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Original Research

Energy Costs of Chair Sitting and Standing Video Exercises in Chinese Older Adults Over 60 Years

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ABSTRACT

***International Journal of Exercise Science* 16(7): 814-827, 2023.** Home-based video exercise interventions improve older adults' physiological performance and functional capacity. Little is known about the energy costs of video exercises in older adults. The Compendium of Physical Activities (PAs) has few items with PA metabolic equivalents (METs) in older adults. This study measured the energy costs of four chair and two standing exercises (sitting Tai Chi, Yoga, mobility ball, aerobics: standing, slow aerobics, and fast aerobics). Fifteen females and 14 males, 62-87 years (M ± SD, 73 ± 7.7 years), were categorized into three age groups (60-69, 70-79, 80-89). Oxygen uptake (VO_2, ml·min^{-1}·kg^{-1}) and heart rate (HR, b·min^{-1}) were measured by indirect calorimetry and heart rate monitor. MET values were calculated as standard- (activity VO_2/3.5), rounded- (significant digit rounded to 0, 3, 5, 8), and corrected METs (individual resting metabolism). Results showed chair Yoga, Tai Chi, and mobility ball ranged from 2.0 to 2.8 rounded METs (light intensity). Chair- and standing aerobics ranged from 3.0 to 4.3 rounded METs (moderate intensity). Averaged HR ranged from 91.9 ± 12.7 b·min^{-1} to 115.4 ± 19.1 b·min^{-1} for all PAs. Corrected METs were higher than standard METs ($P < .05$). Standard METs were similar between age groups ($P > .05$). In conclusion, this study is unique as it measures the energy costs of sitting and standing video exercises that can be performed by older adults at home or in an exercise facility. Knowing the energy costs of PAs for older adults can provide exercises interventions to prevent sedentary lifestyles.

KEY WORDS: Physical activity, METs, energy expenditure, senior adults

INTRODUCTION

Aging is associated with progressive declines in strength, mobility, and cardiorespiratory function and is accelerated by physically inactive lifestyles. Prolonged sitting and increased time spent in other sedentary behaviors increase the risk for mobility disabilities (9,41) and frailty (16) in adults 60 years and older. Sedentary behaviors are also associated with various chronic and metabolic diseases (16). According to an analysis of the 2011, 2013, and 2015 China Health and Retirement Longitudinal Study, 20% of Chinese adults 60 to 74 years and 36.8% of Chinese adults 75 years and older are physically inactive. Analyses also showed that the risk of physical inactivity increases by 25% in adults 60 to 75 years and 65% in adults 76 years and older (26). Previous research has shown that chronically sedentary and frail older adults have difficulty participating in exercise programs because of their limited functional abilities and poor health (9,28). Accordingly, professionals adapt exercise programs for sitting in a chair and standing that older adults can complete at home, in senior centers, and in residential settings. Low- and moderate-intensity exercises improve components of physical fitness (i.e., cardiorespiratory fitness, balance, muscular strength) (25,33,37) and mobility (e.g., walking speed) (46). Further, home-based video exercise interventions improve older people's physiological performance and functional capacity (5,42).

Little is known about the energy costs of chair sitting and standing exercises adapted for older adults. Exercise intensity is measured in METs for use in public health, diagnostic, and exercise settings, where 1 MET is the activity metabolic rate divided by the resting metabolic rate (17). Cut-off points for classifying MET intensities are sedentary (1.0 to 1.5 METs), light (1.6 to 2.9 METs), moderate (3.0 to 5.9 MET), and vigorous (≥ 6.0 METs) (45). The World Health Organization (WHO) recommends that older adults spend 150 to 300 minutes per week in moderate-intensity PAs, or 75 to 150 minutes per week in vigorous-intensity PAs, or a combination of the two volumes. They also recommended engaging in muscle-strengthening activities at least twice a week and performing PAs that emphasize functional balance and strength training at a moderate or greater intensity at least three days a week to enhance functional capacity and prevent falls (45). Light-intensity PAs also have health-enhancing effects for older adults, especially those who require assistance with activities of daily living (14,18,20,31).

Researchers, practitioners, and educators use the Compendium of Physical Activities (Compendium) to identify PA's energy costs (in METs). The Compendium is a comprehensive collection of MET values for nearly 1000 physical activities, divided into 11 categories (e.g., bicycling, exercising, dancing, conditioning, and home activities) (2). Compendium MET values are presented as standard METs, defined as the activity's metabolic rate divided by a resting metabolic rate (RMR) of 3.5 $ml \cdot min^{-1} \cdot kg^{-1}$. To increase the utility of the Compendium, METs are rounded from standard values to present significant digits of 0, 3, 5, and 8. PAs and associated MET values in the 2011 Compendium do not specify specific MET values for different age groups, sexes, and body masses. Instead, the Compendium combines MET values as a single value (2). It is difficult to identify if the MET value for a PA is relevant for different populations, especially older adults. With an aging population, Hall et al. (12) call for more research identifying the energy costs of PAs in older adults. To increase the precision of MET values for older adults, the Compendium needs to present MET values for exercises performed by adults ages 60 and older (2). This change will help exercise professionals and researchers to identify PAs energy costs specific to older adults.

Researchers (4,15,23) have suggested that standard MET values may not reflect an accurate energy cost in individuals. Kozey et al. (23) noted the standard resting MET value of 3.5 $ml \cdot min^{-1} \cdot kg^{-1}$ overestimates measured RMR values and reduces the size of resulting MET values. Kozey et al. provide an equation to correct standard METs for one's RMR and individualized MET values (corrected METs) using the Harris-Benedict derived RMR. Knowing standard METs helps assign MET values to PA questionnaire activities and compare the prevalence of PA intensity levels between populations. However, when referring to the energy cost of PAs in individuals, it is better to use corrected MET values to better estimate of one's energy expenditure (15).

MET values for many exercises performed by older adults in home, community, and residential exercise settings have yet to be measured. This study aimed to measure the MET energy costs of- and assign intensity categories to six video-based sitting and standing exercises in apparently healthy Chinese adults over age 60. The energy costs are presented as standard, corrected, and rounded METs.

METHODS

Participants

Thirty volunteers were recruited for this study. Recruitment methods included posters, on-line messaging, word of mouth, and meetings in senior housing centers with potential volunteers. All participants were between 60 and 89 years (15 men, 15 women, and an average age of 73.0 ± 7.7 years, age range 62~87 years). Prior to the study activities, participants gave informed consent according to the ethical standards of the Declaration of Helsinki (48). The ethics committee of the Shanghai University of Sports approved this study. This research was carried out fully in accordance to the ethical standards of the *International Journal of Exercise Science* (34). Inclusion criteria required participants to be apparently healthy adults aged 60 to 89 years, able to walk with a normal stride and without assistive devices, answer 'yes' to the seven general health questions on the Physical Activity Readiness Questionnaire plus (PAR-Q+) (43) questions, and able to wear a portable oxygen uptake data collection face mask and a heart rate monitor chest strap for up to 90 minutes during exercise. We excluded participants who did not meet the inclusion criteria for the study. We used the 2022 Power Analysis and Sample Size (PASS) software (NCSS, LLC. Kaysville, Utah, USA) to perform a Welch's Test (44) for a one-way ANOVA to determine the statistical power ($1-\beta$) needed to detect a 1 MET difference between the group means (N=10 per group), allowing for unequal group variances ($\sigma = 0.5$) and with a type 1 error of .05. Statistical power was computed as 84%.

Protocol

In this cross-sectional study, three groups of 10 participants per age group of 60-69, 70-79, and 80-89 years completed a single testing session lasting approximately 75-90 minutes. Participants were advised to wear comfortable clothing and athletic shoes and to refrain from eating, smoking, and exercising for two hours before the test. Before exercising, participants were informed of the purpose of the study and described the activities performed. They filled out the Chinese version of the PAR-Q+ (43) to establish eligibility, signed an informed consent form, and had their body mass and height measured without shoes. Blood pressure was measured in duplicate, and resting heart rate (HR) and oxygen uptake (VO_2) were recorded at 10-second intervals for 10 minutes while participants sat quietly.

Participants completed six pre-recorded exercise videos with a 5-minute rest between videos (Table 1).

Table 1. Descriptions of chair sitting and standing exercises.

Exercise	Description
Chair Yoga	Participants sit in a back-supported chair. They raise and press their hands overhead and in front of their body, stretch their back, sides, shoulders, hips, thighs, and leg muscles. Instructors emphasize Yoga breathing techniques during specific exercises. The video includes music and is narrated in Chinese. The exercises are performed from minutes 7:15-12:25 of the video. Link: https://www.youtube.com/watch?v=IKW8X0-2Eww
Chair Tai Chi	Participants sit on a back-supported chair. They complete 18 Shibashi-style Tai Chi movements adapted for sitting in a chair. The video has no narration, and the names of the poses are printed in English. The exercises are performed for the full 7:00 minutes of the video. Link: https://www.youtube.com/watch?v=T2SscwGK4oE
Chair Aerobics	Participants sit on a back-supported chair. Rhythmic exercises performed to fast-paced Chinese music guide head circles, calf raises, marching, bending the knees and swinging the arms, alternating leg extensions with arm extensions overhead and to the front of the body, raising the knees and extending the arms to the side, and circling the arms. The video has no narration, and the names of the movements printed in Chinese. The exercises are performed from minutes 0:55 to 4:44 of the video. Link: https://www.youtube.com/watch?v=u6lIU9dXBck
Chair Mobility Ball	Participants sit on a back-supported chair while holding an unweighted rubber ball approximately 6-to-8 inches in diameter. They pass the ball from one hand to the other, squeeze it between their knees and armpits, rotate it with an extended arm, push it forward and pull it back, lift it overhead and from side to side, toss and catch the ball while alternately sitting and standing, and bending with the ball. The video has background music, and an instructor narrates the video in English. The exercises are performed from minutes 0:20 to 6:35 of the video. Link: https://www.youtube.com/watch?v=yTYdrAOKNcA
Standing, Slow Aerobic Warm-up	An instructor leads participants in exercises of marching in place, step jacks, elbow extensions, bent knee kicks, knee bends, arm raises, elbow circles, hip circles, alternate arm extension upward, leg swings, and jogging in place. The video has background music, and the instructor narrates in English. The exercises are performed from minutes 0:00 to 5:00 of the video. Link: https ://www.youtube.com/watch?v=m2Bni2lcrWw
Standing, Fast Aerobic Warm-up	One instructor and approximately 18 class members lead participants in exercises to fast-paced music (YMCA by the Village People) while marching in place in narrow to wide stances, tapping the foot lateral laterally while alternately extending the elbows behind the body, reaching the arms across in front of the body, and raising the arms over the head. Other exercises include moving the arms in a Y, M, C, A pattern, alternating touching the knees to the elbows, touching the hands to the feet in front of the body, and shifting the body weight from one to the other while rocking the body forward and backward. The exercise keeps the participant in constant motion. The instructor narrates the video in English. The exercises are performed from minutes 1:07 to 7:30 in the video. Link: https://www.youtube.com/watch?v=sEk8bZbeZao

Videos included four seated chair exercises (yoga, Tai Chi, aerobics, mobility ball) and two standing aerobics warm-up exercises (slow aerobics warm-up with background music and fast aerobics warm-up to music). The warm-up for aerobics exercises was measured instead of the actual aerobics class to maintain the exercise intensity at light-to-moderate levels. The videos lasted from 3:49 to 7:00 minutes, with an average duration of 5:30 minutes. The order of videos was randomized for each participant. The videos were displayed on a large screen to simulate an exercise environment in a community class, at a residential center, or home. A research assistant performed each exercise video simulating a class leader as participants watched the videos and performed the exercises. HR and VO_2 measures were recorded every ten seconds during each exercise. The first two minutes of exercise data collection were eliminated as an acclimatization artifact. Participants rated their perceived exertion and pain felt during the exercises on a printed scale after each video. All VO_2 measurements took place in a college laboratory at a constant temperature (20 degrees C), humidity (60%), and barometric pressure (762 mmHg). Following the exercise testing session, participants received a small gift equivalent to $15.

Body mass in kilograms (kg) and height in centimeters (cm) without shoes were measured on laboratory scales. Blood pressure was measured with a UDEX-i2 Blood Pressure monitor (Canon Medtech Supply Corporation, Kawasaki-shi, Nakahara-ju, Japan). HR was measured with a chest-mounted Garmin HRM-3 heart rate monitor (Taiwan, China). VO_2 in milliliters per kilogram of body weight per minute ($ml \cdot kg^{-1} \cdot min^{-1}$) and liters per minute ($l \cdot min^{-1}$) were computed from inspired air volume and percentages of oxygen inhaled, and carbon dioxide exhaled using a Quark Cardiopulmonary Exercise Test system (CPET) system (COSMED, Rome, Italy). The flow meter and a gas analyzer were calibrated before each test according to the manufacturer's instructions. HR and VO_2 were averaged from the second minute of exercise to one minute before the end of the data collection period. Perceived exertion during exercise was measured with the Borg-20 point scale (3), and pain was measured during exercise with the Numeric Pain Rating Scale (29).

Statistical Analysis

We performed statistical analyses with SPSS statistical version 28 for Windows (IBM Corp, Chicago, IL, USA). Means and standard deviations (M ± SD) were calculated for age, body mass, height, VO_2 in $ml \cdot min^{-1} \cdot kg^{-1}$ and $l \cdot min^{-1}$, HR, body mass index (BMI), and MET values computed as standard and corrected values. BMI was calculated as body mass in kg divided by height in meters squared. Standard METs were calculated to provide a MET value independent of individual differences in resting energy expenditure, computed as VO_2 in $ml \cdot min^{-1} \cdot kg^{-1}$ during the activity divided by 3.5 $ml \cdot min^{-1} \cdot kg^{-1}$. Terminal digits for standard MET values were rounded to 0, 3, 5, or 8 to comply with the format used in the Compendium. Corrected METs were computed to estimate the exercise's individual energy costs based on the methods outlined by Kozey et al. (23) using the formula: [Standard METs $ml \cdot min^{-1} \cdot kg^{-1}$ × 3.5 $ml \cdot min^{-1} \cdot kg^{-1}$/Harris-Benedict estimated resting metabolic rate in $ml \cdot min^{-1} \cdot kg^{-1}$]. A Shapiro-Wilk test for small samples was performed and did not show evidence of non-normality of the exercise data ($P > .05$). One-way Analysis of Variance (ANOVA) was used to compare differences in MET values between the three age groups. Chi-Square was used to compare differences in MET values by sex for the three age groups. A P-value $< .05$ was statistically significant.

RESULTS

Of the 30 participants recruited into three age categories (60-69, 70-79, 80-89 years), one male over 80 years failed to complete the exercise and was excluded from the analysis. Subsequently, we analyzed data from 15 women and 14 men. Table 2 presents the resting data for participant characteristics by gender and age group. There were no differences in body mass, height, resting VO_2 and HR between the age groups ($P > .05$). Body mass, height, and BMI were higher in males than females ($P < .05$). Resting VO_2 was higher in females than males ($P < .05$).

Table 2. Descriptive characteristics of the participants.

	N	Mass (kg)	Height (cm)	BMI	Age (years)	Resting VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$)	Resting HR ($b \cdot min^{-1}$)
All	29	60.6±11.0	160.9±8.3	23.3±3.1	73.7±7.7	3.8±1.1	75.0±12.2
Age Group							
60-69	10	61.8±10.2	161.7±9.3	23.6±3.1[b]	64.9±2.2[b]	3.7±1.2	80.8±14.3
70-79	10	64.9±10.0	161.4±7.3	24.8±2.7[b]	71.4±1.9[b]	3.9±1.2	72.7±9.1
80-89	9	54.6±11.2	159.4±9.0	21.3±2.9[b]	82.7±2.9[b]	3.8±0.9	71.3±11.4
Sex							
Female	15	53.5±9.5[a]	154.3±4.5[a]	22.4±3.6	72.9±8.8	4.3±1.2[a]	76.5±9.5
Male	14	68.3±6.3[a]	168.0±4.9[a]	24.2±2.3	72.4±6.6	3.3±0.8[a]	73.6±14.7

[a]Significant difference between females and males in resting VO_2, mass, and height, $P < .05$.
[b]Significant differences between the three age groups for BMI and ages, $P < .05$.

Exercise data are presented as M ± SD, including VO_2, HR, and MET values calculated as standard, rounded, and corrected units (Table 3). Exercise VO_2 values for exercises ranged from 7.4 ± 1.5 $ml \cdot kg^{-1} \cdot min^{-1}$ to 14.7 ± 3.1 $ml \cdot kg^{-1} \cdot min^{-1}$, and HRs ranged from 91.9 ± 12.7 $b \cdot min^{-1}$ to 115.4 ± 19.1 $b \cdot min^{-1}$. Rounded METs ranged from 2.0 to 4.3 METs, with values lower for chair exercises than standing exercises. MET values between age groups were small and not statistically different for standard- and corrected METs ($P > .05$). Standard METs were higher in females than males for the standing, fast aerobic warmup ($P < .05$). There were no differences by sex for the remaining standard- and all corrected MET values ($P > .05$).

Table 3. Means ± standard deviations for ratings of perceived exertion (RPE), pain, oxygen uptake (VO_2), heart rate (HR), standard, corrected, and rounded MET values during video-based exercises for all participants combined and by age group and sex.

Group	N	RPE	Pain	VO_2	HR	Standard METs[a]	Corrected METs[b]	Rounded METs[c]
Chair Yoga								
All	29	0.5±0.8	0.1±0.2	7.5±1.6	91.9±12.7	2.1±0.5	2.6±0.5	2.0
Age Group								
60-69	10	0.8±1.3	0.1±0.3	8.0±1.8	98.1±15.2	2.3±0.5	2.8±0.6	2.3
70-79	10	0.4±0.3	0.1±0.2	7.4±1.8	89.0±11.6	2.1±0.5	2.7±0.6	2.0
80-89	9	0.3±0.4	0.0±0.0	6.9±1.1	88.3±9.2	2.0±0.3	2.4±0.4	2.0
Sex								
Female	15	0.4±0.6	0.0±0.1	7.5±1.8	91.1±10.0	2.2±0.5	2.6±0.6	2.3
Male	14	0.6±1.1	0.1±0.3	7.4±1.4	92.8±15.5	2.1±0.4	2.7±0.5	2.0
Chair Tai Chi								

All	29	0.4±0.5	0.0±0.00	7.4±1.5	94.3±13.9	2.1±0.4	2.6±0.5	2.0
Age Group								
60-69	10	0.6±0.6	0.0±0.0	8.1±1.6	100.4±17.1	2.3±0.5	2.8±0.5	2.3
70-79	10	0.3±0.4	0.0±0.0	6.9±1.3	87.6±11.8	2.0±0.4	2.5±0.4	2.0
80-89	9	0.3±0.4	0.0±0.0	7.0±1.6	94.9±8.8	2.0±0.4	2.5±0.6	2.0
Sex								
Female	15	0.3±0.3	0.0±0.0	7.5±1.8	95.8±11.8	2.2±0.5	2.6±0.6	2.3
Male	14	0.5±0.3	0.0±0.0	7.4±1.4	92.7±16.1	2.0±0.4	2.6±0.4	2.0
Chair mobility ball								
All	29	1.3±1.2	0.1±0.3	9.7±2.1	104.2±15.6	2.8±0.6	3.4±0.7	2.8
Age Group								
60-69	10	1.4±1.2	0.1±0.3	10.4±1.3	109.4±17.8	3.0±0.4	3.6±0.5	3.0
70-79	10	1.1±1.2	0.1±0.2	9.1±2.4	99.2±13.4	2.6±0.7	3.3±0.8	2.5
80-89	9	1.6±1.2	0.1±0.3	9.5±2.3	103.9±15.0	2.7±0.7	3.3±0.7	2.8
Sex								
Female	15	1.0±1.0	0.1±0.3	9.6±2.3	105.7±12.3	2.7±0.7	3.3±0.7	2.8
Male	14	1.7±1.3	0.1±0.3	9.7±1.8	102.6±18.8	2.7±0.5	3.5±0.6	2.8
Chair aerobics								
All	29	0.7±0.6	0.0±0.1	10.1±2.1	101.9±14.6	2.9±0.7	3.5±0.7	3.0
Age Group								
60-69	10	0.5±0.4	0.0±0.0	10.0±2.2	102.8±16.7	2.9±0.6	3.4±0.6	3.0
70-79	10	0.7±0.3	0.1±0.2	10.2±2.5	98.2±15.0	2.9±0.7	3.7±0.8	3.0
80-89	9	0.9±0.9	0.0±0.00	11.4±1.4	105.2±12.7	2.8±0.7	3.5±0.7	2.8
Sex								
Female	15	0.6±0.4	0.0±0.1	10.3±2.7	104.5±14.3	2.9±0.8	3.5±0.8	3.0
Male	14	0.8±0.7	0.0±0.0	9.8±1.8	99.0±15.1	2.8±0.5	3.5±0.6	2.8
Standing, slow aerobic warm-up								
All	29	1.4±1.2	0.1±0.4	12.0±2.5	108.0±16.0	3.4±0.6	4.2±0.7	3.5
Age Group								
60-69	10	1.6±1.1	0.2±0.6	12.6±2.5	113.4±20.8	3.6±0.7	4.3±0.8	3.5
70-79	10	1.3±1.4	0.0±1.4	12.1±2.0	103.6±15.4	3.4±0.6	4.4±0.7	3.5
80-89	9	1.5±1.1	0.0±0.0	11.4±1.4	106.8±7.6	3.3±0.4	4.0±0.6	3.3
Sex								
Female	15	1.0±0.6	0.0±0.0	11.9±2.4	107.6±13.3	3.4±0.7	4.1±0.8	3.5
Male	14	2.0±1.4	0.1±0.5	12.2±1.8	108.4±18.9	3.5±0.5	4.4±0.6	3.5
Standing, fast aerobic warm-up								
All	29	1.9±1.3	0.1±0.2	14.7±3.1	115.4±19.1	4.2±0.9	5.2±1.0	4.3
Age Group								
60-69	10	2.1±1.3	0.0±0.0	15.1±2.5	120.6±18.8	4.3±0.7	5.2±0.7	4.3
70-79	10	1.6±1.4	0.1±0.2	15.2±2.8	111.6±19.4	4.3±0.8	5.5±0.9	4.3
80-89	9	2.0±1.1	0.1±0.3	13.9±4.0	113.8±19.8	4.0±1.1	4.9±1.3	4.0
Sex								
Female	15	1.6±1.2	0.1±0.3	15.8±3.3	95.8±11.8	4.5±0.9[a]	5.4±1.1	4.5
Male	14	2.2±1.3	0.0±0.0	13.6±2.4	92.7±16.1	3.9±0.7[a]	4.9±0.9	4.0

[a]Standard METs were significantly different between males and females, P < .05.
[b]Corrected METs are based on methods of Kozey et al.(23) to estimate the energy cost during rest.
[c]Rounded METs are the standard METs with the significant digits rounded to nearest 0, 3, 5, and 8.

Comparison of mean pain scale scores was negligible (~ 0.1 on a 5-point scale) for all exercises between age groups and by sex (P > .05). Mean RPE scores differed by exercise, with the lowest scores observed for chair Tai Chi and chair Yoga (~7), and the highest scores observed for standing slow- (~12) and fast aerobic exercises (~15). No significant differences in RPE scores were observed between age groups and by sex for each exercise (Table 3) (P > .05).

The mean standard- and corrected MET values for exercises by age group are shown in Figure 1. Across all exercises, standard METs were significantly lower than corrected METs (P < .05).

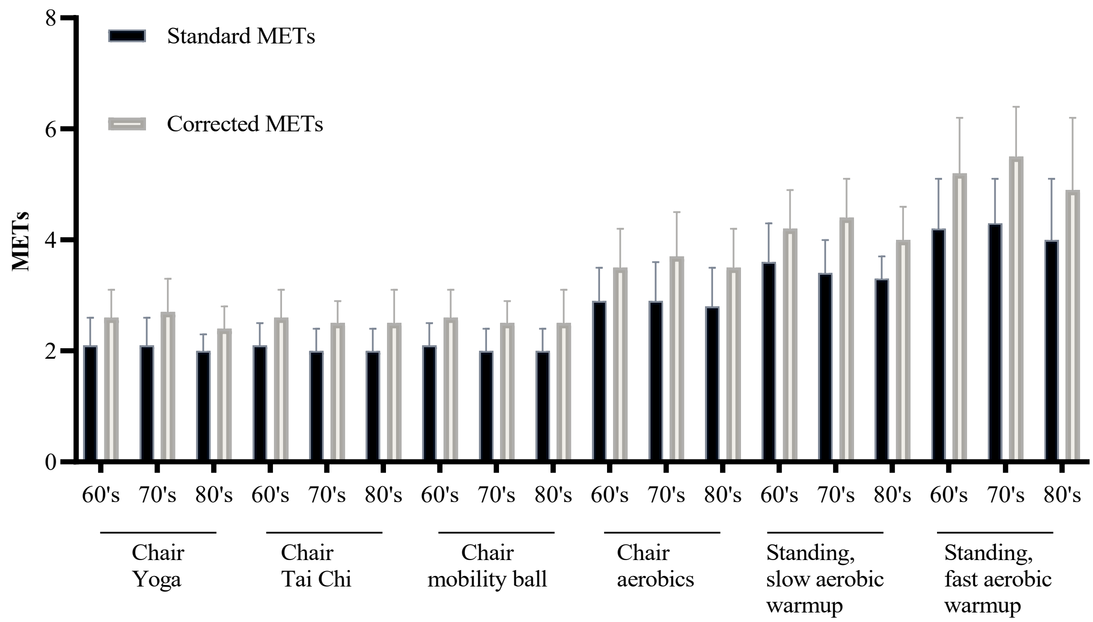

Figure 1. Average standard and corrected MET values for each exercise in the three age groups (60-69, 70-79, 80-89 y). All standard MET values were significantly lower than the corrected MET values (P < .05).

DISCUSSION

This study aimed to determine the MET intensities of six exercises adapted for older adults over 60 years to categorize the exercises by intensity levels. Results showed that the energy costs of two standing and four sitting exercises for all age groups (60-69, 70-79, 80-89 years) combined ranged from 2.1 ± 0.4 to 4.2 ± 0.9 standard METs and 2.6 ± 0.5 to 5.2 ± 1.0 corrected METs. Rounded METs ranged from 2.0 to 3.0 METs for sitting- and 3.5 to 4.2 METs for standing exercises.

Chair Yoga and chair Tai Chi (2.0 METs) require slow, upper-body rhythmic movements. These exercises were easy for participants to perform and seemed appropriate for older adults with low functional capacity and limited mobility. The chair mobility ball exercise (2.8 METs) involves rapid movements of the arms from side-to-side and up-and-down while holding a small ball. The exercise seemed appropriate for older adults who can move quickly and rise from sitting to standing without using their arms to rise out of a chair.
Moderate-intensity PAs, chair aerobics, and standing aerobic warm-ups, require more significant effort to perform. Chair aerobics (3.0 METs) is performed with a fast cadence and

coordinated movements of the hands and feet, moving forward, backward, and side-to-side. This exercise seems appropriate for older adults who can move their limbs rhythmically and follow a fast-paced exercise routine but may have limitations in balance or the ability to stand while exercising. The standing, slow aerobic warm-up (3.5 METs) requires few changes in body position and involves coordinated movements of the arms and legs; it seems appropriate for older adults who may lack the ability to change directions quickly. The standing, fast aerobic warm-up (4.2 METs) includes a fast-paced series of movements to music that requires rapid changes of direction and the ability to remember movement sequences. This exercise seems best suited for older adults with moderate physical fitness who can follow fast-paced movements.

There were no significant differences in the VO_2 values for exercises between age groups. We observed that men, especially those in the 80 to 89 year age group, had difficulty keeping pace with the rapidly changing movements in the standing, fast aerobic warm-up. In contrast, women of all ages could perform the fast, aerobic warm-up with little difficulty. This difference may be due to many Chinese women engaging in group dancing (called square dancing, as in dancing in a public square) regularly during weeknights and on weekends. (35) Overall, participants were able to follow the proper speed and rhythm during upper-body, slower-paced low-intensity exercises, and they were able to perform the moderate-intensity, seated mobility ball exercise with little difficulty. (32,42).

Comparison of the energy costs by sex showed no significant differences for all exercises, except for the standing, fast aerobic warm-up, where VO_2 levels were higher for females than males (4.5 ± 0.92 ml·kg^{-1}·min^{-1} vs. 3.9 ± 0.68 ml·kg^{-1}·min^{-1}). This difference may have resulted from men having difficulty keeping pace with the rhythm and movements of the exercise, resulting in shuffling the feet while standing in place. All exercises were in the same intensity category for males and females (light or moderate), except for the chair mobility ball, where the rounded METs for males was moderate intensity (3.0 METs), and the rounded METs for females was low intensity (2.8 METs). This difference is negligible as the Compendium does not separate MET values by sex.

We computed standard- and corrected MET values to show the differences in the exercise energy costs when using standard and individualized MET values (23). As expected, the average corrected METs were higher than the standard METs for all exercises (Figure 1). MET values were in the same intensity category for standard- and corrected METs (light or moderate intensity) except for the chair mobility ball, which was moderate intensity for the corrected METs and light intensity for the standard METs. The differences in MET values between standard- and corrected METs highlight the importance of using corrected METs to estimate the energy costs in individuals and standard METs in populations (15).

There were no significant differences between the participant's mean ratings of perceived exertion and pain by age group or sex during the exercises ($P > .05$). RPE values increased as the exercise intensity increased. While not statistically significant ($P > .05$), the mean RPE rating for the standing, fast aerobic exercise was higher in females than males, possibly reflecting higher oxygen costs for this activity in females.

This study is unique as it measures the energy cost of seated and standing video exercises that older adults can do at home, in a recreational center, and residential settings. The exercise videos are publicly available on the internet (YouTube) (Table 1). Past measures of PA's energy costs in older adults 60 to 85 years have focused on household chores (e.g., cleaning, cooking, and laundry, 1.3-4.0 METs) (1,10,47), gardening and yard work (e.g., planting, mowing the yard, and clearing brush, 1.5-7.0 METs) (1,8,38–40), walking PAs (8,21), and a few conditioning programs (e.g., outdoor circuit exercise and gym exercise, 1.5-4.8 METs) (7,11,24).

The 2011 Compendium (2) presents rounded MET values for four styles of yoga ranging from 2.5 METs for Hatha Yoga (code 02150) to an estimated 4.0 METs for Power Yoga (code 02160). However, none of these exercises are in a chair. The Compendium also identifies the energy costs of aerobic exercise routines, ranging from 5.0 METs for a low-impact routine (code 03020) to 9.5 METs for a bench-step routine (code 03017). MET values are not identified for seated aerobics and aerobics exercises suitable for older adults. Video exercises presented in the Compendium include activity-promoting video games (e.g., Wii Fit balance and yoga; Exergaming, Dance-Dance Revolution) and video conditioning programs (e.g., yoga, stretching, cardio-resistance) ranging from 2.0 METs to 7.2 METs. The Compendium needs revision to present PA MET values for activities performed by adults 60 years and older.

Over the past several decades, significant changes in social organization, individual behaviors, and an aging population have led to insufficient physical activity in older adults (22). Insufficient physical activity is associated with poor health outcomes, with sedentary adults over 50 years having twice the death risk as those who are physically active (13,27,36). As PA declines with age, older adults' physical abilities to engage in PA also decline (6,12,30). This decline can adversely affect older adults' health status and contribute to mobility disabilities and increased risks for chronic diseases (19,27). Knowing the energy costs of PAs suitable for older adults, especially those with mobility limitations, can aid efforts to provide exercise interventions to prevent the disabling health effects of sedentary and insufficiently active lifestyles.

This study has strengths and limitations. Its strength is in providing measured MET values for exercises performed by older adults with diverse physical abilities. Potential limitations include a relatively low sample size (N=29), the population studied, and measuring the exercise energy costs in a laboratory setting. We designed our study to include 10 participants per age group, a sample size with sufficient power (84%) to detect a 1 MET difference between exercise age-group means. However, mean values between age-groups were smaller than 1 MET (0.1 to 0.6 METs), resulting in insufficient power to detect differences in MET values between age-groups. Also, our participants were older Chinese adults; their energy costs may differ from persons of different races and ethnicity, body size, and BMI. However, one's sex, race and ethnicity, body size, and BMI are minimal concerns as the Compendium does not differentiate MET values based on these characteristics. We measured the exercise energy costs in a university laboratory while participants followed the video exercises on a large screen. MET values obtained in a laboratory may differ from those measured during exercises led by leaders in community settings.

Conclusion: The current study measured the MET energy costs of six video-based chair and standing exercises in adults, ages 60 years and older. Rounded, standard MET values ranged from 2.0 to 3.0 for chair exercises (Tai Chi, Yoga, mobility ball, and chair aerobics) and 3.3 to 4.2 for standing exercises (slow, aerobics warm-up and fast, aerobics warm-up) in all age groups. There was no difference in MET values for exercises by age groups (60-69, 70-79, 80-89 years). As expected, METs corrected for one's individual RMR (corrected METs) were higher than METs using a standard RMR of 3.5 $ml \cdot kg^{-1} \cdot min$. With global increases in aging populations, studies need to measure the energy costs of PAs and exercises of older adults.

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