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Step rate-determined walking intensity and walking recommendation in Chinese young adults: a cross-sectional study

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ABSTRACT

Abstract: There is lack of data on the physiological characteristics of over ground walking and walking recommendations for Chinese young adult. The purpose of the study was to measure walking-related energy expenditure during field testing, to identify step-rate cut-point associated with moderate and vigorous intensity, and to translate physical activity (PA) guidelines into walking goals for Chinese young adults.

Design: Cross-sectional analytic study.

Setting: Two communities from Beijing and Shanghai in China.

Participants: A sample of 226 Chinese adults (117 men, 109 women) with a mean age of 21.7 (±0.2) years, volunteered to participate in the study. All Participants were recreationally active without orthopaedic limitations, free of chronic diseases, not taking any medications that affect metabolism and non-smokers.

Outcome measures: All the participants completed four 6 minincremental over ground walking at different speeds of 3.8, 4.8, 5.6 and 6.4 km/h, respectively. Indirect calorimeter was used to measure energy expenditure at each speed. Receiver operating characteristic curves were used to determine the step-rate cut-points associated with moderate and vigorous intensity activity.

Results: At the same walking speed, step counts per minute were higher in women than in men. No significant differences were found in VO_2 per weight (ml/kg/min) between women and men. Step-rate cut-point associated with walking at 3 metabolic equivalents (METs) and 6METs were 105 and 130 step/min when analysing men and women together. There were slight differences on the cut-points between women and men if data were analysed separately.

Conclusions: In order to meet PA guidelines, Chinese young adult should walk 30 min with at least 105 step/min or 3150 steps or 2 km with the same step-rate per day. Walking at a higher speed of 130 step/min might provide additional health benefit.

ARTICLE SUMMARY

Article focus

- The purpose of the study was to measure walking-related energy expenditure during field testing, to identify step-rate cut-point associated with moderate and vigorous intensity and to translate physical activity guidelines into walking goals for Chinese young adults.
- Step-rate cut-point associated with walking at 3 metabolic equivalent (3METs) and 6METs were 105 step/min and 130 step/min when analysing men and women together. There were slight differences on the cut-points between women and men if data were analysed separately. In order to meet PA guidelines, Chinese young adult should walk 30 min with at least 105 step/min, or 3150 steps or 2 km with the same step-rate per day. Walking at a higher speed of 130 step/min might provide additional health benefit.

Strengths and limitations of this study

- One strength of the present study was large sample size and EE measurement in field settings, which provide sufficient power to identify the step-rate cut-points accurately. Another strength was to provide Chinese young adults a walking recommendation in the form of relative flexible assistive tool. People can achieve their own exercise goal by using different calculations, such as step rate, walking during, total walking steps and/or walking distance. There were a number of limitations in this study. The first limitation was the small age range of young participants. It was known that gait and energy expenditure will be different between older and young individuals. Therefore, the cut-point established might not be suitable for older population. The second limitation was the use of a constant (3.5 ml/kg/min) as an estimated value of resting energy expenditure, so the step-rate cut-point developed by the estimated value of MET might be overestimated. The third of limitation was lack of cross-validation.

INTRODUCTION

Engaging in adequate amounts of physical activity (PA) has positive effect on energy balance, weight control, cardiorespiratory fitness and other health benefits.[1–5] It has been recommended that all adults perform at least 30 min of moderate-intensity aerobic

activity 5 day each week to achieve health benefits of exercise, and PA of greater intensity or of longer duration can promote additional benefits to health.[3] Among all the activities, walking is regarded by public as the most common exercise.[6] Obviously it is a meaningful research area to explore how much walking is enough to meet PA guideline.

Some steps-based walking recommendation is developed by researchers.[7–10] The most widely recognised step recommendation is to accumulate 10 000 steps/day. However, the goal of 10 000 steps per day is based on very limited evidence, may be unrealistic for many people.[11] In addition, it has not incorporated the activity intensity. Intensity is an important index of PA recommendations due to health benefits depend on the intensity of activity.[12]

Step rate (step/min) is one of the important parameters of walking gait and can be used to identify intensity in free-living walking.[13] In addition, step rate, as a simple indicator of ambulatory behaviour, can be captured easily. More specific, if walking duration and step numbers are known, intensity (step rate) can be calculated, therefore, certain specific cut-points (step/min) can be used to indicate intensity categories. Recently, studies have been conducted to identify step rates that correspond to intensity classifications.[14 15] These studies have found that walking at a pace of 100 step/min corresponds to moderate intensity and this finding may be used to promote public health recommendation of accumulating 3000 steps in 30 min to meet PA guidelines. Although these studies provide insightful data, there are limitations in their research methods. First, step-rate cut-points were obtained under controlled laboratory conditions, such as treadmill walking, which may differ from realistic activities (such as ground walking). Second, the small sample sizes from these previous studies limit its generalisability to larger population.

Physiological responses of PA are dependent on the biological characteristics of the study population, such as race, height, weight, gender and age.[16] Most current walking recommendation studies were based on Westerners.[17 18] No studies have been conducted in Chinese sample. It is well known that China is experiencing rapid economic growth. In China, family-owned vehicle is getting more popular; therefore, more young people are driving instead of walking for daily activities. An evidence-based walking recommendation is critical for Chinese adults.

The purposes of this study were: (1) to identify step-rate threshold associated with moderate and vigorous intensity activity for Chinese young adult and (2) to translate PA guidelines into walking recommendation for Chinese young adults.

METHODS

Participants

A community-based sample of 226 Chinese adults (117 men, 109 women) with a mean age of 21.7 (±0.2) years volunteered to participate in the study. All participants were recreationally active without orthopaedic limitations, free of chronic diseases, not taking any medications that affect metabolism and non-smokers. This study was reviewed and approved by China Institute of Sport Science Institutional Review Board. Participants provided written informed consent to participate in the study.

Walking testing

For walking test, we applied the previously established method to control over ground walking speed.[19] Briefly, an indoor room at room temperature (22.5±0.7°C), well ventilated and with concrete floor was used. An area of 15 m×10 m rectangular field (circumference of 50 m) was marked. Markers were placed on the edges (four sides) of the field with 5 m apart and used as tracking indicators while the subjects were walking along the edges. Participants were required to perform four walking tests at four different walking speeds 3.8, 4.8, 5.6 and 6.4 km/h for 6 min, respectively. During the test, participants were reminded of remaining natural gait, looking straight and moving from one marker to the next. They took 10 min rest before the test, and 5 min rest between each test. It was proved that subjects could easily maintain the preset walking speed by following the instructions and markers on the ground, and also keep the normal, relaxed walking manner.[19]

Energy expenditure was measured by the Cortex MetaMax 3B metabolic analyser (German). Steady-state VO_2 was recorded as an average of the last 2 min of each exercise bout. Metabolic equivalents (METs) were calculated by dividing steady-state VO_2 by 3.5 ml/kg. Moderate intensity was defined as 3.00–5.99 METs, while vigorous intensity for 6.00–8.99 METs.

After participants reached the steady state at each walking speed level (after 3 min), the steps per min were recorded by a trained staff through hand counter. Numbers of steps were recorded twice at each walking speed, and the average value was calculated.

Height and weight measurement

Height was measured without shoes to the nearest 0.1 cm using a calibrated electronic height metre. Weight was measured in light clothing and without shoes to the nearest 0.1 kg using a calibrated electronic scale. Body mass index was calculated as weight in kilograms (kg) divided by height in metres squared.

Statistics analysis

Descriptive statistics were expressed as mean±SD for the physiological variables under each walking speed. Gender differences were tested using independent t tests.

Step-rate cut-points were determined using receiver operating characteristic (ROC) curves. ROC curves were developed to examine optimal cut-points in terms of sensitivity (correctly identifying participants who were at

Table 1 Participant characteristics by gender

Variable (Mean±SD)	Women	Men	All
n	109	117	226
Age (year)	21.8±2.0	21.7±2.0	21.7±2.0
Height (cm)	166.2±5.4	175.7±5.0	170.1±6.1
Weight (kg)	59.6±8.3	69.1±8.4	64.5±9.6
BMI (kg/m^2)	21.5±2.5	22.4±2.4	22.0±2.5

BMI, body mass index.

moderate intensity or vigorous intensity activity) and specificity (correctly identifying those who were not at moderate intensity or vigorous intensity activity).

An α level of 0.05 was used to determine significance for all statistics analysis. All analyses were performed using SPSS V.16.0.

RESULTS

The characteristics of the study participants are presented in table 1. Comparison between men and women regarding measured variables at each walking speed in men and women is presented in table 2. The heart rate and VO_2 (l/min) in men were significantly higher ($p<0.05$) than those in women at the same speed of walking. When VO_2 was adjusted for body mass, the sex effect disappeared. No significant differences were found in VO_2 per kg between women and men across different speeds.

Table 2 also shows that under the same walking speed, the step rate was different among participants. At the same walking speed, step rate was higher in women than in men. Although higher step rate consumes more EE, there is no significant relationship between VO_2 and step rate within each speed (Pearson correlation coefficient r=0.28). The step rate increased accordingly while the walking speed increased in both men and women. There was significant correlation between the step rate and VO_2 (Pearson correlation coefficient r=0.73).

There were significant differences between the MET value calculated from measured VO_2 with recommended value from PA Compendium.[20] The measured METs were significantly higher than recommended value at 4.8, 5.6 and 6.4 km/h, respectively (figure 1).

The different cut-point regarding step rate among men and women is shown in table 3. According to MPA and VPA identified from indirect calorimetry, ROC-curve suggested that the optimal step-rate cut-point was 105 step/min for MPA with 85% sensitivity and 74% specificity. For the VPA cut-point, the optimal step-rate was 130 step/min with 96% sensitivity and 67% specificity. Women had slightly higher cut-point than men.

DISCUSSION

The main purpose of this study was to use indirect calorimeter to identify a step-rate cut-point associated with activity intensity in a field environment. To our knowledge, this was the first attempt to establish a walking target for Chinese people. We identified the optimal step-rate cut-point was 105 step/min for MPA and 130 step/min for VPA. Applying cut point for MPA to calculate the walking steps and distance taken to meet

Table 2 Comparison between men and women regarding measured variables at each walking speed

		Men		Women		
		Mean	SD	Mean	SD	p Value
3.8 km/h	HR	83.2	10.3	87.8	9.1	0.02
	VO_2 (ml/kg/min)	10.47	0.67	10.32	0.69	0.25
	VO_2 (l/min)	0.72	0.05	0.61	0.04	<0.00
	METs	2.93	0.21	2.91	0.19	0.78
	Step rate (step/min)	95.71	3.12	97.46	3.36	<0.00
4.8 km/h	HR	93.3	11.1	102.3	9.6	<0.00
	VO_2 (ml/kg/min)	13.94	1.41	13.58	1.63	0.82
	VO_2 (l/ min)	0.97	0.12	0.82	0.14	<0.00
	METs	4.02	0.45	3.96	0.61	0.40
	Step rate (step/min)	113.06	6.25	115.68	5.85	0.001
5.6 km/h	HR	102.2	11.6	113.4	11.0	<0.00
	VO_2 (ml/kg/min)	15.99	1.72	15.94	1.86	0.84
	VO_2 (l/min)	1.10	0.14	0.95	0.18	<0.00
	METs	4.58	0.50	4.58	0.71	0.95
	Step rate (step/min)	119.61	6.22	123.01	6.93	<0.00
6.4 km/h	HR	114.2	14.3	126.9	12.9	<0.00
	VO_2 (ml/kg/min)	19.07	2.29	19.02	2.66	0.88
	VO_2 (l/min)	1.32	0.19	1.14	0.21	<0.00
	METs	5.46	0.67	5.50	0.93	0.74
	Step rate (step/min)	126.01	7.02	131.00	8.40	<0.00

HR, heart rate; METs, metabolic equivalent, divide VO_2 by 3.5 ml/kg.

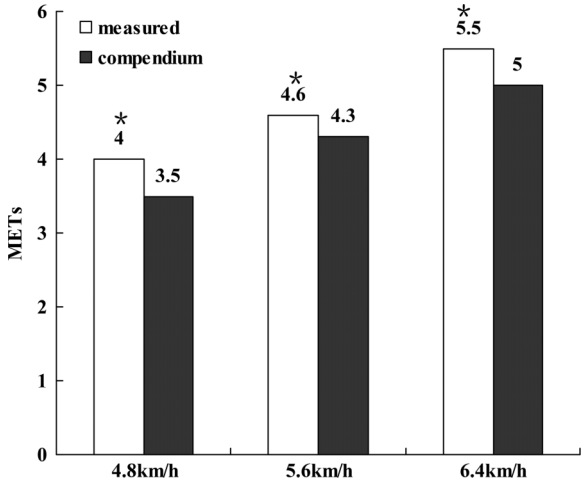

Figure 1 White column: measured value. Black column: PA Compendium recommendation. Comparison of the measured metabolic equivalents value and Compendium. (*significantly different (one-sample t test) from Compendium value).

PA guidelines, 30 min of moderate-intensity activity corresponds to 3100 steps in young men and 3200 steps in young women, or roughly 3150 steps for both. If steps are converted to walking distance, it is about 2 km.

We tested four different walking speeds in this study. Three of them were significantly corresponded with PA Compendium.[20] When compared with EE reference from PA Compendium, the EE measured from our study was higher for three walking speeds. Previous studies showed inconsistent results when comparing measured EE with compendium reference. Some reported higher value,[21] others reported lower value.[22 23] The inconsistency might be due to difference in sample characteristics, testing methods and test environment.[21 24 25] Therefore, it is not proper to perform complete result comparisons for different test condition. For the current study test setting might be a contributor to the difference. We conducted the walking test in a field setting, not on a treadmill. Our previous study found that walking-related energy expenditure in the field was different from treadmill testing.[19] However, the intensity of these three walking speeds in present study was between 4.0 and 5.5 MET, which was in the range of 3–6 MET as moderate intensity identified by PA Compendium.

Objective measurement method and larger sample size allowed this study to establish the step-rate cut-point related to intensity (METs) as a minimum threshold for MPA walking and VPA walking. To date, four other studies have used indirect calorimeter to validate a step-rate cut-point associated with moderate or vigorous intensity walking. Simon *et al*[14] measured the step rate and intensity on a treadmill. Different cut points were obtained from different statistical method, and the author concluded walking at 100 step/min on ground level would meet the moderate-intensity walking recommendation. Tudor-Locke *et al*[15] determined that 96 and 107 step/min as the minimum threshold for moderate-intensity walking, and 125 and 136 step/min for vigorous-intensity for young men and women. The two other studies supported the 100 step/min as moderate-intensity walking cadence while emphasised inter-individual variation of step rate were apparent due to anthropometric differences such as height and leg length.[26 27] Our finding corresponded closely with these previous studies, although our cut point was slightly higher. The similar findings of these studies are encouraging given the differences between the sample characteristics and methodologies, which offer some evidence that will support the development of a consensus step-rate recommendation for the people in different countries.

In addition, we found that there was significant difference of step rate between young men and women at the same walking speed; therefore, it seems proper to have different cut-point recommendation for men and women separately. The gender differences in the mean step rate may be caused by differences in height and leg length. At the same walking speed, female's step

Table 3 Step-rate (step/min) cut-points associated with MPA and VPA in women and men from the present study and other literatures

		Simon *et al*[14]				
Intensity classification	**The present study (ROC analysis)**	**Linear regression analysis**	**ROC analysis**	**Tudor *et al*[15]**	**Beets *et al*[26]**	**Rowe *et al*[27]**
MPA (3METs)						
All	105	89	107	100	100 (85–111)*	100 (90–113)*
Men	104	92	102	96		
Women	107	91	115	107		
VPA (6METs)						
All	130	ND	ND	130	ND	ND
Men	127			125		
Women	137			136		

*The range of step rate based on difference of leg length[26] and height.[27]
ND, no data provided; METs, metabolic equivalent; ROC, receiver operating characteristic curves used to determine the step-rate cut-points.

frequency is higher than male's due to shorter height and shorter lower limb. However, since the difference of step rate between men and women was less than 10 steps/min, considering the needs to establish the walking recommendation in a relatively simple way, we think that single step-rate recommendation would be more effective in PA promotion and intervention application. Therefore, we suggest 105 and 130 step/min cut-points to be corresponded to MPA and VPA. However, if the recommendations of individualised step rate would be developed in the future, physical differences such as height, leg length and gender should also be considered.

In order to associate our step-rate cut-point with PA guideline,[3] the minimum walking steps of 3150 steps daily for MPA were considered based on our study results. It should be emphasised that 3150 steps need to be taken above the basic number of daily steps.[15] Recent study has reported the daily walking steps goal for American people is 8000 steps, derived from accelerometer data,[10] but an earlier study reported 10 000 steps.[8] Since people have different PA patterns, it is difficult to establish consistent total number of walking steps for everyone. Moreover, there is not a comprehensive walking recommendation if only walking steps is involved but not the intensity. Therefore, it is practical and useful to provide a general suggestion that how many extra steps individual needs to take above the daily activities and how fast to walk for health promotion. Specially, Chinese young adult should walk at least 30 min with a minimal 105 steps/min, or 3150 steps or 2 km with the same step rate daily to meet PA guidelines. They will perform vigorous-intensity activity if 130 step/min is reached and this will provide more health benefit.

China is experiencing rapid economic growth. With the increase of private car ownership and the reduction of the intensity of work, a rapid decrease of PA levels of Chinese people has caused widespread concern. Data from 2007 China PA and Exercise Survey showed that the proportion of young people aged 20–29 years to participate in regular exercise is the lowest among survey population aged 16–70 years old, with only 6.2%.[28] Walking is the most common and easy exercise. Walking above the certain speed can improve the health of people.[29] Therefore, a walking recommendation built on scientific evidence for Chinese young adults is a meaningful step to help them promote the PA levels.

One strength of the present study was large sample size and EE measurement in field settings, which provide sufficient power to identify the step-rate cut-points accurately. Another strength was to provide Chinese young adults a walking recommendation in form of relative flexible assistive tool. People can achieve their own exercise goal by using different calculations, such as step rate, walking during, total walking steps and/or walking distance. There were a number of limitations in this study. The first limitation was the small age range of young participants. It was known that gait and energy expenditure will be different between older and young individuals.[30] At the same walking speed, older people will have the gait of shorter step length and faster step rate.[31] Therefore, the cut-point established might not be suitable for older population. The second limitation was the use of a constant (3.5 ml/kg/min) as an estimated value of resting energy expenditure, instead of a direct measurement for calculating METs. Although the use of this constant is widely accepted in the scientific literature, it is likely to overestimate resting-energy expenditure at the individual level.[23 24] Then, the step-rate cut-point developed by the estimated value of MET might be overestimated. The third of limitation was lack of cross-validation. Considering the data collected under the current controlled environment may be different from the real environment, future study should focus on establishing the validity of the current cut-points through independent validation studies in real-life field walking.

CONCLUSION

The step-rate cut-points corresponding to activity intensity categories (in terms of MET levels) have been set up by this study. It could be useful for recommending appropriate amounts of walking exercise to meet PA guidelines for Chinese young adults. The findings from this study indicate that Chinese young adult should walk at least 30 min with a minimal 105 step/min, or 3150 steps with the same step rate daily to meet PA guidelines. There were slight differences on step-rate threshold and minimal steps between women and men, so further specific step-rate recommendations can be developed for different gender groups.

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Contributors HW participated in the design of the study, performed the statistical analysis and drafted the manuscript. Y-fZ participated in the study coordination and collection of data. L-lX carried out the walking test. C-mJ conceived the study and participated in its design. All authors read and approved the final manuscript.

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Competing interests None.

Patient consent Obtained.

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