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ORIGINAL ARTICLE

Gross and relative energy cost of domestic household activities in Asian men

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BACKGROUND/OBJECTIVES: Obesity is on the rise and participation in exercise has declined. Domestic household activities may help meet the recommended daily physical activity levels. This study aimed to measure the energy costs of household activities among Asian males.

SUBJECTS/METHODS: This was a randomised cross-over study conducted in a whole-body calorimeter. The energy costs of 14 domestic household activities, divided into two studies, were measured in 10 healthy Asian males. Participants' weight, height, body composition and basal metabolic rate were measured on the first test visit. A standard breakfast was served and participants rested for an hour before the measurement of energy costs of domestic household activities. During the measurements, each activity was performed for 20 min, and participants rested for 30 min between activities.

RESULTS: The mean energy costs of domestic household activities ranged from 5.92 to 11.97 kJ/min, which were significantly different between activities (repeated measures analysis of variance, $P < 0.001$). When expressed as metabolic equivalents (METS), all domestic household activities were classified as low-intensity physical activities. Actual METS ($METS_{actual}$) were significantly different to standard METS of eight activities, which may be partly explained by the universal assumption of 3.5 ml O_2/kg/min made during the calculation of METS in the Asian population.

CONCLUSIONS: The energy costs of a range of domestic household activities reported in this study may assist in the planning of physical activities among Asians to meet national physical activity guidelines.

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INTRODUCTION

Over-nutrition is a worldwide problem, and a rapid increase in the prevalence of overweight and obesity was also reported in Singapore. The prevalence of obesity in Singapore, defined as body mass index >30 kg m^{-2}, was reported to be 10.8% in 2010.[1] The prevalence of obesity was higher and grew more rapidly in males than females from 4.1% in 1992 to 12.1% in 2010. The growth was the highest in males aged below 60 years. On the other hand, the prevalence of obesity was lower among Singaporean females, reported to be 6.1% in 1992 and 9.5% in 2010.[1]

On the basis of an energy balance model, higher prevalence of obesity among Singaporeans may be attributed to their increasing dietary intake and/or decreasing physical activity levels. The National Nutrition Survey conducted in 2010 reported that total daily energy intake has increased by >600 kcal per day in males and ~500 kcal per day in females from 1998 to 2010.[2] Although higher dietary intake was associated with increasing prevalence of obesity, it is difficult to establish causation as higher intake may be due to higher-energy requirements after weight gain. However, faster growth in obesity prevalence among males in Singapore may partly be explained by the finding that they are less likely to eat healthily as compared with their female counterparts.[3] On the other hand, a more telling trend was found in the changes in physical activity patterns in recent years.

Evidence suggests that human energy expenditure contributed by physical activity has not declined in the past few decades,[4–6] although this is not confirmed by all.[7] Proxy measures for physical inactivity, such as increased second car ownership, increased use of labour-saving devices in the house and increased time spent on television viewing, have been related to the epidemiological increase in obesity.[8] However, some argued that this observation may be confounded by methodological limitations, and some studies did not include domestic household activities in their assessment of physical activity.[9] Taking into account of domestic household activities in the analysis, metabolic equivalents of tasks (METS) estimated from five national databases (US, UK, Brazil, China and India) revealed that METS-hour per week was in fact on the decline.[9] A decline in physical activity pattern was also observed in Singapore. The Health Promotion Board of Singapore recommended at least 150 min of physical activity per week for Singaporean adults, but this recommendation was not met by a majority of Singaporeans. The National Sports Participation Survey in 2011[10] has reported that 54% of their survey respondents indicated that they had not participated in any form of exercise in 3 months before the survey, which was 9% higher than the previous survey conducted in 2005. Moreover, the proportion of Singaporeans who exercised at least once a week has declined during this period of time. When examined based on gender, over half of Singaporean males and females reported a sedentary lifestyle (50 and 58%, respectively).

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In light of declining sports (often of vigorous intensity) participation, increasing light and moderate intensity physical activities may be an appropriate strategy to assist in body weight regulation. Indeed, non-exercise activity thermogenesis (NEAT) has been proposed to be an important component of human daily energy expenditure that helps regulate body weight,[11] and it refers to the energy used for a wide range of activities including domestic housework. There is a disparity in the amount of time spent on housework by males and females globally. Overall, smaller proportions of adult males engaged in household activities, and among those who did spent less time in those activities than adult females.[12–14] Given that most household activities are considered as low intensity, no difference in intensity of these activities is expected between genders. National time use survey data are not available in Singapore, but the data from 26 other countries revealed that females spent between 44 and 205 min per day more than males on domestic household activities.[15] Given that males spent less time on household activities and that weight problems are more serious in Singaporean males, increasing time spent on domestic household activities may be an appropriate compensation strategy to assist weight management. This suggestion is supported by epidemiological data from China, which reported an inverse relationship between domestic household activity participation and body weight of Asian adult males.[16] Before pursuing this idea further, the energy costs of common household activities in males need to be determined first, and this was the primary aim of our study.

METHODS

Study design

Data for this study were collected and combined from two randomised cross-over studies conducted in a whole-body calorimeter (WBC). Study 1 and Study 2 shared similar experimental protocols in a WBC, but participants performed two different sets of domestic household activities. Although a similar previous study recruited 18 participants,[17] the researchers used a portable device that required less resources than the WBC method used in our study. Therefore, we limited our target sample size to 10 participants per study based on the availability of the facility.

Participants

Both original studies recruited participants who were adult males, from an ethnic Chinese background, aged 21–39 years, non-smokers, not suffering from major diseases, not taking medication and not engaged in regular competitive sports that may alter energy expenditure. Participants were recruited from the university populations including students and staff, as well as from the local community through study flyers. Eligible participants provided written consent before study commencement.

Experimental protocol

This study consisted of a screening plus three test visits in a WBC. During the screening visit, volunteers were screened for eligibility before written consent was obtained. After enrolment, participants were familiarised with the WBC study protocol for test days, and they were reminded to avoid caffeine, alcohol and vigorous physical activities on the day before test visits. On test days, participants arrived at the research facility between 0800 and 0830 hours after an overnight fasting of 12 h. Upon arrival, participants' height and weight were measured (Seca 763 GmbH & Co., KG, Hamburg, Germany). Body composition was assessed using a four-compartment model[18] based on weight (Seca 763 GmbH & Co., KG), body volume measured by air displacement plethysmography (BodPod, Life Measurements Inc, Concord, CA, USA), total body water measured with bioelectric impedance (Tanita BC418, Tanita Inc., Tokyo, Japan) and bone mineral content measured with the dual-energy X-ray absorptiometry method (Hologic Discovery Wi, APEX Software version 4.0.1, Hologic Inc., Bedford, MA, USA). After anthropometric measurements, participants entered the WBC, where the resting metabolic rate (RMR) was measured for 45 min while participants were resting in a supine position. After RMR, participants consumed a standard breakfast consisting of biscuits and orange juice (1113 kJ in total). An hour after breakfast, participants were asked to commence domestic household activities. During each test visit in a WBC, the energy costs of up to three domestic household activities (randomised with https://www.randomizer.org) were measured. Participants performed each domestic household activity for 20 min, with a 30-min break between activities. Instruction videos were shown in an attempt to standardise the frequency and intensity of these activities across all participants. The study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures involving human participants were approved by the Domain Specific Review Board of National Healthcare Group (approval #2014/00631). This trial was also registered with clinicaltrials.gov (NCT02594618).

Domestic household activities

The energy costs of 14 domestic household activities were assessed in two separate studies. Study 1 assessed six activities, namely, folding laundry, ironing clothes, sweeping floor, cleaning bathroom, changing bedlinen and organising items, whereas study 2 assessed eight other activities including scrubbing floor, washing dishes, chopping vegetables, hanging clothes, stirring/whisking, clearing waste, mopping floor and making dough. The selected household activities in this study were performed regularly by both men and women. In addition, the selection of the household activities was based on feasibility within a WBC. These activities were also categorised as upper+static lower body (U static) or upper +dynamic lower body (U dynamic) domestic household activities.

Energy costs of domestic household activities

Energy expenditure was assessed through gaseous exchanges using a dual-room WBC facility located at the Clinical Nutrition Research Centre. The WBC chambers are open-circuit air-tight indirect calorimeters with a total volume of 13.5 m^3. Each chamber is furnished with a full-sized foldaway bed, a fold-down writing table, a folding chair, a television, a laptop, a computer network connection, a telephone, an intercom system, a deep-freeze toilet, and a built-in sink and mirror. A window on the door allowed researchers to check participants' compliance to performing domestic household activities. Before each test visit, the WBC was calibrated against standard gases. During test session, gaseous exchanges were measured continuously as oxygen consumption and carbon dioxide production through differences between inlet and outlet oxygen (O_2) and carbon dioxide (CO_2) concentrations. Oxygen concentration was measured using a paramagnetic O_2 analyser (Model AO2020, module Magnos206, ABB Automation GmbH, Friedburg, Germany), whereas carbon dioxide concentration was measured using an infrared photometer (Model AO2020, module Uras26, ABB Automation GmbH). The air samples are measured in an automated sequence and alternated with calibration span gas (18% O_2, 0.8% CO_2 and balance nitrogen) and zero (100% nitrogen) gases.[19] Gaseous exchanges were measured under standard temperature, pressure and dry. The accuracy of the WBC chambers was routinely tested through the combustion of a known amount of methanol. The accuracy of O_2 and CO_2 measurements in our WBC facility was $O_2 = 100.6 \pm 0.5\%$ (chamber 1) and $100.9 \pm 0.4\%$ (chamber 2), and $CO_2 = 99.2 \pm 0.5\%$ (chamber 1) and $99.7 \pm 0.5\%$ (chamber 2), whereas the coefficient of variation was 3.0% ($n = 21$) for repeated 30-min RMR measurements with our WBC facility.

Data and statistical analysis

Energy expenditure was calculated based on volume of O_2 consumption (VO_2) and CO_2 production (VCO_2) using the Weir equation.[20] RMR was defined as a 20-min steady-state energy expenditure measured during the 45-min measurement period. Oxygen consumption per minute per kg body weight during RMR measurement was also calculated. Energy costs of domestic household activities were calculated as energy expenditure during the final 15 min (steady state) of the 20-min household activity data. In addition, they were calculated per unit fat-free mass (FFM) to normalise the energy expenditure of activities. $METS_{actual}$ were based on the O_2 consumption per kg body weight per minute during the RMR measurement, and METS were calculated based on the standard protocol of 3.5 ml O_2 consumption per kg body weight per minute. Descriptive statistics were reported as mean ± s.d. The distribution of data was checked with normality tests, and parametric or non-parametric tests were chosen accordingly. Correlations between body weight and energy costs were performed with Pearson's correlation coefficient. Independent-samples *t*-tests were used to compare participants' demographics between study 1 and 2, and paired-samples *t*-tests were used to compare $METS_{actual}$ and

METS of each domestic household activity, and differences between $METS_{actual}$ and METS of all 14 domestic household activities were compared using a general linear model for repeated measures analysis of variance with Bonferroni corrections. Statistical analyses were performed with the statistical package SPSS (version 23.0, IBM Inc., Chicago, IL, USA).

RESULTS

Demographics

Participants' anthropometric measurements and RMR (kJ/min) are shown in Table 1. Oxygen consumption per kg body weight per minute during RMR was 3.24 ± 0.45 ml/kg/min (study 1) and 3.18 ± 0.26 ml/kg/min (study 2). These variables were not statistically significant between study 1 and 2 ($P > 0.05$).

Energy costs of domestic household activities

The energy costs of various domestic household activities measured in this study are presented as energy expenditure (EE), EE per kg FFM, $METS_{actual}$ and METS in Table 2. Energy costs were significantly different between all domestic household activities (general linear model for repeated measures analysis of variance, $P < 0.001$). The actual and standard METS of domestic household activities in this study were also compared against METS published in previous studies and the Compendium of Physical Activities[21,22] (Table 3). Body weight correlated with the (a) EE of organising items ($r = -0.671$, $P = 0.048$) only, (b) $METS_{actual}$ of mopping floor ($r = -0.665$, $P = 0.036$) only and (c) METS of folding clothes ($r = -0.774$, $P = 0.014$), cleaning bathroom ($r = -0.864$, $P = 0.003$), changing bedlinen ($r = -0.814$, $P = 0.004$), organising items ($r = -0.765$, $P = 0.016$), mopping floor ($r = -0.769$, $P = 0.009$), and dough making and kneading ($r = -0.646$, $P = 0.044$). $METS_{actual}$ and METS of scrubbing floor, washing dishes, chopping vegetables, hanging clothes, mopping floor, clearing waste, stirring and whisking, and dough making and kneading were significantly different (paired *t*-tests, $P < 0.05$; Table 2). Table 4 shows the amount of time (in minutes) of domestic household activities that is equivalent to the recommended 150 min a week of moderate activity at 4.3 METS (brisk walking for exercise at 3.5 m.p.h.).

Table 1. Participants' baseline characteristics

	Study 1 (n = *10*)	*Study 2* (n = *10*)
Age (years)	25.4 ± 3.7	26.4 ± 5.1
Weight (kg)	64.8 ± 3.2	64.4 ± 2.3
Height (m)	1.73 ± 0.01	1.70 ± 0.03
BMI (kg/m^2)	21.5 ± 1.3	22.2 ± 0.6
FM (%)	15.7 ± 6.7	17.7 ± 6.4
FFM (kg)	54.0 ± 3.6	52.5 ± 4.0
RMR (kJ/min)	4.27 ± 0.50	4.14 ± 0.29

Abbreviations: BMI, body mass index; FM, fat mass; FFM, fat-free mass; RMR, resting metabolic rate. All variables were not statistically significant between studies.

DISCUSSION

The aim of this study was to determine the energy costs of selected domestic household activities among Singaporean adults, which could be applied to increase NEAT and assist weight regulation. Energy costs of domestic household activities were presented in a number of ways such as EE, EE per kg FFM, $METS_{actual}$ and METS. These methods differ in complexity and could be applied in different settings. Energy costs of activities are discussed in greater details as follow: from the simplest EE method, to the $METS_{actual}$ and METS that account for basal metabolic rates.

In our study, the mean EE for 14 activities ranged from 5.92 to 11.97 kJ/min. Three previous studies that recruited Asians also reported the energy costs of a range of household activities, among which three were also measured in our studies. The energy costs of these three household activities were lower or similar to our observations: (1) sweeping floor costs 5.70,[23] 3.20[24] and 9.20 kJ/min[25] vs 9.37 kJ/min in our study; (2) organising items costs 3.07 kJ/min[24] vs 11.72 kJ/min in our study; and (3) mopping floor costs 4.25 kJ/min[24] vs 10.10 kJ/min in our study. The discrepancies are likely to be explained by the different genders, ethnicity and how the activities are conducted between studies. To enable comparison of energy costs between two study populations, EE per kg FFM was also calculated. Another reason EE per kg FFM was calculated was because only male adults were recruited in our studies, and per unit FFM values may allow us to use the values to estimate energy costs of these domestic household activities in females too. This tabulation was supported by a previous study that did not find a difference in energy cost of

Table 2. EE, EE per kg FFM, $METS_{actual}$ and METS of domestic household activities

	Activity type[a]	*EE*[b] *(kJ/min;* n = *10)*	*EE per kg FFM*[b] *(kJ/kg/min;* n = *10)*	*$METS_{actual}$*[b] *(*n = *10)*	*METS*[b] *(*n = *10)*	*Correlation, $METS_{actual}$ and METS,* r *(*P*)*	*t-tests $METS_{actual}$ vs METS,* P
Folding laundry[c]	U static	8.15 ± 0.46	0.15 ± 0.02	1.95 ± 0.29	1.76 ± 0.16	0.007 (0.986)	0.117
Ironing clothes	U static	7.48 ± 0.42	0.14 ± 0.01	1.79 ± 0.27	1.63 ± 0.12	− 0.014 (0.970)	0.116
Washing dishes	U static	7.18 ± 0.80	0.14 ± 0.01	1.75 ± 0.20	1.58 ± 0.19	0.745 (0.013)[d]	0.004[d]
Chopping vegetables	U static	7.01 ± 0.84	0.13 ± 0.01	1.70 ± 0.20	1.54 ± 0.20	0.796 (0.006)[d]	0.003[d]
Dough making and kneading	U static	8.06 ± 0.92	0.15 ± 0.02	1.93 ± 0.20	1.76 ± 0.24	0.818 (0.004)[d]	0.003[d]
Sweeping floor	U dynamic	9.37 ± 1.26	0.17 ± 0.03	2.25 ± 0.43	2.05 ± 0.30	0.575 (0.082)	0.102
Cleaning bathroom[c]	U dynamic	9.62 ± 0.67	0.18 ± 0.01	2.30 ± 0.27	2.08 ± 0.22	− 0.142 (0.716)	0.127
Changing bedlinen	U dynamic	11.97 ± 0.76	0.22 ± 0.02	2.88 ± 0.39	2.62 ± 0.24	0.033 (0.928)	0.118
Organising items[c]	U dynamic	11.72 ± 2.35	0.22 ± 0.05	2.84 ± 0.81	2.56 ± 0.62	0.778 (0.014)[d]	0.127
Scrubbing floor	U dynamic	8.65 ± 1.22	0.17 ± 0.02	2.08 ± 0.26	1.89 ± 0.24	0.786 (0.007)[d]	0.005[d]
Hanging clothes	U dynamic	8.90 ± 0.84	0.17 ± 0.02	2.16 ± 0.17	1.95 ± 0.17	0.500 (0.141)	0.004[d]
Stirring/whisking	U dynamic	5.92 ± 0.50	0.11 ± 0.01	1.43 ± 0.10	1.30 ± 0.11	0.423 (0.223)	0.005[d]
Clearing waste	U dynamic	9.28 ± 1.20	0.18 ± 0.03	2.25 ± 0.26	2.04 ± 0.27	0.772 (0.009)[d]	0.005[d]
Mopping floor	U dynamic	10.08 ± 0.97	0.19 ± 0.02	2.43 ± 0.25	2.20 ± 0.27	0.748 (0.013)[d]	0.004[d]

Abbreviations: EE, energy expenditure; FFM, fat-free mass; GLM RMANOVA, general linear model for repeated measures analysis of variance; METS, metabolic equivalents. [a]Classification of activities: U static—upper+static lower body domestic household activities; U dynamic—upper+dynamic lower body domestic household activities; [b]Significantly different between domestic household activities, GLM RMANOVA, $P < 0.001$; [c]$n = 9$; [d]Statistical significance, $P < 0.05$.

Table 3. Comparison of METS between measured, published and compendium values

	$METS_{actual}$ (range)	Published	Compendium[21,22]	Compendium activity code
Chopping vegetables	1.70 ± 0.20 (1.39–1.96)	—	2.0	05050 cooking or food preparation—standing or sitting or in general (not broken into stand/walk components), manual appliances
Stirring/whisking	1.43 ± 0.10 (1.32–1.60)	—		
Dough making and kneading	1.93 ± 0.20 (1.69–2.37)	—		
Folding laundry[a]	1.95 ± 0.29 (1.67–2.55)	2.3[CA 42]	2.0	05090 implied standing – laundry, fold or hang clothes
Hanging clothes	2.15 ± 0.17 (1.91–2.40)	1.4–1.7[AS 30]		
Ironing clothes	1.79 ± 0.27 (1.54–2.41)	—	2.3	05070 ironing
Sweeping floor	2.25 ± 0.43 (1.58–3.05)	3.1–3.5[CA 31,32,42–44]	2.3	05011 cleaning, sweeping, slow, light effort
Washing dishes	1.75 ± 0.20 (1.54–2.20)	1.2–1.6[AS 30] 2.3[AS 17] 1.9[CA 42]	2.3	05041 wash dishes
Changing bedlinen	2.87 ± 0.39 (2.45–3.66)	2.0–2.5[AS 30]	2.5	05040 cleaning, light (dusting, straightening up, changing linen, carrying out trash
Clearing waste	2.25 ± 0.26 (1.85–2.61)	—		
Organising items[a]	2.84 ± 0.80 (2.14–4.26)	—	3.5	05146 Standing—packing/ unpacking boxes
Mopping floor	2.43 ± 0.25 (1.92–2.80)	2.3–2.7[AS 30] 3.5[CA 42]	3.5	05021 mopping
Cleaning bathroom[a]	2.29 ± 0.27 (2.01–2.88)	—	3.8	05130 scrubbing floor, on hands and knees, scrubbing bathroom, bathtub
Scrubbing floor	2.09 ± 0.25 (1.63–2.38)	—		

Abbreviations: AS, Asians; CA, Caucasians; METS, metabolic equivalents. [a]$n = 9$.

Table 4. Amount of time to spend on domestic household activities to meet the minimum recommended physical activity level of 150 min per week at METS 4.3 intensity

	$METS_{actual}$ (ascending)	Minutes required to meet the minimum recommended 150 min per week at METS 4.3 (walking for exercise at 3.5 m.p.h., brisk)
Stirring/whisking	1.43 ± 0.10	451 min per week
Chopping vegetables	1.70 ± 0.20	380 min per week
Washing dishes	1.75 ± 0.20	369 min per week
Ironing clothes	1.79 ± 0.27	360 min per week
Dough making and kneading	1.93 ± 0.20	334 min per week
Folding laundry[a]	1.95 ± 0.29	330 min per week
Scrubbing floor	2.08 ± 0.26	309 min per week
Hanging clothes	2.16 ± 0.17	299 min per week
Clearing waste	2.25 ± 0.26	286 min per week
Sweeping floor	2.25 ± 0.43	286 min per week
Cleaning bathroom[a]	2.30 ± 0.27	281 min per week
Mopping floor	2.43 ± 0.25	266 min per week
Organising items[a]	2.84 ± 0.81	227 min per week
Changing bedlinen	2.88 ± 0.39	224 min per week
Means of 14 activities ($n = 137$)	2.12 ± 0.51	304 min per week or 44 min per day

Abbreviation: METS, metabolic equivalents. [a]$n = 9$.

domestic household activities between men and women after being calculated as per unit FFM.[26] Hence, we believe that EE per kg FFM in this study is transferable to Asian females, but confirmation through future research is required. Future studies should also include adults from a wider range of body weight to examine whether the energy costs of these domestic household activities are applicable to adults who are overweight or obese. If EE per kg FFM is proven to be transferable across all gender and weight groups, it will provide a simple, quick and easy method to predict energy expenditure related to domestic household activities in a clinical setting in the future.

Apart from EE per kg FFM, METS is also an accepted and widely used method in quantifying physical activity intensity, as well as in the calculation of total energy expenditure for a range of activities.[22] In 1936, Dill[27] proposed that exercise intensity can be expressed as the ratio of the work metabolic rate to the RMR, METS, and further recommended guidelines for classifying physical activity into moderate, hard and maximal intensity categories. Now METS are based on the World Health Organization's physical activity intensity cutoffs,[28] and all domestic household activities in this study were classified as low-intensity physical activities (both $METS_{actual}$ and METS were below 3.0). The METS values reported in the Compendium of Physical Activity[22] were compiled predominantly from the Caucasian populations. To date, only three studies reported the METS of domestic household activities in Asians.[17,29,30] The METS of resting, sitting and standing were only measured in a study,[29] and it was excluded in our discussion. In the first of the two other studies of an Asian population, the METS of domestic household activities (those that were also investigated in our study) were 1.6 ± 0.4 for washing laundry (similar or close to washing dishes in our study), 1.7 ± 0.3 for hanging clothes (identical), 2.5 ± 0.7 for making bed (similar to changing bedlinen in our study) and 2.7 ± 0.5 for mopping floor (identical), in younger adults.[30] These values were in close agreement with the METS documented in our study. In the second study, older adults were recruited and washing dishes was the only domestic household activity that was in common with our study. The METS of washing dishes were reported to be 2.3 ± 0.5,[17] which was higher than 1.58 ± 0.19 in our study. Greater metabolic demand for older adults to perform domestic household activities is not likely to be to be the explanation as METS of domestic household activities in this age group have been shown to be either lower[30] or comparable[31,32] but not higher than younger populations. Therefore, a difference in METS for washing dishes may be explained by differences in the measurement method (a portable calorimeter was carried at the back and may increase energy demand in older adults) and study duration (5- vs 20-min measurements).

Although all domestic household activities in this study are classified as low-intensity physical activity, together or when done over longer periods they can contribute significantly to the total amount of physical activity. The Health Promotion Board of Singapore recommends >150 min of physical activity per week for Singaporean adults. It requires 44 min per day of mixed household activities to mimic the minimum recommended 150 min of walking a week. When compared with 150 min of brisk walking for exercise (METS = 4.3) per week, the results demonstrate that it only requires 44 min of mixed household activities per day to reach the same level of physical activity. In other words, household activities can contribute to meet the recommended amount of physical activity per week. In light of the declining sports participation, the part of NEAT within daily energy expenditure has gotten more attention.[33] NEAT, which includes household activities and less sitting time, has been proposed as pivotal factors in the regulation of energy expenditure and weight management.[34]

Mayer *et al.* were the first to propose that energy balance is best regulated at high (but not excessive) levels of physical activity. They further hypothesised that there may be a minimal threshold of energy throughput for optimal weight regulation.[35] By increasing physical activity, one is more likely to be above threshold and reach the well-regulated zone in which energy intake and expenditure are very sensitive to each other.[36,37] Following this theory, Hill *et al* predicted that weight gain in 90% of the population could be prevented by reducing the positive energy balance by 100 kcal per day (420 kJ per day).[38] In China, Zhai *et al.*[39] found that a decrease in the positive energy balance by 45 kcal per day (189 kJ per day) would prevent weight gain. To put this in perspective and show the relevance of household activities, 45 kcal per day (189 kJ per day) could be achieved by doing 21 min of a mix of the tested household chores per day. Therefore, household activities might be considered as an easy non-invasive way to increase energy expenditure and decrease the positive energy balance and promote weight maintenance.

A number of challenges were faced in this study when expressing physical activity in a universally comparable way. First, significant differences were found between $METS_{actual}$ and METS (Table 1), which were derived from the assumed vs measured rate of O_2 usage. The assumption that 3.5 ml of oxygen is used per kg body weight per minute may not be appropriate for our population in Asia. This can be explained by a higher fat percentage or a less metabolically active body composition in Asians at a certain body mass index when compared with Caucasians.[40] Indeed, oxygen consumption per kg body weight per min was found to be 3.24 ± 0.45 in Study 1 and 3.18 ± 0.26 in Study 2. When compared with the assumed value (3.5 ml/kg/min), the values from study 1 were not significantly different (*t*-test, $P = 0.495$), but they were significantly different in study 2 (*t*-test, $P = 0.004$), which explained the significant differences between $METS_{actual}$ and METS observed from study 2 (Table 1). The error generated from the assumed 3.5 ml O_2/kg/min was not unique to our study and has also been reported previously.[41,42]

Second, a comparison of the METS of domestic household activities from our study against published values[22] revealed noticeable discrepancies (Table 2) and may lead to errors in EE estimation if METS are used in a clinical setting among Asians. Biggest differences were found in domestic household activities such as cleaning bathroom, scrubbing floor, mopping floor and organising items, where the METS values were smaller in our study population. Possible explanations to this include differences in the study population used in the compendium (older adults, women and Caucasians), variations in the activity intensity and the pace when these activities were measured and space limitations. The differences in study populations may underlie the inappropriate assumption of 3.5 ml O_2/kg/min as discussed earlier, whereas the pace and activity intensity are thought to be an even bigger contributor. Although the WRC provides a comfortable environment to measure energy costs of various domestic household activities, it was limited in space within the chamber and hence may have produced lower METS on activities that may originally require some mobility such as sweeping, mopping and scrubbing floor. In previous studies where energy costs were measured using a portable Douglas bag method (hence not space-limiting), the METS of sweeping and mopping floor (Table 2) were reported to be higher than the METS in our study.[31,32,43,44] However, because lower METS (than the Compendium) were also found in stationery domestic household activities that did not require mobility such as washing dishes in this study, limited space in the WBC cannot be the only explanation. Hence, other factors such as potential differences in mechanical efficiency in performing these activities, and the differences in intensity of domestic household activities between study participants in the WBC were also considered. The pace and intensity of domestic household activities performed were difficult to standardise even though participants were asked to replicate the activities shown on the instruction videos. Through our observations, activities such as scrubbing the floor, dough making and kneading, and organising items were performed at different levels of intensity between individuals. Our observations were also confirmed by the bigger variation of METS found in these activities. There is also a trend where domestic household activities that were higher in METS tended to have higher standard deviations. Although it is difficult to standardise the intensity, inter-individual variations in activity pace could be standardised using a metronome in future studies.

Third, the compendium of physical activity provides broad activity codes/groups, and, in some instances, a number of domestic household activities in our study shared a same activity code (Table 2). The METS of these activities varied because of the nature of the activities, but only one METS value was provided by the compendium, and hence may lead to over- or under-estimation of total energy expenditure when used in a clinical setting. In addition, the compendium classified four of the activities in our study as moderate intensity (3.0–6.0), but the METS in our study were all below the 3.0 cutoff. In summary, our observations suggest that METS based on the 1-MET constant may not be appropriate for Asians, and adjustments to METS calculation[45] may be required if these values are to be compared with the compendium.

CONCLUSIONS

This study provided energy costs of common domestic household activities to be used in an Asian population, which could be used while planning and prescribing daily physical activities to increase NEAT of Asian males. This way household activities can contribute to meet the recommended amount of physical activity per week. Moreover, they might be considered as an easy means to increase energy expenditure, decrease a positive energy balance and promote weight maintenance. The use of METS from the compendium of physical activity may overestimate physical activities in this population and should be used with care.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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