log to assess agreement of domains of physical activity, by calculating the mean difference (PAQ2-PA-log) of time estimates from PAQ2 and the PA-log.

Results

Paragraph Number 17

Over 80% of our study population had accelerometer data for 3 or more measurement periods (mean=3.22, SD=0.87), with more than 5 days of data for each measurement week (mean=5.78, SD=1.67). Participants had at least 10 hours (600 min) of accelerometer wear time for 71% of days measured (mean=854.6 min, SD=151.1), and over 95% of the study population completed four PA-logs.

Paragraph Number 18

On average, participants were 53.4 years of age, with a mean body mass index (BMI) of 23.7 kg/m^2 at baseline, and 47% of the study population reported at least a high school education (Table 1). Compared with men, women were younger and had a higher average BMI. Women were also less likely than men to be educated at a high school level or above, and they were less likely to drink alcohol and to smoke cigarettes.

Paragraph Number 19

Time spent in moderate-to-vigorous activity was higher and time spent sedentary was lower when moderate-to-vigorous activity and sedentary behavior were self-reported than when measured by accelerometry ($p<0.05$) (Table 2). Median time spent in moderate-to-vigorous activity ranged from 79.5 min/day (IQR:57.2,105.7) by accelerometry to 93.7 min/day on the PAQ (IQR:58.2,147.8) and 97.9 min/day (IQR:65.9,138.6) on the PA-log. As men and women differed with respect to time spent in physical activity and sedentary behavior, results are also presented by gender. Compared with men, women self-reported a greater amount of total physical activity and time spent in moderate-to-vigorous activity ($p<0.05$), although accelerometer-measured total activity and time spent in moderate-to-vigorous activity did not differ by gender. For all three instruments, women were less sedentary and spent more time in light activity than men ($p<0.001$). In Table 2 we also present time spent in various domains of physical activity from PAQ2 and the PA-log. We observed gender differences for self-reported activity across domains, as women reported more time spent walking and doing household chores, while cycling was the only activity more common among men than women ($p<0.001$). Time spent in occupational or leisure-time activity did not differ by gender ($p>0.05$).

Paragraph Number 20

On average, 402 days separated the two PAQ administrations, with slightly less time between administrations for women than for men (mean=395 vs. 410 days, respectively; $p=0.03$). Estimates of physical activity and sedentary behavior did not systematically differ between the two PAQs, and the stability of physical activity was not influenced by time between PAQs (data not shown). Self-reports of total physical activity were moderately consistent over time (ICC=0.65), as was assessment of physical activity intensity levels (ICC=0.48–0.61) and domains (ICC=0.40–0.86) (Table 3). Occupational activity (including sitting, ICC=0.85) and leisure-time activity (ICC=0.66) were most stable across PAQ assessments.

Paragraph Number 21

The stability of self-reported total physical activity, moderate-to-vigorous activity, and sedentary behavior over time did not systematically differ by education level (middle school or less versus high school or above), BMI (<24 kg/m^2 versus ≥ 24 kg/m^2) or age (<60 versus ≥ 60 years) (data not shown). However, compared with men, intra-class correlations for sedentary behavior and walking were weaker among women, whereas correlations for occupational activity were stronger among women (Table 3). The stability of household activity was similar among men and women (ICC=0.51).

Validity of the Physical Activity Questionnaire

Paragraph Number 22—Total physical activity as assessed by PAQ2 showed reasonable correlations with total physical activity measured by accelerometry ($\rho=0.30$), and correlations between methods were weaker for moderate-to-vigorous activity ($\rho=0.17$) than for light activity ($\rho=0.36$) (Table 4). Self-reported sedentary behavior correlated weakly with accelerometer-measured time spent sedentary ($\rho=0.16$), and all physical activity variables from PAQ2 except household activity were inversely correlated with sedentary behavior from accelerometry. Since the accelerometer is likely to underestimate bicycling, we also evaluated

the correlation of time spent in moderate-to-vigorous activity by accelerometer with self-reported moderate-to-vigorous activity after excluding time spent cycling, and we observed slight attenuation of the correlation coefficient (ρ=0.14, data not shown). Table 4 also shows correlations between physical activity from PAQ2 and physical activity variables reported on the PA-log, which were more pronounced (ρ=0.36–0.85) than those observed between PAQ2 and accelerometry.

Paragraph Number 23—Compared with accelerometry, the PAQ significantly overestimated time spent in moderate-to-vigorous activity and underestimated time spent in light activity and sedentary behavior (Table 5). The 95% LOA varied by subcomponents of activity, but indicated underestimation of moderate-to-vigorous activity, light activity, and sedentary behavior by more than 2 hours/day and overestimation of moderate-to-vigorous activity, light activity, and sedentary behavior by nearly 3 hours/day. We did not observe heterogeneity in the association of self-reported and accelerometer-measured moderate-to-vigorous activity, light activity, and sedentary behavior across strata of gender, education, or BMI (data not shown). However, the mean difference between the PAQ and accelerometry for each physical activity variable was less for younger (40–59 years) than older (≥60 years) participants, although 95% LOA were wide irrespective of age.

Paragraph Number 24—When comparing PAQ2 with the PA-log (Table 5), PAQ2 significantly overestimated total physical activity and underestimated light activity and sedentary behavior, and although the mean difference for moderate-to-vigorous activity was not statistically significant, 95% LOA were wide. With respect to domains of physical activity, PAQ2 significantly overestimated time spent walking, in active transport, and cycling, but underestimated time spent in household and leisure-time activity. No difference was observed for occupational activity ($p>0.05$).

Paragraph Number 25—Table 6 shows a positive association of mean total physical activity, moderate-to-vigorous activity, light activity, and sedentary behavior measured by accelerometry with quartiles of corresponding variables from the PAQ. Trends for all physical activity variables and for sedentary behavior were statistically significant ($p<0.05$).

Discussion

Paragraph Number 26

We observed modest validity of a comprehensive PAQ, developed to assess the full range of physical activities common among adults in urban Shanghai. The correlation coefficient of 0.30 for total physical activity in our study is similar to prior validation studies of both global (8,9,20) and comprehensive (11) PAQs using accelerometry as the criterion method. Although the PAQ assessments correlate modestly to weakly with the criterion measurements, the PAQ performed well at ranking individuals according to categories of total physical activity, moderate-to-vigorous activity, light activity, and sedentary behavior. The ability of the PAQ to discriminate quartiles of physical activity levels indicates that the instrument is suitable for use in etiologic studies.

Paragraph Number 27

While the PAQ was able to rank individuals according to physical activity level, it showed weak to modest absolute validity when compared with accelerometer-measured physical activity and sedentary behavior. The ability of the PAQ to assess individual-level estimates of moderate-to-vigorous activity, light activity, or sedentary behavior is poor, as indicated by the mean differences between instruments. Furthermore, we noted greater mean differences between the PAQ and accelerometry among persons older than 60 years of age. One

explanation is that misreporting increases with age, although the observation of low validity of the PAQ for assessing sedentary behavior suggests that the PAQ may better ascertain dynamic activities, which are more likely engaged in by younger than older persons.

Paragraph Number 28

Our observation of overestimation of physical activity and underestimation of sedentary behavior by self-report methods is consistent with the literature (18,27,31,34). Yet the relative contribution of participants misreporting physical activity versus the accelerometer failing to capture certain behaviors remains unclear. The structure of our PAQ, interrogating the spectrum of activities in which an adult in urban Shanghai might participate, may have encouraged over-reporting of physical activities, whereas failure of the accelerometer to capture certain behaviors such as cycling and upper body movement may have underestimated those types of physical activity. However, contrary to expectations, exclusion of self-reported time spent cycling did not improve correlations between the PAQ and accelerometry. Yet self-reported household physical activity, which likely involves upper body movement, was inversely correlated with accelerometer-measured total activity and moderate-to-vigorous activity in our study. This supports previous observations that accelerometry underestimates domestic activity (13), despite employment of a lower threshold (760 ct/min) for moderate-to-vigorous activity that intended to capture this type of activity (23). It is also possible that household activity suffers from over-reporting (32), and lower validity of the PAQ among older women may result from greater participation in household activity by this population subgroup (16). In addition, the large differences between the PAQ and accelerometry in measuring sedentary behavior suggest that the PAQ may under-ascertain physical inactivity.

Paragraph Number 29

We also observed stronger correlations with accelerometry for self-reported light physical activity than for moderate-to-vigorous activity, in contrast with some (17,26), but not all (41), previous studies that showed superior validity of self-reported vigorous than non-vigorous activities. Differences in the criterion methods and the PAQs used across studies likely contribute to this inconsistency.

Paragraph Number 30

Estimates of physical activity from the PAQ showed superior agreement with the PA-log than with the accelerometer, as previously observed for a global PAQ in a Chinese population (20). Considering the similar structure and content of the PAQ and the PA-log in our study, which are both self-report instruments, modest to strong correlations (ρ=0.36–0.85) between the PAQ and the PA-log across physical activity domains could be anticipated. However, the potential that the errors in the PAQ and the PA-log are correlated suggests that the PA-log may not be the most suitable criterion method for assessing the validity of the PAQ (10). Yet the PA-log is the most practical instrument for examination of the validity of physical activity domains, since objective methods such as accelerometers cannot distinguish the type or context of activity.

Paragraph Number 31

The stability of physical activity between PAQ administrations did not vary by intensity level of physical activity. Previous reports have observed that high versus low intensity physical activity is either better captured by PAQs or is better reported by participants (5,7,15,34,36, 41). Regarding domains of physical activity, however, occupational and leisure-time physical activity were most consistently reported across PAQ assessments. This observation is consistent with prior reports of more consistent recall of routine activities compared with less structured activities, *e.g.* walking (17,26,36). Although the extent of time elapsed between PAQ

administrations may have attenuated estimates (3,6,15,32), our results correspond to test-retest estimates in the range of 0.31–0.73 from previous reports with intervals lasting one year or longer (3,17,26,32). Considering the duration of time between PAQ1 and PAQ2 (~1 year), changes in physical activity behavior are feasible.

Paragraph Number 32

Overall, physical activity was stable across subgroups defined by gender, age, education level, and BMI. However, modest differences in the consistency of walking and sedentary behavior by gender may indicate subgroup-specific differences in participation in these activities between the two PAQ administrations.

Paragraph Number 33

We must consider several other limitations of our study and the potential implications for our results. Neither accelerometry nor the PA-log represents a "gold standard" method of physical activity measurement, and neither instrument directly and independently captures total physical activity, activity intensity, and domains of physical activity. Yet the use of objective methods such as accelerometry in a validation study limits the potential for correlated error that likely exists when comparing the PAQ with another self-report method, *e.g.*, the PA-log. However, it is possible that participants' reporting on the PA-log may have been influenced by wearing accelerometers during the same time period, or vice versa, that activity patterns were altered by completing the PA-log, although the influence of a PA-log on questionnaire validity has been shown to be minor (37). In addition, the quality of accelerometer data may have been improved by requiring at least 3 valid days of monitor wear; yet we observed exceptional compliance with the study protocol, and we collected more than 5 valid days of data for each measurement week for 80% of our study population. In our study, PAQ2 showed stronger correlations with the PA-log than did PAQ1 (data not shown), indicating that participants' reporting on the PAQ may have successively improved following quarterly completion of the PA-log. Alternatively, such a difference may result from the fact that the time frame of reference of PAQ1 did not overlap with the time of PA-log completion. Regardless, the correlations of PAQ1 and PAQ2 with accelerometry were similar (data not shown), suggesting that our results do not overestimate the validity of the PAQ when compared with an objective criterion. Another potential limitation is the possibility that the cut-points chosen to distinguish accelerometer intensity levels influenced estimates of the absolute validity of the PAQ (12, 22), although the ability of the PAQ to rank physical activity levels is unlikely to be sensitive to small changes in accelerometer cut-point within a given intensity level. Moreover, the ability of counts/min/day to rank total physical activity does not depend on accelerometer cut-points.

Paragraph Number 34

The PAQ evaluated in this study was designed to assess the range of types (household, transportation, occupation and volunteer work, caring for others, recreation and exercise, stair climbing) and parameters (intensity, frequency, duration) of physical activities typical of adults in Shanghai. Strengths of our study include the study design, with two administrations of the PAQ and repeated measures of the accelerometer and the PA-log over a one-year period. In addition, we observed a high rate of compliance by participants and good quality and completeness of physical activity data.

Paragraph Number 35

In summary, the PAQ is valid for classifying individuals into quartiles of total physical activity and certain physical activity subcomponents. The potential for under-ascertainment of sedentary behavior and light activity and the limited validity of the PAQ among older persons

should be considered, but the PAQ will be useful to assess physical activity as an exposure in etiologic studies among adults in urban China.

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REFERENCES

1. Ainsworth BE, Haskell WL, Whitt MC, et al. Compendium of physical activities: an update of activity codes and MET intensities. Med Sci Sports Exerc 2000;32(9 Suppl):S498–S504. [PubMed: 10993420]
2. Ainsworth BE, Irwin ML, Addy CL, Whitt MC, Stolarczyk LM. Moderate physical activity patterns of minority women: the Cross-Cultural Activity Participation Study. J Womens Health Gend Based Med 1999;8(6):805–813. [PubMed: 10495261]
3. Ainsworth BE, Leon AS, Richardson MT, Jacobs DR, Paffenbarger RS Jr. Accuracy of the College Alumnus Physical Activity Questionnaire. J Clin Epidemiol 1993;46(12):1403–1411. [PubMed: 8263567]
4. Bauman A, Allman-Farinelli M, Huxley R, James WP. Leisure-time physical activity alone may not be a sufficient public health approach to prevent obesity--a focus on China. Obes Rev 2008;9 Suppl 1:119–126. [PubMed: 18307713]
5. Blair SN, Dowda M, Pate RR, et al. Reliability of long-term recall of participation in physical activity by middle-aged men and women. Am J Epidemiol 1991;133(3):266–275. [PubMed: 2000844]
6. Booth ML, Owen N, Bauman AE, Gore CJ. Retest reliability of recall measures of leisure-time physical activity in Australian adults. Int J Epidemiol 1996;25(1):153–159. [PubMed: 8666485]
7. Brown WJ, Trost SG, Bauman A, Mummery K, Owen N. Test-retest reliability of four physical activity measures used in population surveys. J Sci Med Sport 2004;7(2):205–215. [PubMed: 15362316]
8. Craig CL, Marshall AL, Sjostrom M, et al. International physical activity questionnaire: 12-country reliability and validity. Med Sci Sports Exerc 2003;35(8):1381–1395. [PubMed: 12900694]
9. Cust AE, Smith BJ, Chau J, et al. Validity and repeatability of the EPIC physical activity questionnaire: a validation study using accelerometers as an objective measure. Int J Behav Nutr Phys Act 2008;5:33. [PubMed: 18513450]
10. Ferrari P, Friedenreich C, Matthews CE. The role of measurement error in estimating levels of physical activity. Am J Epidemiol 2007;166(7):832–840. [PubMed: 17670910]
11. Friedenreich CM, Courneya KS, Neilson HK, et al. Reliability and validity of the Past Year Total Physical Activity Questionnaire. Am J Epidemiol 2006;163(10):959–970. [PubMed: 16524954]
12. Ham SA, Reis JP, Strath SJ, Dubose KD, Ainsworth BE. Discrepancies between methods of identifying objectively determined physical activity. Med Sci Sports Exerc 2007;39(1):52–58. [PubMed: 17218884]
13. Hendelman D, Miller K, Baggett C, Debold E, Freedson P. Validity of accelerometry for the assessment of moderate intensity physical activity in the field. Med Sci Sports Exerc 2000;32(9 Suppl):S442–S449. [PubMed: 10993413]
14. Hu G, Pekkarinen H, Hanninen O, Yu Z, Guo Z, Tian H. Commuting, leisure-time physical activity, and cardiovascular risk factors in China. Med Sci Sports Exerc 2002;34(2):234–238. [PubMed: 11828231]
15. Jacobs DR Jr, Ainsworth BE, Hartman TJ, Leon AS. A simultaneous evaluation of 10 commonly used physical activity questionnaires. Med Sci Sports Exerc 1993;25(1):81–91. [PubMed: 8423759]
16. Jurj AL, Wen W, Gao YT, et al. Patterns and correlates of physical activity: a cross-sectional study in urban Chinese women. BMC Public Health 2007;7:213. [PubMed: 17711585]
17. Jurj AL, Wen W, Xiang YB, et al. Reproducibility and validity of the Shanghai Men's Health Study physical activity questionnaire. Am J Epidemiol 2007;165(10):1124–1133. [PubMed: 17351289]

18. Klesges RC, Eck LH, Mellon MW, Fulliton W, Somes GW, Hanson CL. The accuracy of self-reports of physical activity. Med Sci Sports Exerc 1990;22(5):690–697. [PubMed: 2233209]
19. Lee SA, Xu WH, Zheng W, et al. Physical activity patterns and their correlates among Chinese men in Shanghai. Med Sci Sports Exerc 2007;39(10):1700–1707. [PubMed: 17909395]
20. Macfarlane DJ, Lee CC, Ho EY, Chan KL, Chan DT. Reliability and validity of the Chinese version of IPAQ (short, last 7 days). J Sci Med Sport 2007;10(1):45–51. [PubMed: 16807105]
21. Masse LC. Reliability, validity, and methodological issues in assessing physical activity in a cross-cultural setting. Res Q Exerc Sport 2000;71(2 Suppl):S54–S58. [PubMed: 10925826]
22. Masse LC, Fuemmeler BF, Anderson CB, et al. Accelerometer data reduction: a comparison of four reduction algorithms on select outcome variables. Med Sci Sports Exerc 2005;37(11 Suppl):S544–S554. [PubMed: 16294117]
23. Matthews CE. Calibration of accelerometer output for adults. Med Sci Sports Exerc 2005;37(11 Suppl):S512–S522. [PubMed: 16294114]
24. Matthews CE, Ainsworth BE, Hanby C, et al. Development and testing of a short physical activity recall questionnaire. Med Sci Sports Exerc 2005;37(6):986–994. [PubMed: 15947724]
25. Matthews CE, Chen KY, Freedson PS, et al. Amount of time spent in sedentary behaviors in the United States, 2003–2004. Am J Epidemiol 2008;167(7):875–881. [PubMed: 18303006]
26. Matthews CE, Shu XO, Yang G, et al. Reproducibility and validity of the Shanghai Women's Health Study physical activity questionnaire. Am J Epidemiol 2003;158(11):1114–1122. [PubMed: 14630608]
27. Matton L, Wijndaele K, Duvigneaud N, et al. Reliability and validity of the Flemish Physical Activity Computerized Questionnaire in adults. Res Q Exerc Sport 2007;78(4):293–306. [PubMed: 17941534]
28. Monda KL, Gordon-Larsen P, Stevens J, Popkin BM. China's transition: the effect of rapid urbanization on adult occupational physical activity. Soc Sci Med 2007;64(4):858–870. [PubMed: 17125897]
29. Ng SW, Norton EC, Popkin BM. Why have physical activity levels declined among Chinese adults? Findings from the 1991–2006 China health and nutrition surveys. Soc Sci Med 2009;68(7):1305–1314. [PubMed: 19232811]
30. Popkin BM. Will China's nutrition transition overwhelm its health care system and slow economic growth? Health Aff (Millwood) 2008;27(4):1064–1076. [PubMed: 18607042]
31. Prince SA, Adamo KB, Hamel ME, Hardt J, Gorber SC, Tremblay M. A comparison of direct versus self-report measures for assessing physical activity in adults: a systematic review. Int J Behav Nutr Phys Act 2008;5:56. [PubMed: 18990237]
32. Richardson MT, Leon AS, Jacobs DR Jr, Ainsworth BE, Serfass R. Comprehensive evaluation of the Minnesota Leisure Time Physical Activity Questionnaire. J Clin Epidemiol 1994;47(3):271–281. [PubMed: 8138837]
33. Rosner B, Willett WC. Interval estimates for correlation coefficients corrected for within-person variation: implications for study design and hypothesis testing. Am J Epidemiol 1988;127(2):377–386. [PubMed: 3337089]
34. Sallis JF, Saelens BE. Assessment of physical activity by self-report: status, limitations, and future directions. Res Q Exerc Sport 2000;71(2 Suppl):S1–S14. [PubMed: 10925819]
35. Shu XO, Yang G, Jin F, et al. Validity and reproducibility of the food frequency questionnaire used in the Shanghai Women's Health Study. Eur J Clin Nutr 2004;58(1):17–23. [PubMed: 14679362]
36. Slattery ML, Jacobs DR Jr. Assessment of ability to recall physical activity of several years ago. Ann Epidemiol 1995;5(4):292–296. [PubMed: 8520711]
37. Timperio A, Salmon J, Rosenberg M, Bull FC. Do logbooks influence recall of physical activity in validation studies? Med Sci Sports Exerc 2004;36(7):1181–1186. [PubMed: 15235322]
38. Troiano RP, Berrigan D, Dodd KW, Masse LC, Tilert T, McDowell M. Physical activity in the United States measured by accelerometer. Med Sci Sports Exerc 2008;40(1):181–188. [PubMed: 18091006]
39. Villegas R, Yang G, Liu D, et al. Validity and reproducibility of the food-frequency questionnaire used in the Shanghai men's health study. Br J Nutr 2007;97(5):993–1000. [PubMed: 17381986]

40. Yang G, Kong L, Zhao W, et al. Emergence of chronic non-communicable diseases in China. Lancet 2008;372(9650):1697–1705. [PubMed: 18930526]

41. Yore MM, Ham SA, Ainsworth BE, et al. Reliability and validity of the instrument used in BRFSS to assess physical activity. Med Sci Sports Exerc 2007;39(8):1267–1274. [PubMed: 17762359]

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Table 1

Characteristics of the study population, N=545 men and women in the Shanghai Physical Activity Study

	Total (N=545)		**Men (N=271)**		**Women (N=274)**	
	Mean	SD*	Mean	SD	Mean	SD
Age (yrs)	53.4	9.4	55.7	9.4	51.2	8.8
Weight (kg)	63.5	10.4	67.1	10.8	59.9	8.6
Height (m)	1.6	0.1	1.7	0.1	1.6	0.1
BMI (kg/m^2)*	23.7	3.2	23.4	3.3	24.0	3.2
Waist-to-hip ratio	0.85	0.07	0.89	0.06	0.81	0.05
	Frequency	%	Frequency	%	Frequency	%
Education: high school or more	257	47	143	53	114	42
Most recent occupation: farmers or workers†	306	56	158	58	148	54
Ever smoked cigarettes	192	35	183	68	9	3
Ever drank alcohol	102	19	94	35	8	3

*SD: standard deviation; BMI: body mass index.

†Most recent occupation.

Table 2

Participation in physical activity, median and IQR (inter-quartile range), as measured: by accelerometer; by physical activity questionnaire from the second administration (PAQ2); by physical activity log (PA-log).

	Total (N=545)			Men (N=271)			Women (N=274)			
	Median	IQR		Median	IQR		Median	IQR		p-value*
Accelerometer†										
Total physical activity (ct/min/day)	264.0	205.8,	334.9	258.1	201.5,	336.0	271.5	208.5,	333.3	0.55
Moderate-to-vigorous activity (min/day)	79.5	57.2,	105.7	78.1	54.6,	104.5	81.2	58.3,	107.5	0.43
Light activity (min/day)	236.7	197.4,	277.0	227.1	192.6,	263.8	244.1	206.9,	294.7	<0.001
Sedentary behavior (min/day)	507.8	448.6,	568.1	517.4	462.0,	584.4	498.3	437.5,	556.5	0.002
PAQ2‡										
Total physical activity (MET-hr/day)	15.6	11.7,	21.5	14.2	10.2,	20.3	16.8	13.1,	22.4	<0.001
Moderate-to-vigorous activity (min/day)	93.7	58.2,	147.8	82.8	48.0,	136.0	100.7	64.4,	153.8	0.003
Light activity (min/day)	169.5	106.4,	236.5	132.0	78.8,	236.5	177.3	118.2,	248.3	<0.001
Sedentary behavior (min/day)	344.8	248.3,	466.3	356.7	271.9,	496.6	325.1	241.7,	433.5	0.01
Walking (min/day)	59.1	24.6,	88.7	43.3	16.3,	73.9	59.1	29.6,	88.7	<0.001
Household activity (min/day)	54.9	42.2,	67.6	47.9	35.9,	63.3	59.1	47.1,	73.3	<0.001
Occupational activity (min/day)¶	118.2	43.3,	216.7	118.2	43.3,	216.7	130.0	51.2,	237.4	0.37
Occupational activity, with sitting (min/day)¶	346.8	260.1,	354.7	346.8	260.1,	354.7	346.8	274.0,	354.7	0.39
Active transport (min/day)¥	3.3	0.0,	28.9	13.1	0.0,	29.6	0.0	0.0,	21.7	<0.001
Cycling (min/day)	0.0	0.0,	19.7	2.0	0.0,	29.6	0.0	0.0,	3.9	<0.001
Leisure-time activity (min/day)	0.0	0.0,	14.8	0.0	0.0,	7.9	0.0	0.0,	24.6	0.07
PAQ1‡										
Total physical activity (MET-hr/day)	16.0	11.6,	21.9	15.2	10.5,	21.6	16.9	13.1,	21.9	0.01
Moderate-to-vigorous activity (min/day)	87.1	52.2,	130.5	75.4	44.7,	127.3	90.9	61.5,	133.2	0.02
Light activity (min/day)	177.3	118.2,	273.6	169.5	103.4,	261.1	192.1	147.8,	295.6	<0.001
Sedentary behavior (min/day)	333.1	240.4,	443.4	354.7	246.3,	474.9	317.2	239.1,	419.0	0.03

	Total (N=545)			Men (N=271)			Women (N=274)			
	Median	IQR		Median	IQR		Median	IQR		p-value*
Walking (min/day)	53.7	24.3,	88.7	41.2	15.8,	82.8	59.1	29.6,	88.7	<0.001
Household activity (min/day)	51.6	38.6,	67.6	46.4	33.8,	63.3	55.5	45.6,	69.8	<0.001
Occupational activity (min/day)¶	151.7	65.0,	216.7	155.5	86.7,	216.7	138.9	51.7,	243.4	0.73
Occupational activity, with sitting (min/day)¶	346.8	281.8,	354.7	346.8	281.7,	354.7	346.8	270.9,	352.5	0.33
Active transport (min/day)¥	8.5	0.0,	29.6	14.4	0.0,	29.6	0.0	0.0,	28.9	0.001
Cycling (min/day)	0.0	0.0,	24.6	5.3	0.0,	29.6	0.0	0.0,	9.9	<0.001
Leisure-time activity (min/day)	0.0	0.0,	29.6	0.0	0.0,	15.8	0.0	0.0,	29.6	0.07
PA-log‡§										
Total physical activity (MET-hr/day)	12.7	9.5,	16.9	11.6	8.4,	15.3	13.7	10.7,	17.8	<0.001
Moderate-to-vigorous activity (min/day)	97.9	65.9,	138.6	92.4	56.5,	137.2	102.9	72.0,	141.0	0.02
Light activity (min/day)	194.2	139.1,	249.9	162.7	122.3,	235.0	215.4	172.7,	264.6	<0.001
Sedentary behavior (min/day)	425.0	346.6,	520.0	436.1	363.6,	542.9	405.7	319.5,	497.3	0.002
Walking (min/day)	36.3	20.3,	56.8	35.2	17.1,	54.1	38.4	23.6,	59.0	0.04
Household activity (min/day)	158.4	101.8,	225.5	113.1	73.2,	166.3	203.7	154.5,	258.3	<0.001
Occupational activity (min/day)¶	125.89§	67.8,	198.9	135.8	79.0,	195.3	109.3	63.5,	202.9	0.30
Occupational activity, with sitting (min/day)¶	321.7§	273.9,	368.5	328.0	286.1,	370.1	310.1	263.7,	367.2	0.10
Active transport (min/day)¥	0.0	0.0,	15.3	0.0	0.0,	17.9	0.0	0.0,	13.6	0.07
Cycling (min/day)	0.0	0.0,	16.4	4.0	0.0,	25.0	0.0	0.0,	6.8	<0.001
Leisure-time activity (min/day)	15.0	0.0,	40.8	14.0	0.0,	36.4	16.1	0.0,	44.5	0.26

*p-value from Kruskal-Wallis test for the difference in participation in physical activity by gender.

†Time spent in various intensities of activity from accelerometer: moderate-to-vigorous activity ≥760 ct/min; light activity 100 ct/min-759 ct/min; sedentary behavior.

‡Time spent in various intensities of activity as reported on PAQ1, PAQ2 and the PA-log: moderate-to-vigorous activity >3.0 METs; light activity 2.0–3.0 METs; sedentary behavior.

¶Among employed participants.

¥ Active transport includes walking or cycling for work or getting about.

§ p-value from Wilcoxon sign-rank test for the difference in participation in physical activity subcomponents from accelerometer with PAQ1, PAQ2 and with the PA-log <0.05 for all physical activity variables except occupational activity.

Table 3

Intraclass correlation coefficients (ICC) for repeated administrations of the PAQ*

	ICC§		
	TOTAL	**Men**	**Women**
Total physical activity (MET-hr/day)	0.65	0.61	0.69
Moderate-to-vigorous activity (min/day)	0.55	0.58	0.48
Light activity (min/day)	0.59	0.56	0.58
Sedentary behavior (min/day)	0.56	0.61	0.49
Walking (min/day)	0.51	0.54	0.40
Household (min/day)	0.54	0.51	0.51
Occupational activity (min/day)†	0.63	0.56	0.71
Occupational activity, with sitting (min/day)†	0.85	0.83	0.86
Active transport (min/day)‡	0.53	0.57	0.49
Cycling (min/day)	0.62	0.65	0.59
Leisure-time activity (min/day)	0.66	0.65	0.66

*Average time between PAQ administrations=402 days; Time spent in various intensities of activity as reported on the PAQ: moderate-to-vigorous activity >3.0 METs; light activity 2.0–3.0 METs; sedentary behavior <1.5 METs.

§ICC: intra-class correlation coefficient

†Among employed participants.

‡Active transport includes walking or cycling for work or getting about.

Table 4

Spearman correlation coefficients of the association between physical activity from the physical activity questionnaire (PAQ2) and physical activity from accelerometry and the physical activity log (PA-log), total cohort (N=545) and for men (N=271) and women (N=274) separately.

	Accelerometer†				PA-log‡
PAQ2‡	Total physical activity	Moderate-to-vigorous activity	Light activity	Sedentary behavior	Corresponding intensity or domain of activity
Total physical activity	0.30*	0.32*	0.36*	−0.30*	0.68*
Moderate-to-vigorous activity	0.17*	0.17*	0.13**	−0.14*	0.61*
Light activity	0.26*	0.26*	0.36*	−0.27*	0.69*
Sedentary behavior	−0.06	−0.06	−0.20*	0.16*	0.73*
Walking	0.10**	0.10**	−0.04	−0.08	0.42*
Household activity	−0.12**	−0.13**	−0.03	0.04	0.36*
Occupational activity§	0.19**	0.19**	0.20*	−0.32*	0.73*
Occupational activity, with sitting§	−0.05	0.02	0.03	−0.04	0.51*
Active transport§§	0.22*	0.21*	0.18*	−0.10*	0.61*
Cycling	0.08	0.08	0.19*	−0.08	0.85*
Leisure-time activity	0.10**	0.08	0.03	−0.02	0.54*

† Time spent in physical activity from accelerometer: moderate-to-vigorous activity ≥760 ct/min; light activity 100 ct/min-759 ct/min; sedentary behavior <100 ct/min.

‡ Time spent in physical activity as reported on PAQ2 and the PA-log: moderate-to-vigorous activity >3.0 METs; light activity 2.0–3.0 METs; sedentary behavior <1.5 METs.

* p-value <0.001,

** p-value <0.05

§ Among employed participants.

§§ Active transport includes walking or cycling for work or getting about.

Table 5

Mean difference 95% confidence intervals (CI) and 95% limits of agreement (LOA) for physical activity and sedentary behavior from the physical activity questionnaire (PAQ2) and the accelerometer and the physical activity log (PA-log)

PAQ2 - Accelerometer	Mean difference†	95%CI		95% LOA	
Moderate-to-vigorous activity (min/day)	24.3	18.1,	30.6	−123.9,	172.5
40–59 years	10.2	−131.6,	−104.2	−444.2,	208.5
60+ years	60.6	−252.1,	−228.9	−516.8,	35.8
Light activity (min/day)	−57.0	−66.3,	−47.8	−276.4,	162.3
40–59 years	−39.8	−49.4,	−30.1	−270.2,	190.6
60+ years	−101.3	−107.9,	−94.7	−258.5,	55.8
Sedentary behavior (min/day)	−152.3	−166.2,	−138.4	−484.0,	179.4
40–59 years	−117.9	−131.6,	−104.2	−444.2,	208.5
60+ years	−240.5	−252.1,	−228.9	−516.8,	35.8

PAQ2 - PA-log	Mean difference‡	95%CI		95% LOA	
Total physical activity (MET-hr/day)	3.2	2.7,	3.6	−8.1,	14.4
Moderate-to-vigorous activity (min/day)	1.2	−3.9,	6.3	−120.1,	122.6
Light activity (min/day)	−18.7	−25.6,	−11.8	−182.6,	145.2
Sedentary behavior (min/day)	−70.3	−78.8,	−61.9	−271.8,	131.1
Walking (min/day)	19.7	15.5,	23.9	−80.1,	119.6
Household activity (min/day)	−113.5	−120.7,	−106.4	−283.3,	56.2
Occupational activity (min/day)§	−0.2	−10.2,	9.7	−152.8,	152.3
Occupational activity, with sitting (min/day)§	1.9	−10.0,	13.8	−181.1,	184.9
Active transport (min/day)§§	8.3	6.4,	53.7	−36.4,	53.0
Cycling (min/day)	2.6	1.2,	3.9	−29.7,	34.9
Leisure-time activity (min/day)	−12.5	−15.0,	−10.0	−71.6,	46.6

† Mean difference = PAQ2 - accelerometer

‡ Mean difference = PAQ2 - PA-log

§ Among employed participants.

§§ Active transport includes walking or cycling for work or getting about.

Table 6

Ranking of physical activity and sedentary behavior by the physical activity questionnaire (PAQ2) used in the Shanghai Physical Activity Study: mean (SD) of physical activity or sedentary behavior from the accelerometer by quartiles of physical activity or sedentary behavior from the PAQ2.

	Quartiles from PAQ2			
	1	**2**	**3**	**4**†
Total physical activity, MET-hr/day	232.8 (99.3)	270.3 (94.4)	292.5 (101.2)	311.6 (102.4)
Moderate-to-vigorous activity, min/day	78.7 (40.3)	78.8 (33.5)	84.2 (33.2)	94.1 (40.7)
Light activity, min/day	207.9 (56.8)	237.8 (68.8)	254.8 (60.2)	265.8 (58.7)
Sedentary behavior, min/day	499.0 (98.5)	513.5 (97.3)	496.4 (107.3)	545.0 (94.8)

† p-value from Spearman rank correlation <0.001 for all variables.