Comparisons of the Physiological and Psychophysical Responses of Handweighted Walking with Three Different Arm Movements in Sedentary Chinese Women
缺乏運動的女性在步行時配以啞鈴及三種不同擺手方式對生理及自覺歇力程度反應的比較研究

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Abstract

The purpose of this study was to compare the physiological and psychophysical responses during six 20-minute walking sessions at 1.34 m·sec^{-1} and 6% gradient, that employed three different arm movements with and without a 0.45kg hand held weight (HHW) per hand, in fifteen sedentary Chinese college females (mean age = 25.1 ± 1.2 years). The sequence of test sessions was randomized and included two normal arm movements, two vigorous arm movements and two moderate arm pumping, walking with and without a 0.45kg HHW per hand. Dependent variables included oxygen uptake (VO_2, heart rate (HR) and ratings of perceived exertion (RPE). Statistics used included three, 2-way ANOVA (2 loading conditions x 3 different arm movements) and Tukey's post hoc test. Significant differences were noted between protocols involving hand weights and no hand weights ($p<0.05$) and among the three different arm movements ($p<0.01$). However, there were no significant differences with post hoc testing and the interaction. Based on lower RPE values, the minimal influence of the natural gait and the increased exercise intensity, walking with a 0.45kg HHW in each hand, while maintaining moderate arm pumping, was a recommended exercise prescription for sedentary Chinese women.

摘要

在香港，步行是一種普遍的活動。本文目的是比較缺乏運動的女性在每秒 1.34 米 (時速 3 英哩) 速度和 6% 傾斜度的步行機上，步行六次二十分鐘的生理分別。內容包括利用三種擺手方式 (自然、急速及大幅度) 和兩種手部負重情況 (無負重及每隻手各拿一磅啞鈴)，進行運動攝氧量、運動心跳率及自覺歇力的測試，尋找出最能達至訓練效果的步行方式。結果顯示：較佳方式為每隻手拿著一磅啞鈴及大幅度擺手步行法，可建議給經常缺乏運動的女性作為運動指引。

Introduction

The use of hand-held weights (HHWs) while walking is currently popular in general fitness, weight loss, and rehabilitation programs. Many research focused on the physiological responses to exercise with added heavy weights (0.45 to 2.27kg) at exaggerated pumping height from 0.6 to 1.1m, such as Auble, Schwartz and Robertson, (1987), Auble and Schwartz (1991), Francis and Hoobler (1986), Graves et al. (1987), Graves, Sagiv, Pollock and Miltenberger (1988), Makalous, Araujo and Thomas (1988), Miller and Stamford (1987), Lind and McNicol (1968), Owens, Al-Ahmed and Moffatt (1989), Sheldahl, Wilke, Tristani and Kalbfleisch (1983), Zarandona, Nelson, Conlee and Fisher (1986). Some studies reported that a 1 to 15 ml·kg^{-1}·min^{-1} or 6 to 91% increase in the energy cost when walking at different speeds (1.52 to 1.66 m·sec^{-1}) on a treadmill with 0.45kg HHWs.

To date, no research has compared physiological and psychophysical responses using lighter HHWs (0.45kg) while walking with a moderate pumping height, a normal and a vigorous arm movement. Moreover, the frequency of vigorous arm movement has not been reported in previous studies (Borysyk, Franklin, Gordon & Timmis, 1986; Makalous, Araujo & Thomas, 1988). Furthermore, no studies have used sedentary Chinese females as subjects. In addition, all of the exercise bouts were very short (four to eight minutes), except the study of Makalous,

Araujo and Thomas (1988) where the exercise bouts were of 30 minutes duration. Since the American College of Sports Medicine (ACSM 1998a, 1998b) recommends that the duration of aerobic exercise should be between 20 and 60 minutes, it is worth examining physiological and psychophysical responses during longer periods of exercise.

According to the Hong Kong Sports Development Board (1997), walking ranked as the fourth most popular sports activity for women in 1997. Ng (1998) investigated the physical activity patterns of Hong Kong junior secondary school children in their leisure time and found that walking ranked at the top. Helping sedentary women select the optimum intensity of exercise, however, presents a special challenge for the exercise therapist. A valid and practical means of determining mode-specific exercise prescription for sedentary women is needed as this population are not familiar or trained in using HHWs or engaging in long exercise bouts (Hofstetter et al., 1991; Martin & Morgan, 1991; Nigg, 1985).

Therefore, the purpose of this investigation was to compare perceived exertion (RPE), heart rate (HR) and oxygen consumption (VO_2), while walking with or without a 0.45kg HHW in each hand, with three different arm movements (moderate pumping height, normal and vigorous arm movements); and to make recommendations regarding exercise prescription.

Method

Participants

Seventeen female college students volunteered to participate in this study and fifteen completed all testing sessions. All 15 subjects were Chinese with mean age (±SD) of 25.1 (±1.2) years and were not presently on an exercise program. Physical and physiological characteristics are presented in Table 1.

Table 1. Physical and Physiological Characteristics of the Subject (N = 15)

Variables	Mean ± SD
Age (year)	25.1 ± 1.2
Body composition	
Height (cm.)	159.2 ± 3.6
Weight (kg)	57.0 ± 7.1
Body Mass Index ($kg \cdot m^{-2}$)	22.5 ± 2.8
Percent Fat (%)	28.3 ± 4.4
Cardiorespiratory fitness	
Resting Heart Rate ($beats \cdot min^{-1}$)	71.4 ± 11.3
Resting Systolic Blood Pressure (mm Hg)	110.0 ± 9.5
Resting Diastolic Blood Pressure (mm Hg)	66.5 ± 4.7

Familiarization

Each subject reported to the laboratory for a one-hour familiarization session prior to data collection. Subjects practised walking on the treadmill (model: Powerjog EG 30, Birmingham, UK) with a 0.45kg HHW in each hand, performing the vigorous arm movement and the moderate arm pumping action accordingly. For exercise without HHWs, subjects were instructed to perform the same arm movements.

Movement Description

Moderate Arm Pumping (MAP) – Subjects used 0.45kg commercially available HHWs without a strap. They performed the "walk-and-pump" method of walking movements with hand weights according to the level one motion described by Schwartz (1984).

Figure 1. Arm Movement with a 0.45kg HHW in Each Hand.

Vigorous Arm Movement (VAM) – Subjects followed the rhythm of an audible tone which was emitted from a pre-recorded tape, completing one arm swing movement with each tone, the frequency being 70 swings per minute. The vertical distance was measured from the position of the weight handles and was the same for each arm swing. The fixed vertical distance traveled from waist to chest level was marked with tapes by a floor-mounted stand beside the treadmill (see Figure 2). The normal arm movement is shown in Figures 3.

Figure 2. Walking with a VAM and a 0.45kg HHW in Each Hand.

Figure 3. Walking with a NAM and a 0.45kg HHW in Each Hand.

After familiarization, each subject attended the laboratory on six separate occasions separated by at least 48 hours. Prior to the first test session, body mass (to the nearest 0.5kg), stature (to the nearest 0.5cm), resting heart rate, resting blood pressure and percentage of body fat were determined.

Body Composition

The percentage of body fat was determined using Bodystat 500 (Bodystat Ltd., Isle of Man, British Isles) following the procedure described by Lukaski, Bolonchuk, Hall and Siders (1986). The measurements were performed in duplicate without removing the electrodes and the mean value was used in further analyses. Measurements were taken on the right side of the body.

Resting Heart Rate and Blood Pressure

Resting heart rate and blood pressure were taken by using an Omron Automatic Digital Blood Pressure Monitor (model no. HEM-705CP) in a sitting position following 10 minutes of rest.

Test Sessions

The protocols involved walking in six test conditions, three with hand weights and three without hand weights, at a constant speed of 1.34 $m \cdot sec^{-1}$ and a gradient of 6% on the treadmill. These included: 1) two normal arm swings walking with and without HHWs; 2) two vigorous arm movements walking with and without HHWs; 3) two moderate arm pump heights walking with and without HHWs. The order was randomly assigned, with one trial per condition so as to reduce the influence of learning technique. No subject had prior knowledge as to which protocol was to be administered on a particular day. The duration of each workload was 20 minutes, in order to meet the recommendation of the ACSM for aerobic exercise (1998a). Test personnel monitored the specified range of arm motion and the frequency of arm movement and corrected subjects with verbal feedback when necessary. The prospective for premature test termination was retrospective volitional cessation of exercise, failure to adhere to the requirements of the specific protocol, an unsteady gait, dizziness or lack of coherence.

Physiological and Psychophysical Measurements

Oxygen Uptake (VO_2) – During the measurements of VO_2, the subject breathed through a lightweight SPEAK-EASY facemask (Respironics, Inc., Monroville, PA.) with a low resistance, non-rebreathing valve. The expired gases were analysed using Oxycon 4 (Jaeger, Mijnhardt, Germany). The mean VO_2 at 19 and 20 minutes was used for the subject's VO_2 score.

Heart Rate (HR) – The Sports Tester PE4000 (Polar Electro, Kempele, Finland) was used to measure heart rate every 15 seconds during the test. The mean score of heart rate at 19 and 20 minutes was used as the subject's heart rate score.

Ratings of Perceived Exertion (RPE) – Subjects were asked to rate their perceived exertion using a 15-point scale with values from 6 to 20 (Borg, 1982). RPE scores were obtained from subjects at the end of each exercise bout.

Data Analysis

All data were analyzed using the Statistical Package for the Social Sciences (SPSS version 6.1). The variance caused the main effects of the independent variables, namely: Factor A - The effects of the three different arm movements on the variance. Factor B - The effects of two different load conditions (no HHW and a 0.45kg HHW in each hand) on the variance. Therefore, the differences between protocols for each dependent variable (i.e. HR, VO_2 and RPE) were statistically analysed using three 3 x 2 factorial Analyses of Variance (ANOVA) with Repeated Measures. An alpha level of $p < .05$ was used for all statistical tests to determine the presence or lack of significant differences. If an F-ratio for Factor A and B was significant, a Tukey's post hoc procedure was utilised to identify the source of differences and any interaction occurring among Factors A and B.

Results

The findings in Tables 2, 3 and 4 indicate that the mean values for VO_2, HR and RPE were significantly greater in the protocols that included walking with a 0.45kg HHW in each hand, as opposed to those protocols without a HHW in each hand. The variables of VO_2 ($F[1, 29] = 4.11$, $P = 0.046$), HR ($F[1, 29] = 9.19$, $P = 0.003$), and RPE ($F[1, 29] = 7.00$, $P = 0.010$) were all significant at the .05 level, although no significant differences were found with post hoc testing.

There were significant differences among the three different arm movements as shown in Tables 2, 3 and 4. The variables of VO_2 (F[2, 28] = 4.92, P = 0.009), HR (F[2, 28] = 6.26, P = 0.003), and RPE (F[2, 28] = 4.13, P = 0.0019) were all significant at the .05 level, while no significant differences were found with post hoc testing.

Tables 2, 3 and 4 indicate that the variables of VO_2 (F [2, 28] = 0.30), HR (F[2, 28] = 0.50), and RPE (F[2, 28] = 0.62) were not significant at the .05 level. There was no combined effect of the loading conditions and the three different arm movements on physiological and psycho-physical responses.

Table 2. Analysis of Variance for Oxygen Consumption (VO_2).

SOURCE OF VARIATION	Sum of square (*SS*)	df	Variance (*MS*)	*F* value	*P* value
Load Conditions *(A)*	15.33	1	15.33	4.11	0.046*
Different Arm Movements *(B)*	36.66	2	18.33	4.92	0.009**
Interaction *AB*	2.24	2	1.12	0.30#	
Error	318.22	84	3.79		
Total	372.45	89			

* $P < 0.05$
** $P < 0.01$
\# $P > 0.05$

Table 3. Analysis of Variance for Heart Rate (HR).

SOURCE OF VARIATION	Sum of square (*SS*)	df	Variance (*MS*)	*F* value	*P* value
Load Conditions *(A)*	1233	1	1233	9.19	0.003**
Different Arm Movements *(B)*	1680	2	840	6.26	0.003**
Interaction *AB*	136	2	68	0.50#	
Error	11396	84	136		
Total	14445	89			

** $P < 0.01$
\# $P > 0.05$

Table 4. Analysis of Variance for Rating of Perceived Exertion (RPE).

SOURCE OF VARIATION	Sum of square (*SS*)	df	Variance (*MS*)	*F* value	*P* value
Load Conditions *(A)*	48.40	1	48.40	7.00	0.010**
Different Arm Movements *(B)*	57.09	2	28.54	4.13	0.0019**
Interaction *AB*	8.60	2	4.30	0.62#	
Error	586.40	84	6.98		
Total	700.49	89			

** $P < 0.01$
\# $P > 0.05$

The results in Table 5 summarize the effects of the three different arm movements on HR, VO_2 and RPE. Compared with NAM, while walking with no HHW in each hand, the VAM and the MAP significantly increased heart rate from (mean ± SD) 127.9 ± 12.0 beats·min^{-1} to 136.0 ± 8.7 beats·min^{-1}, and from127.9 ± 12.0 beats·min^{-1} to 131.3 ± 10.2 beats·min^{-1} respectively; oxygen consumption was significantly increased from (mean ± SD) 13.6 ± 1.4 ml·kg^{-1}·min^{-1} to 14.6 ± 2.4 ml·kg^{-1}·min^{-1}, and

from 13.6 ± 1.4 ml·kg^{-1}·min^{-1} to 14.6 ± 1.3 ml·kg^{-1}·min^{-1} respectively; and ratings of perceived exertion significantly increased from (mean ± SD) 9.3 ± 2.3 units to 10.5 ± 2.7 units, and from 9.3 ± 2.3 units to 10.1 ± 2.6 units respectively. However, there was no significant difference in heart rate, oxygen consumption and ratings of perceived exertion between MAP and VAM, while walking with or without HHWs.

Table 5. Summary Data for Heart Rate (HR), Oxygen Consumption (VO_2) and Ratings of Perceived Exertion (RPE) during Walking with Two Different Load Conditions and Three Different Arm Movements.

	LOAD CONDITION					
	WITH a 0.45kg Hand-Held Weight in each hand (N =15)			*WITHOUT* a 0.45kg Hand-Held Weight in each hand (N =15)		
	DIFFERENT ARM MOVEMENT			DIFFERENT ARM MOVEMENT		
	Normal	Vigorous	Moderate	Normal	Vigorous	Moderate
Variable	ean ± S	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
RPE (Borg units)	9.9 ± 2.6	12.5 ± 2.8	11.9 ± 2.9	9.3 ± 2.3	10.5 ± 2.7	10.1 ± 2.6
HR (beats·min^{-1})	31.8 ± 12.	144.8 ± 11.0	140.8 ± 14.8	127.9 ± 12.0	136.0 ± 8.7	131.3 ± 10.2
VO_2 (ml·kg^{-1}·min^{-1})	14.0 ± 1.7	15.7 ± 2.4	15.5 ± 2.2	13.6 ± 1.4	14.6 ± 2.4	14.6 ± 1.3

When walking with a 0.45kg HHW in each hand and performing normal arm movement, moderate arm pumping and vigorous arm movement, the mean exercise intensity, expressed as a percent of maximum heart rate (HRmax = 220 - age), was 48.8 (±SD = 9.1)%, 56.0 (±SD = 11.7)% and 59.2 (±SD = 8.8)% respectively. When walking without a 0.45kg HHW in each hand and performing normal arm movement, moderate arm pumping and vigorous arm movement, the mean exercise intensity, expressed as a percent of maximum heart rate, was 45.8 (±SD = 7.8)%, 48.5 (±SD = 6.7)% and 52.1 (±SD = 7.1)% respectively.

Discussion

There was a significant increase in oxygen uptake ranging from 0.45 to 3.75 ml·kg^{-1}·min^{-1} when walking with a HHW in each hand. Similar findings were reported by Auble, Schwartz and Robertson (1987), since they found that there were significant increases in oxygen uptake ranging from 3.6 to 15.0 ml·kg^{-1}·min^{-1} when walking at 1.57 m·sec^{-1} with a 0.45kg hand weight per hand. However, the findings of the present study were at variance with those given by Makalous, Araujo and Thomas (1988), Graves et al. (1987), and Zarandona et al. (1986). They reported slight (range from 1.0 to 1.9 ml·kg^{-1}·min^{-1} or 6 to 8%) but not significant increases in oxygen consumption during walking with a 0.45kg HHW in each hand.

Since interactions between factors were independent of the main effects, they could occur whether or not the main effects were significant (Rothstein, 1985). In the present study, the interaction between Factor A (the two loading conditions) and Factor B (the three different arm movements) showed no significant difference. This indicates that the effect of Factor A was the same for all Factor B conditions. This is in contrast to the findings of Auble, Schwartz and Robertson (1987) who found that there was an interaction between changes in handweight and range of arm motion.

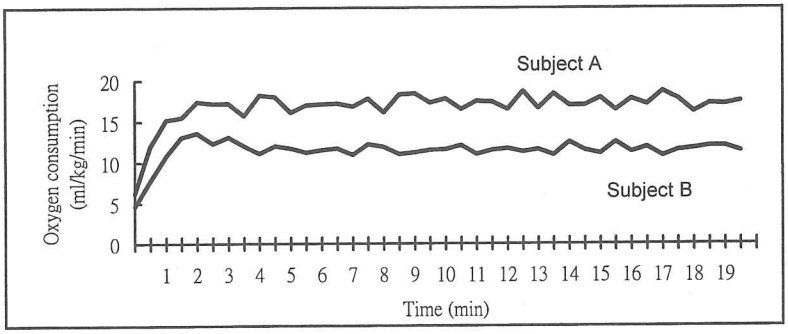
Although all subjects could maintain the 70 swing·min^{-1} pumping cadence during VAM with a 0.45kg HHW in each hand for 20 minutes, some subjects complained of upper and lower arm weariness and shoulder tightness after the 20 minute exercise period. This observation was at variance with that of Bryant and colleagues (1993), when subjects walked at 1.79m·s^{-1}, on a level surface, pumping a 2.73kg HHW in each hand from mid-thigh to the top of the ear. They found that not all subjects could maintain the 60 swing·min^{-1} pumping cadence and terminated the tests. This might be related to the unsteady gait associated with VAM and have contributed to higher ratings of effort (Bryant et al., 1993). Owens and associates (1989) suggested that employing vigorous arm swings might not be desirable as normal walking mechanics are disrupted. This could lead to localised fatigue of smaller muscle groups of the arms or place undue stress on the ultra-structure of the shoulder, especially if the activity was continued for 20-60 minutes.

The percentage of HRmax for the six walking protocols

in the present investigation was between 45.8% and 59.2%. Only walking with a 0.45kg HHW in each hand and performing MAP and VAM reached the recommended exercise intensity training range of 55% to 90% HRmax (ACSM, 1998a, 1998b). Although the other four walking protocols did not induce the recommended training intensity, they still achieve a training effect, especially for specific populations, such as sedentary persons and the elderly (ACSM, 1998a).

Figure 4 demonstrates two examples of oxygen consumption during walking when performing NAM with HHWs. They were chosen from the fifteen subjects to show the great diversity of physiological responses. There are three observations from these two examples. First, the physiological responses of the subjects achieved steady state after two minutes walking. This supported the views of Makalous and associates (1988), who found that average heart rate did not change significantly after five minutes of exercise. Second, body weight relative to the 0.45kg HHW might explain differences of physiological response. This implies that the use of 0.45kg HHWs might be too heavy for some individuals with relatively smaller body size, while too light for other individuals. Individual differences, which might be observed at equivalent absolute workloads, decreased at the same percentage VO_2max, in comparisons between lean and obese subjects (Skinner, Hustler, Bergsteinova & Buskirk, 1973). Third, the difference in physiological and psychophysical responses related to different exercises with hand weights might relate to varying arm strength. Therefore, the relative weight of the HHW in relation to body mass and upper body strength might be taken into consideration for exercise prescription rather than percentage VO_2max, percentage HRmax, and RPE. However, this hypothesis was not investigated in the present study and would be an area of future investigation.

Figure 4. Oxygen Consumption Responses of Subjects A and B during Walking with NAM and a 0.45kg HHW in Each Hand.



In conclusion, based on the RPE value, heart rate and oxygen uptake responses, walking with moderate arm pumping was the best for exercise prescription, as the RPE value was lower than that with vigorous arm movement, although exercise intensities were similar. Moreover, unlike the exercise protocol with vigorous arm movement, walking with moderate arm pumping did not disturb the normal gait or increase shoulder tightness. Therefore, walking with moderate arm pumping would be relatively comfortable and useful for sedentary women who want to increase exercise intensity in order to reach their training threshold.

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