



Energy Cost of Reclining, Sitting, and Standing Activities in Chinese Adults

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ABSTRACT

International Journal of Exercise Science 15(7): 1202-1211, 2022. The 2011 Compendium presents MET values for sedentary behaviors (SBs) and light-intensity physical activities (LIPAs). Some entries have estimated METs, others have multiple activities in a single entry, and newer activities are not in the Compendium. Accurate MET values are needed to increase the validity and generalizability of the Compendium. This study measured and analyzed SBs and LIPAs' energy costs in reclining, sitting, standing postures, and fidgeting. Indirect calorimetry measured the energy costs (VO_2 , $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) in 11 males and seven females (30.7 ± 7.6 y). Two groups of 9 participants each completed 17 randomly assigned activities (9 in group 1; 8 in group 2) for 5 minutes with a 2-minute rest between tasks. Standard METs were calculated as $\text{VO}_2 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1} / 3.5 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$. Results showed mean MET values for doing nothing (recline: 1.3, sit: 1.3, stand: 1.3); Watching TV on a mobile phone (recline: 1.3, sit: 1.3); Reading (recline: 1.5, sit: 1.0); Writing (recline: 1.5, sit: 1.3, stand: 1.3); Texting or viewing websites on a mobile phone (recline: 1.3, sit: 1.3, stand: 1.3); Fidgeting (sit hands only: 1.5, sit feet only: 1.8, stand hands and feet: 2.0); Typing (stand: 1.3). Measured vs. Compendium METs were the same for five SBs and LIPAs, higher for three SBs and LIPAs (by 0.2 METs), and lower for one SB (by 0.3 METs). In conclusion, the activities ranged from 1.0 to 2.0 METs, categorized as sedentary and light-intensity. Increasing the accuracy of Compendium MET values increases its utility for the correct classification of SB and LIPAs.

KEY WORDS: Energy expenditure, physical activity, inactivity, Compendium of Physical Activities, sedentary, light-intensity physical activity

INTRODUCTION

Researchers, educators, and public health specialists use the Compendium of Physical Activities (Compendium) (2) to identify the energy costs of sedentary behaviors (SBs) and light-intensity physical activities (LIPAs) for use in intervention studies (4), to estimate the energy costs of activities (10), and for population health purposes (28). The 2011 Compendium contains MET

values for 38 SBs (≤ 1.5 METs, $n=27$) and LIPAs (1.6-2.9 METs, $n=11$) entries performed in reclining, sitting, and standing postures in the Inactivity and Miscellaneous Categories. The entries vary from doing nothing and reading to typing and playing board games. The Compendium estimates MET values for nearly one-third of the Inactivity and Miscellaneous Category entries (34%), and several entries have multiple LIPAs combined in a single entry. Estimated MET values can be problematic, introducing errors in calculating energy expenditure or classifying activities by intensity. Including multiple LIPAs in a single entry also can introduce errors into calculations if MET values differ for individual activities in the entry. For example, code 09050 has multiple activities combined as a single entry (standing and talking in person, on the phone, using a computer, or text messaging) measured as 1.8 METs. However, MET values are unknown for each activity in the combined Compendium entry. Since the latest Compendium in 2011, newer SBs and LIPAs are prevalent among adults (i.e., texting and watching videos on a mobile phone), but the energy costs of the SBs and LIPAs are not measured.

We have identified 17 SBs and LIPAs performed in reclining ($n=5$), sitting ($n=7$), and standing ($n=5$) postures that warrant measurement of their energy costs. Nine SBs and LIPAs are single entries in the 2011 Compendium's Inactivity and Miscellaneous categories. Four are SBs in Compendium entries with multiple SBs in a single entry, and four are new SBs. Types of SBs and LIPAs selected are doing nothing, watching television on a mobile phone, texting or viewing websites on a mobile phone, reading a book, writing in a notebook, typing on a computer, and fidgeting. Of the 13 SBs and LIPAs from the Compendium, three have estimated METs. Ten have been measured previously but have limited references for the assigned MET values or multiple references with a wide range of MET values.

Having accurate MET values to classify SBs and LIPAs has public health significance. Inaccurate estimates of the energy costs of SBs and LIPAs can cause under- or overestimation of energy expended in research studies relating SBs and LIPAs to health outcomes (14). For example, several epidemiological studies refer to the Compendium to identify MET values used in computing PA exposures as MET-hours per week, calculated by multiplying MET values for a specific activity by the hours performed (15, 16, 19). Determination of thresholds for reduced cancer risks (e.g., 7.5-15 MET-hour per week) is dependent on an accurate assessment of MET values (19). Inaccurate MET values can also misclassify the time one spends in SBs or LIPAs if the intensity levels are assigned incorrectly to specific activities. For example, according to national data, nearly all US adults spend up to 6.5 hours per day in sedentary pursuits (e.g., watching television, using a computer, reading) during leisure time (8). Time spent in sedentary pursuits may increase or decrease if MET values for SBs are found to correspond with LIPA MET values instead. Accordingly, it is vital to correctly classify SB and LIPA-specific activities to avoid systematic errors in reporting sedentary pursuits in research and population health monitoring.

The purpose of this study is to increase the MET values' accuracy in the 2011 Compendium of PAs by measuring the energy costs of 17 SBs, and LIPAs performed in reclining, sitting, standing

postures, and fidgeting in healthy Chinese adults.

METHODS

Participants

This cross-sectional study recruited a convenience sample of 20 Chinese adults (11 males and nine females, aged 31.5 ± 7.6 , range 22-48 years) from the Shanghai University of Sport. Prior to study activities, participants gave informed consent according to the ethical standards of the Helsinki Declaration (30). The Ethics Committee of Shanghai University of Sport approved this study. This research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (23). Inclusion criteria were, being aged 19-59 y, having no mobility limitations, being cognitively able to follow directions, answering 'yes' to the seven general health questions on the 2018 Physical Activity Readiness Questionnaire for Everyone (PAR- Q+) (29), and able and willing to wear a data collection face mask for up to 75 minutes for testing. Volunteers were excluded from participation if they failed to meet the inclusion criteria. We performed a single mean sample size power calculation ($[Z\alpha/2 \sigma]^2/d^2$, where $Z\alpha/2 = 1.96$, $\sigma = 1.64$, and $d = 1$) to estimate the minimum number of participants needed to detect a 1 MET-unit difference between measured and Compendium values. The calculation predicted a sample size of 10 to provide a statistical power of 80% and a type 1 error of 0.05.

Protocol

Two groups of 10 participants per group completed a single testing session lasting approximately 70 minutes. Each group completed different activities to reduce fatigue and participant time to complete all activities. Group one completed nine activities, and group two completed eight activities (Table 1).

Table 1. Sedentary behaviors and light-intensity physical activities performed by groups one and two.

Group 1 (n=10)	Group 2 (n=10)
1. Recline quietly on a bed and do nothing	1. Sit in a chair and read a book
2. Recline quietly on a bed and watch television on a mobile phone	2. Sit in a chair and write in a notebook
3. Recline while reading a book	3. Sit in a chair while texting or viewing websites on a mobile phone
4. Recline while writing in a notebook	4. Stand quietly and do nothing
5. Recline while texting or viewing websites on a mobile phone	5. Stand while fidgeting one's arms and legs
6. Sit quietly on a chair and do nothing	6. Stand while writing in a notebook
7. Sit quietly and watch television on a mobile phone	7. Stand while texting or viewing websites on a mobile phone
8. Sit quietly while fidgeting one's hands	8. Stand while typing on a computer
9. Sit quietly while fidgeting one's feet	

All participants refrained from eating, drinking caffeinated beverages, exercise, and smoking for at least two hours before data collection. Before data collection, participants completed the PAR-Q+ and had weight and height measured without shoes. Blood pressure was measured in

duplicate while sitting quietly. Participants sat quietly for five minutes to measure their resting heart rate (HR) and oxygen uptake (VO_2).

Participants performed tasks for five minutes with a two-minute rest between tasks. VO_2 in milliliters per milligram per minute ($\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) and HR in beats per minute ($\text{b}\cdot\text{min}^{-1}$) were measured continuously. While resting, participants watched a 1-minute video of each activity to familiarize them with the activities and standardized data collection. Doing nothing, watching television on a mobile phone, reading a book, writing in a notebook, and texting or viewing websites on a mobile phone were performed in reclining and sitting postures. Fidgeting was performed in sitting and standing postures. Typing, doing nothing, writing, and texting or viewing websites on a mobile phone were performed standing. Participants performed tasks in random order. Participants received a small gift valued at \$10 at the end of each session.

Data Sources: Age in years (y) and sex were obtained by self-report. Body mass (kilograms, kg) and height (centimeters, cm) were measured on laboratory scales. Blood pressure was measured using UDEX-i2 Blood Pressure monitor (Canon Medtech Supply Corporation, Kawasaki-shi, Nakahara-ju, Japan). VO_2 in $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ and HR in $\text{b}\cdot\text{min}^{-1}$ were measured by a Cosmed K4b2 Portable Indirect Calorimetry system (Cosmed, Rome, Italy) and Garmin HRM-3 (Taiwan, China), respectively. The Cosmed K4b has an ICC test-retest reliability of 0.70-0.90 (12); correlations with a laboratory metabolic cart are 0.87-0.97 (25). HR and VO_2 values were averaged from minutes 2-4 of the 5-minute data collection period. Participants provided their mobile phones, and the study staff provided reading, writing, and typing materials.

Statistical Analysis

We computed means, and standard deviations (\pm sd) for age, body mass, height, body mass index (BMI), resting blood pressure, HR, VO_2 , and computed MET values. BMI was calculated as body mass in kg divided by height in meters squared and standard METs as activity VO_2 in $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}/3.5 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$. Terminal digits for MET values were rounded to 0, 3, 5, or 8 to comply with the format used in the Compendium. Independent t-tests compared differences in age, body mass, height, BMI, resting blood pressure, resting HR, and resting VO_2 , and chi-square compared differences by sex between the two data collection groups. Using subtraction, we compared the measured METs with Compendium METs. We did not perform statistical analysis on the difference between the measured METs and the Compendium METs. A $P < .05$ was statistically significant. Data were analyzed using Excel Microsoft Office Professional Plus 2016.

RESULTS

Of the 20 participants starting the study, we removed one participant's data due to uncontrolled coughing during the testing session, invalidating the VO_2 data. We removed another participant's data due to an equipment malfunction. Table 2 presents data for 18 remaining participants, with nine per group. The groups were similar in sex, age, body mass, height, BMI, resting blood pressures, sitting HR, and sitting VO_2 . There were no significant differences for any of the variables between the groups ($P > .05$).

Table 2. Descriptive characteristics of participants by data collection group and combined (n = 18).

Variable	All mean ± sd	Group 1 mean ± sd	Group 2 mean ± sd	(P-value) ^a
Males: females (n)	18 (11:7)	9 (6:3)	9 (5:4)	0.90
Age (y)	30.7±6.6	32.9±7.7	28.4±4.8	0.16
Body Mass (kg)	63.6±9.2	61.5±7.7	65.6±10.4	0.89
Height (cm)	166.3±6.2	166.4±5.5	166.3±7.1	0.96
Body mass index (BMI, kg/m ²)	22.9±2.4	22.7±2.2	23.7±2.5	0.21
Resting SBP (mmHg)	113.1±10.6	114.8±10.4	111.3±10.7	0.49
Resting DBP (mmHg)	71.0±8.6	70.8±9.8	71.2±7.7	0.92
Sitting Heart Rate (b·min ⁻¹)	69.0±5.4 ^a	68.9±5.0	72.5±6.6 ^b	0.93
Sitting VO ₂ (ml·kg ⁻¹ ·min ⁻¹)	3.8±1.1	3.7±1.2	3.71±1.8	0.90

SBP, systolic blood pressure; DBP, diastolic blood pressure. ^a Comparison of participants in each group was performed with a t-test for continuous variables and a Chi-Square test for sex. ^bMissing data for one participant.

Table 3 presents the means ± sd and ranges for measured HR, VO₂, and METs for activities performed in reclining, sitting, standing postures, and fidgeting. We present rounded- and Compendium METs as a single value only. Mean HR values were lowest during reclining and highest during standing activities. The mean measured VO₂ values for reclining, sitting, and standing activities ranged from 3.91 to 5.19 ml·kg⁻¹·min⁻¹, with rounded METs ranging from 1.0 to 1.5 METs. VO₂ and rounded MET values for fidgeting ranged from 5.26 and 7.11 ml·kg⁻¹·min⁻¹ and 1.5 to 2.0 METs, respectively. Measured (rounded) MET values were the same as Compendium values for five SBs and LIPAs, lower for one measured SB (by -0.3 METs), and higher for three measured SBs and LIPAs (by +0.2 METS) than Compendium values.

Table 3. Mean ± standard deviation and ranges for the energy cost of sedentary behaviors and light-intensity physical activities by posture and the task performed (N=18)

Posture and Task	HR b·min ⁻¹ (x ± sd) (range)	VO ₂ ml·kg ⁻¹ ·min ⁻¹ (x ± sd) (range)	Standard METs (x ± sd) (range)	Standard Rounded METs ^a	2011 Compendium Standard Rounded METs	Measured Minus Estimated METs
Reclining	-	-	-	-	-	-
Doing nothing (07011)	60.44±5.79 (53 -68)	4.45±0.99 (3.43-6.37)	1.27±0.28 (1.0, 1.8)	1.3	1.3	0
Watching TV on a mobile phone	62.20±5.94 (51-71)	4.09±0.66 (3.23-5.01)	1.17±0.19 (0.9, 1.4)	1.3	New activity	-
Reading a book (07070)	64.12±7.38 (54-76)	5.19±1.84 (2.77-9.06)	1.48±0.53 (0.8, 2.6)	1.5	1.3	+0.2
Writing in a notebook (07050)	65.08±6.79 (54-78)	5.06±0.87 (3.15-6.24)	1.45±0.25 (0.9, 1.8)	1.5	1.3 ^b	+0.2
Texting or viewing websites on a mobile phone	64.61±7.10 (52-74)	4.82±1.43 ^c (3.71-8.02)	1.38±0.41 (0.6, 2.3)	1.3	New activity	-
Sitting	-	-	-	-	-	-
Doing nothing (07021)	65.05±6.55 (57-77)	4.29±1.33 (2.62-6.49)	1.23±0.38 (0.8, 1.9)	1.3	1.3	0

Watching TV on mobile phone (07020)	64.00±5.51 (54-71)	4.19±1.42 (3.00-7.68)	1.20±0.40 (0.9, 2.2)	1.3	1.3	0
Fidgeting one's hands (07022)	70.37±7.38 (60-80)	5.26±1.46 (3.15-8.24)	1.50±0.42 (0.9, 2.4)	1.5	1.5	0
Fidgeting one's feet (07023)	71.17±7.23 (63-81)	6.19±1.37 (3.70-8.21)	1.77±0.39 (1.1, 2.2)	1.8	1.8	0
Reading a book (09030)	73.20±9.91 (61-96)	3.91±0.84 (2.54-5.35)	1.12±0.24 (0.7-1.5)	1.0	1.3	-0.3
Writing in a notebook ^d	70.09±9.94 (57-91)	4.04±0.89 (2.70-5.37)	1.21±0.26 (0.9-1.5)	1.3	New activity	-
Texting or viewing websites on a mobile phone ^e	67.65±11.16 (58-94)	4.0±0.88 (2.62-5.20)	1.15±0.25 (0.8-1.5)	1.3	New activity	-
Standing	-	-	-	-	-	-
Doing nothing ^f	79.82±11.04 (63-90)	4.03±0.89 (3.08-6.13)	1.15±0.25 (0.9-1.8)	1.3	New activity	-
Fidgeting one's arms and legs (07041)	83.16±11.53 (68-109)	7.11±1.38 (5.37-9.94)	2.03±0.39 (1.5-2.8)	2.0	1.8	+0.2
Writing in a notebook	79.82±11.04 (67-104)	4.76±0.93 (3.51-6.41)	1.36±0.26 (1.0,1.8)	1.3	New activity	-
Texting or viewing websites on a mobile phone	78.33±11.97 (63-104)	4.16±0.95 (3.12-5.67)	1.19±0.27 (0.9-1.6)	1.3	New activity	-
Typing on a computer ^g	75.67±9.20 (67-94)	4.82±1.56 (2.7-7.24)	1.38±0.45 (0.7-2.1)	1.3	New activity	-

^aRounded MET values reflect the significant digit rounding (0, 3, 5, 8) used in the Adult Compendium of Physical Activities. ^bMET values in italics are estimated. ^cMissing data for one participant. ^dActivity separated from the combined Compendium code 09040 sitting, writing, desk work, typing (measured at 1.3 METs). ^eActivity separated from the combined Compendium code 09055 sitting, talking in person, on the phone, computer or text messaging, light effort (*estimated at 1.5 METs*). ^fActivity separated from the combined Compendium code 07040 stand quietly, in a line (measured at 1.3 METs). ^gActivity separated from the combined Compendium code 09050 standing, talking in person, on the phone, computer or text messaging, light effort (*estimated at 1.8 METs*).

DISCUSSION

Measured energy costs for activities performed in reclining, sitting, and standing postures, and fidgeting with the hands while sitting ranged from 1.0 to 1.5 METs, categorizing them as SBs (1.0 to 1.5 METs) (1). Energy costs for fidgeting increased with greater involvement of the body mass; sitting and fidgeting with the feet (1.8), and standing fidgeting with the hands and feet (2.0 METs) categorizing them as LIPAs, ranging from 1.6 to 2.9 METs (1).

Most of the 13 activities from the Compendium reflect SBs that adults perform for relaxation during their leisure time (i.e., reading, writing, watching television and videos on mobile phones; texting, or viewing websites) and in some occupational settings (i.e., standing and writing or typing). Four new activities were created by separating them from Compendium entries. For example, "sitting and writing in a notebook" (measured at 1.3 METs) was extracted from code 09040, "sitting, writing, desk work, typing". "Standing and typing on a computer" (measured at 1.3 METs) was extracted from code 09050, "standing, talking in person, on the phone, computer or text messaging, light effort" (estimated at 1.8 METs). With advances in

technology, texting and viewing websites on a mobile phone have become popular activities since publishing the Compendium 2011. We extracted "texting" from the Compendium combined entries, "talking in person, on the phone, computer, or text messaging, light effort" listed for sitting (09055, 1.5 METs) and standing postures (09050, 1.8 METs). We then combined "texting" with "viewing websites on a mobile phone" to create three new Compendium entries, "texting and viewing websites on a mobile phone" with a MET value of 1.3 for reclining, sitting, and standing postures.

Measurement of the 10 SBs and LIPAs from the Compendium entries with previously measured MET values were the same or differed by 0.2 to 0.3 METs. We remeasured these activities because nearly half of the MET values in the Compendium's Inactivity and Miscellaneous categories were from studies published prior to 2011. Some activities in the Compendium had many published studies (i.e., code 07011, "Lying quietly, doing nothing, lying in bed awake, listening to music, not talking or reading") ([6](#), [7](#), [9](#), [11](#), [13](#), [18](#), [20](#), [24](#), [26](#), [27](#)) citing MET values and others had as few as one study (i.e., code 07041, "standing and fidgeting") ([17](#)). An activity in the 2011 Compendium with many published studies "Lying quietly, doing nothing, lying in bed awake, listening to music, not talking or reading" (code 07011, 1.3 METs) based its MET value on 11 studies ranging from 0.91 METs ([11](#)) to 1.37 METs ([6](#)). We measured "reclining and doing nothing" as 1.3 METs, with values ranging from 1.0 METs to 1.8 METs. A similar example is code 07021, "sitting and doing nothing." The Compendium bases its 1.3 MET value on 27 studies with energy cost values ranging from 1.0 METs ([17](#)) to 1.47 METs ([26](#)). Our average value was similar (1.3 METs), ranging from 0.8 METs to 1.9 METs. Alternatively, the Compendium bases its MET value for "standing and fidgeting" (code 07041, 1.8 METs) on one measurement by Levine et al. in 2000 ([17](#)). We measured "standing and fidgeting with one's arms and legs" at 2.0 METs.

Not all Compendium entries have references to support the MET values. For example, the Compendium has included "reclining and reading a book" (code 07070, 1.3 METs) since the Compendium's first publication in 1993 ([3](#)). However, there are no studies identified to support the MET value. We measured "reclining and reading a book" at 1.5 METs. Also, the Compendium estimates the energy costs for "reclining and writing" (code 07050) at 1.3 METs. We measured the activity at 1.5 METs. The examples presented here show the importance of having multiple studies measure the energy costs of SBs and PAs.

The energy cost values measured in this study are variable in the oxygen costs required to complete an activity. For example, it is counterintuitive that the measured energy costs for "doing nothing" and "texting or viewing websites on a mobile phone" are the same (1.3 METs) for reclining, sitting, and standing body postures. However, given the considerable variation in energy expended in different body positions ([5](#), [21](#)), it is plausible that MET values for reclining, sitting, and standing SBs can have the same energy cost. In a review of 30 studies on the energy expended in sitting and standing postures, Miles-Chan ([21](#)) noted a large intra- and inter-individual variability in the energy costs of standing that can range from below 10% to above 30% of the energy costs of sitting. We also noted that the measured energy cost for "reclining

and reading a book" (code 07070) and "reclining and writing in a notebook" (code 07050) was measured at 1.5 METs. The MET value for reclining is higher than the MET values measured for the same SBs in sitting and standing postures (1.0 METs and 1.3 METs, respectively). Differences in the values may be due to three reasons. First, the participants had to tilt their reclining posture slightly when wearing the Cosmed K4b2 Portable Indirect Calorimetry system on their back while reading and writing. The body posture may have increased the energy cost of the SBs. Second, reclining and holding a book and writing in a notebook may increase the energy cost of the SBs over the energy costs of reading and writing while sitting and standing (e.g., participants can balance the book on one's lap to read and set the notebook on a table to write). Third, variability in the energy cost of the SBs may have resulted in unequal MET values across postures (see Table 3 for the range of values for these activities).

Despite having measured values for the energy costs of SBs and LIPAs in this study, a caveat to the findings is that energy expenditure varies by weight, age, body mass, nutritional status, and body mechanics while performing an activity (22). The energy cost of SBs and LIPAs also varies by study design and methods used to collect the data (21). Accordingly, the MET values presented in this study should not be considered definitive energy costs of specific activities but to contribute additional MET values to studies reviewed when assigning new and revised MET values to the Compendium.

This study has strengths and limitations. The primary strength is measuring MET values for SBs and LIPAs performed by adults in leisure-time and occupational settings. Potential limitations are the sample size, population studied, and not presenting sex-specific MET values. While we recruited an adequate sample size ($n=10$) to estimate actual MET values, we had to delete data for two participants due to difficulties in data collection. This deletion left nine participants per group resulting in the study being underpowered (recommended 10 subjects per group) needed to detect a 1 MET difference between measured and Compendium values. Our participants were of the Chinese race, and their energy costs may differ from persons of different races and ethnicities. Further, we did not stratify the results by sex. These concerns are not significant as the MET values in the Compendium are averaged from studies with diverse populations and are not stratified by age or sex when assigning MET values to Compendium entries.

Conclusion: To update the activities and MET values listed in the 2011 Compendium of Physical Activities, we measured the energy costs of 17 SBs and LIPAs performed in reclining, sitting, standing postures, and fidgeting. Measured MET values ranged from 1.0 to 2.0 METs and differed by fewer than ≤ 0.3 METs from values presented for the same activities in the Compendium. We measured MET values for mobile phone-related SBs, and individual SBs separated from Compendium entries with multiple activities. The MET values measured in this study provide additional resources to classify SBs and LIPAs in a revised Compendium of Physical Activities.

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