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Effect of Wearing the Cosmed K4b² Metabolic System on 1 Mile Walking Performance in Older Adults

by
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This study examined in older adults the effects of wearing the Cosmed K4b2 metabolic system with face mask during the 1-mile Rockport Fitness Walking Test (RFWT). A randomised cross-over design was used (13 males, 12 females, age: 67±4 (yrs). Walking time, walking speed and final heart rate were recorded and predicted VO2max calculated. Participants had a constant walking speed during the RFWT (P = 0.24) not influenced by wearing the Cosmed K4b2. Using Bland-Altman analysis, bias for walking time, heart rate and predicted VO2max was not significant. The predicted VO2max wearing the Cosmed K4b2 was within 0.05±0.36 L·min-1. Wearing the Cosmed K4b2 metabolic system with face mask did not influence 1-mile walking performance in older adults. This observation allows the Cosmed K4b2 metabolic system to be used during walking tests in older adults to examine metabolic and physiologic adaptations by controlled exercise interventions.

Key words: Rockport Fitness Walking Test, portable metabolic system, predicted maximal oxygen uptake, aging

Introduction

The importance of physical exercise training in the aging population is becoming more apparent (Spirduso et al., 2005). As our population ages due to increased life expectancy, there is a need to improve standard of living through independency in later years (Curl, 2000). Maintenance of cardiovascular fitness is an essential prerequisite for independent living of older adults (Fenstermaker et al., 1992) as cardiovascular fitness reflects the ability of the respiratory and cardiovascular systems to deliver oxygen to skeletal muscle during activity (McArdle et al., 2000). However, it declines at a rate of 1% per year from the age of 25 onwards (Hardman and Stensel, 2003). Regular exercise by older adults has the potential to reduce the decrements in cardiovascular fitness (Curl, 2000) and maintain functional ability (Fahlman et al., 2007). In addition, there is evidence that cardiovascular fitness improves executive control processes (McAuley et al., 2004) which tend to deteriorate with age (West, 1996, Kramer et al., 1999). Thus, regular exercise may represent a neuro-protective intervention with a potential positive influence on cognition and brain function throughout the later years of adulthood.

Maximal oxygen consumption (VO_2max) reflects the cardiovascular fitness of an individual (Bassett and Howley, 2000) and is commonly used to evaluate the effects of a training programme (e.g. Ferrara et al., 2006). However, direct measurement of maximal oxygen consumption requires individuals to exercise to the point of volitional exhaustion, and in-

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volves a degree of risk, particularly for older adults (Kervio et al., 2003). In addition, direct testing for maximal oxygen uptake is costly and time consuming (Sidney and Shephard, 1977; Fenstermaker et al., 1992; Kervio et al., 2003). Therefore, submaximal exercise tests that predict cardiovascular fitness provide a useful alternative in older adults. Examples of submaximal exercise tests for older adults include the 6-min walk test (Kervio et al., 2003), Harvard Step Test (Burke, 1976), Cooper's 12-minute run-walk test (Sidney and Shephard, 1977) and the 1-mile Rockport Fitness Walking Test (RFWT) (Fenstermaker et al., 1992). The 1-mile Rockport Fitness Walking Test (RFWT) allows prediction of maximal oxygen uptake from heart rate, age, sex, body weight and walking time (Kline et al., 1987). Regression equations to predict maximal oxygen uptake from the RFWT were validated for adults between the ages of 30 and 69 years (Kline et al., 1987) and cross-validated by Fenstermaker et al. (1992) for subjects of 65-79 years.

Although the RFWT allows prediction of maximal oxygen uptake, the use of indirect calorimetry during the walk could provide data on physiological and metabolic responses, for example as a result of training programmes with older adults. Such tests would require use of a portable metabolic system such as the Cosmed K4b^2. The Cosmed K4b^2 consists of a portable unit (PU), harness and battery (McLaughlin et al., 2001). The Cosmed K2 has been used previously to examine physiological and metabolic responses during the 1-mile walk test in older adults (age: 66.1 ± 5.9) (Bazzano et al., 1995). However, it was not considered whether the portable metabolic system would affect the 1-mile walking performance. It is possible that the weight of the portable system and the potential perceived discomfort of the face mask may influence the physiological responses and walking performance. To our knowledge, only one study (Bales et al., 2001) tested the influence of wearing a portable metabolic system (i.e. Oxylog instrument, 4.31 kg) on aerobic capacity during a high-intensity step test and found no effect in young adults. Interestingly, older adults do respond with higher heart rates during treadmill walking while wearing nose clip and mouthpiece (Greig et al., 1993). Although a number of studies confirmed validity and reliability of the Cosmed K4b^2 over a wide range of exercise intensities (Duffield et al., 2004; Hausswirth et al., 1997; McLaughlin et al., 2001), it is not known whether the wearing of a metabolic system with face mask during non-treadmill walking tests in elderly adults would influence the walking performance.

The purpose of the present study was to examine in older adults the effect of wearing the Cosmed K4b^2 portable metabolic system during the 1-mile walk on pacing strategy, completion time, heart rate, and predicted VO_2max. It was hypothesised that wearing the Cosmed K4b^2 would have no effect on the performance of the 1-mile walking test in older adults. Confirmation of the hypothesis would allow future studies to examine the effect of a structured exercise intervention on physiological and metabolic responses during 1-mile walking in older adults.

Methods

Subjects

Twelve male and thirteen female (n=25) adults between 60 and 75 years of age volunteered to participate in the study. Participants had not recently been involved in any structured exercise and lived an independent, non-institutional lifestyle. Before participating in the study, each individual completed a health history questionnaire and provided written informed consent. All procedures of the study were approved by the University of Chichester Ethics Committee. Anthropometrical and physiological characteristics of the participants are shown in Table 1. BMI values classified 10 participants to have normal body weight (BMI: 18.5-24.9), 11 to be overweight (BMI: 25-29.9), and 4 class I obese (BMI: 30+) (Hardman and Stensel, 2003).

Preliminary Measures

Resting heart rate and blood pressure (Omron 705 IT, Medisave, UK) were measured after participants were seated for 20-minutes followed by measurement of height (Holtain Ltd, Crymych, U.K.), weight (Seca Model 880, Seca, UK) and body fat using bioelectric impedance analysis (BC418 MA, Tanita, UK).

Walking Test Procedures

Participants were instructed to walk at a fast constant pace and completed one familiarisation walk. In older adults, walking time was slower for the first walk compared to consecutive walks having equal but faster times (Fenstermaker et al., 1992). Participants walked 28 1/2 times around a wooden floored

Table 1
Anthropometrical and physiological characteristics of the subjects (mean ±SD)

Age (years)	67 ± 4
Height (m)	1.68 ± 0.09
Body mass (kg)	73.9 ± 13.4
Body mass index (kg·m^{-2})	26.1 ± 3.4
Body fat (%) – males	28.0 ± 7.3
Body fat (%) – females	33.6 ± 5.9
Resting heart rate (beats·min^{-1})	77 ± 9
Blood pressure (mm Hg)	143/83 ± 17/11

gymnasium (19x9m). Course configurations for the 6-minute walk test (Konopka et al., 2008) reported larger walking distance on an oval track (144.3 yd) compared to a smaller rectangular track (20-by-5yard – similar to the current configuration). In addition, these test's were internally consistent (intra-class correlation coefficient = 0.95) allowing a smaller course configuration for the present study. Course configuration in the present study was kept constant to allow comparison between walking conditions (Konopka et al., 2008). Participants undertook two walking test sessions (cross-over design): 1-mile walk without the Cosmed K4b^2 (i.e. RFWT), and 1-mile walk with the Cosmed K4b^2 (RFWT$_{Cosmed}$). Each session was separated by at least one day and no more than 1-week. Half of the participants performed either RFWT or RFWT$_{Cosmed}$ as first walking session. Heart rate was measured with a Polar Heart rate monitor (FS1, Polar UK).

Cosmed K4b^2 portable metabolic system:

The Cosmed K4b^2 is a metabolic system that consists of a portable unit (PU: dimensions 170×55×100mm; weight: 475g) and battery (dimensions 170×48×90mm; weight: 400g)). The system is worn on the chest using a harness that fits over both shoulders and around the waist (PU in front pocket and battery in back pocket). A temperature and heart rate receiver is attached to one of the supporting straps and a flexible rubber facemask (Hans-Rudolph, Kansas City, MO) is placed over the participants' mouth and nose using a net head cap and four clips to secure. The Cosmed K4b^2 system was warmed up for 40 minutes prior to calibration as per the manufacturer's guidelines. Calibration involved 10 pumps of a 3 L syringe into the Cosmed turbine for volume of expired air during ventilation, a room air calibration (20.93% O_2 and 0.03% CO_2) and a calibration with a standard gas mixture of O_2 (15.6%) and CO_2 (5.66%) (Linde gas, UK). Although the aim of this study was not related to measurement of physiological responses, the oxygen uptake values would allow appreciation for the intensity of the walk for older adults.

Analysis

VO_2max was estimated using a generalized L·min^{-1} equation developed by Kline et al. (1987) and recommended by Fenstermaker et al. (1992):

$$\dot{V}O_{2max} = 6.9652 + (0.0091 \times WT) - (0.0257 \times AGE) + (0.5955 \times SEX) - (0.2240 \times T) - (0.0115 \times HR)$$

with WT = body weight in pounds, AGE = years, T = time in minutes to 100ths of a minute taken at the completion of the 1-mile walk, HR = heart rate determined at the completion of the walk (beats·min^{-1}) SEX = female 0, male 1.

A paired samples t-test was used to compare the means of walking speed for RFWT and RFWT$_{Cosmed}$. Visual analysis was used to examine the shape of distribution for pace throughout the walk, as well as exploring similarities and differences across the time periods (Fallowfield et al., 2005). Box and whisker plots were used as opposed to a parametric statistical test because strides per minute were chosen by the participants throughout the 1-mile walk. A comparison of walking times, heart rates, and estimated $\dot{V}O_2max$ for RFWT and RFWT$_{Cosmed}$ were carried out. Absolute data were expressed as mean±SD. Limits of agreement (LoA) was used to allow comparison of both walking conditions (RFWT versus RFWT$_{Cosmed}$) (Bland and Altman, 1986). LoA analysis determines 95% confidence limits, mean, standard deviation (SD) and standard error (SE) for each data set to show if systematic bias (i.e. mean difference) was present. T-tests were used for analysis of systematic bias and regression analysis was employed to detect heteroscedasticity (i.e. relation between variation and value of the measurement). When heteroscedasticity was determined, ratio LoA using log transformed values was used as suggested by Nevill and Atkinson (1997). The 95% LoA expresses the range of the difference scores within 95% of the population is expected to fall, and allows interpretation of the range of individual difference scores between the two conditions (Atkinson and Nevill, 1998).

Results

Walking Pace and Striding Frequency

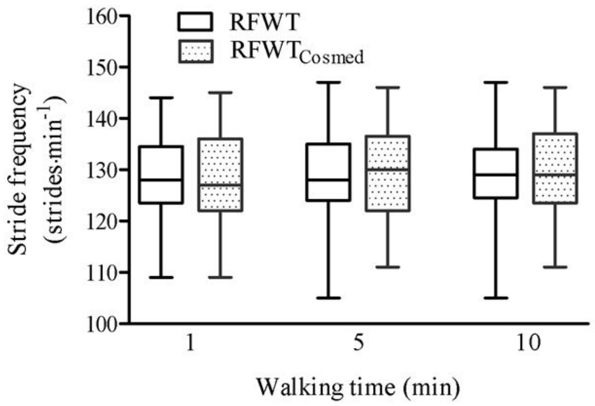

Fig. 1

Box and whisker plots of stride frequency at 1, 5 and 10 minutes during the 1-mile Rockport Fitness Walking Test (RFWT) and during the RFWT wearing the Cosmed K4b2 (RFWTCosmed).

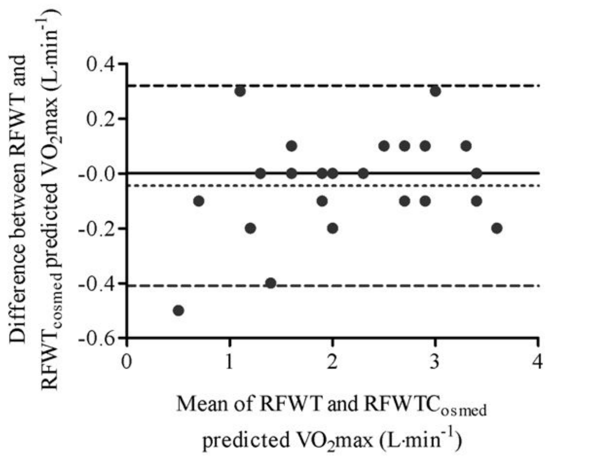

Fig. 2

Bland and Altman plot of the difference between the predicted VO_2max ($L·min^{-1}$) from the 1-mile Rockport Fitness Walking Test (RFWT) and from the RFWT wearing the Cosmed K4b2 (RFWTCosmed). Each circle represents data of one participant. Dashed lines represent mean difference ± 2 SD of the two walking tests, with the dotted line representing a non-significant bias. All participants but one were within the limits of agreement.

Average walking pace was 1.77±0.22 $m·sec^{-1}$ and 1.79±0.26 $m·sec^{-1}$ for RFWT and $RFWT_{Cosmed}$, respectively, and not different (p=0.24). Stride frequency of both walking sessions are presented in Figure 1. The range of striding frequency was 109-144 $strides·min^{-1}$ for RFWT and 109-145 $strides·min^{-1}$ for $RFWT_{Cosmed}$. Median values for stride frequency in both walks were similar at minute 1 (RFWT: 128 $strides·min^{-1}$; $RFWT_{Cosmed}$: 127 $strides·min^{-1}$). At 10 minutes, stride frequency was increased slightly in both conditions (RFWT: 129 $strides·min^{-1}$; $RFWT_{Cosmed}$: 129 $strides·min^{-1}$). At min 5 and 10 in the RFWT condition, the range of striding frequency was 42 $strides·min^{-1}$ and wider than the range at the same time points in the $RFWT_{Cosmed}$ (35 $strides·min^{-1}$). Whiskers below the median at min 1, 5 and 10 for the RFWT were longer. This suggests the lower 25% of measured striding frequencies is more skewed than the upper 25%. For min 1, 5 and 10 in the $RFWT_{Cosmed}$ condition, whiskers were only slightly skewed although the interquartile range in this condition was slightly larger than at similar time point in the RFWT condition, indicating the middle 50% of the $RFWT_{Cosmed}$ data covering a greater range. The degree of overlap between all six box and whisker plots (Figure 1) is large suggesting stride frequency is similar throughout and between each walk.

Walking Time

Bland-Altman analyses for walking times are presented by both absolute and ratio limits of agreement (LoA) in Tables 2 and 3. A positive correlation between the absolute difference and the mean for walking time (r=0.225) justify ratio LoA (i.e. log transformed measurements). Walking times for RFWT and $RFWT_{Cosmed}$ were 921±128 s and 913±133 s, respectively. The bias of walking time was 1.011 and non-significant (t=0.31; p>0.05) with 95% of the ratios between 0.91 and 1.11 (Table 2). Consequently, if a participant completed RFWT in 762 s, for example, walking time could be as low as 712 seconds, or as high as 868 seconds for $RFWT_{Cosmed}$. This example indicates a constant ratio percentage change in walking performance.

Table 2

Method comparison of the 1-mile walking test with and without the Cosmed K4b2. Systematic bias with 95% limits of agreement (LoA) are expressed in ratio terms

	Time (Sec)	Heart Rate ($b·min^{-1}$)	VO_2max($L·min^{-1}$)
Bias (t-test)	1.011 (0.31)	1.001 (0.94)	-0.068 (0.22)
95% LoA	0.9129 – 1.107	0.84 – 1.19	0.9129-1.119
r	-0.086	0.054	-0.086

r, correlation coefficient.

Table 3

Method comparison of the 1-mile walking test with and without the Cosmed K4b². Systematic bias with 95% limits of agreement (LoA) are expressed in ratio terms

	Time (sec)	Heart Rate (b·min^{-1})	$\dot{V}O_2max$(L·min^{-1})
Bias (t-test)	8.40 (0.39)	-0.040 (0.99)	-0.045 (0.24)
95% LoA	-86.18 - 102.98	-22.48 – 22.40	-0.41 – 0.32
r	0.225	0.278	-0.275

r, correlation coefficient.

Heart Rate

Bland-Altman results for heart rate at the end of the 1-mile walk are presented by absolute and ratio limits of agreement (LoA) in Tables 2 and 3. A positive correlation between the absolute difference and the mean for heart rate (r = 0.278) indicates ratio LoA to be appropriate (log transformed measurements). Heart rate was similar for both walking conditions (RFWT: 126±15 beats·min^{-1}; $RFWT_{Cosmed}$: 126±17 beats·min^{-1}). Heart rate data had a non-significant bias of 1.001 (Table 2) and 95% of the ratios between 0.84 and 1.19. Thus, a participant with a heart rate of 121 beats·min^{-1} in the RFWT could have a heart rate as low as 101 beats·min^{-1} and as high as 143 beats·min^{-1} for $RFWT_{Cosmed}$.

Predicted $\dot{V}O_2max$

$\dot{V}O_2max$ had a negative correlation (r = -0.275) between the absolute difference and the mean indicating absolute LoA to be the best form of analysis (Table 3). $\dot{V}O_2max$ for RFWT was 2.10±0.91 L·min^{-1} and 2.15±0.86 L·min^{-1} for $RFWT_{Cosmed}$, respectively (Figure 2). Bland-Altman results for $\dot{V}O_2max$ $RFWT_{Cosmed}$ vs. VO_2max RFWT) illustrate fixed bias (-0.045). However, there was no difference between the predicted VO_2max in both walking conditions (Table 3). The 95% LoA are shown in Figure 2 (-0.41 and +0.32 L·min^{-1}) identifying one outlier below the 95% limit.

Discussion

The primary finding of the present study was that there was no effect of wearing the Cosmed K4b² metabolic system with face mask on the predicted maximal oxygen uptake values of older adults by the 1-mile Rockport Fitness Walking Test (RFWT). The prediction of maximal oxygen uptake requires equation input of heart rate and walking time (Kline et al., 1987) and recordings of these parameters were not affected. In addition, participants maintained during both walking sessions a similar and constant striding frequency without receiving feedback during the walk. Although striding frequency for all participants was measured only at three similar timepoints (i.e. 1, 5 and 10 min), an apparent change in striding frequency was not obvious despite substantial individual differences in walking time.

The walking-speed instructions requested participants to complete the RFWT as fast as possible but in a constant pace. In a recent study by Fitzsimons et al. (2005) on responses to walking-speed instructions (i.e. slow, comfortable, brisk or fast) in older women (age: 78.2±2.4 years), the instruction to walk fast resulted in a speed of 1.42 m·s^{-1}. Walking speed of the older women in our study was 1.67±0.21 m·sec^{-1} and 1.68±0.19 m·sec^{-1} for RFWT and $RFWT_{Cosmed}$, respectively, values to be 75% of the participant's maximal walking speed (unpublished observations). However, compared with Fitzsimons et al. (2005) our participants were slightly younger. Our data may confirm the importance of walking instructions for older adults (Fitzsimons et al., 2005) when provided to walk for health reasons. The choosen walking speed resulted in vigorous intensity exercise as our participants walked at 65% of their prediced maximal oxygen uptake (unpublished observations). This is higher than required according to guidelines by the American College of Sports Medicine (ACSM 2000) when performing aerobic activities for health.

The walking times for RFWT and $RFWT_{Cosmed}$ for older women were similar (16.18 ±2.22 min and 16.0 ± 1.93 min, repectively) and comparable to other studies (Fenstermaker et al., 1992; Bazzano et al., 1998). 1-mile walking times in older women (age 69.4±4.2 years) were 16.99 ± 2.17 min and 16.73 ± 2.12 min (Fenstermaker et al., 1992) for walk 2 and 3 in a series of 3. In that study, the first walk (i.e. familiarization) gave a significantly slower time (i.e. 19.01 ± 4.18 min). Bazzano et al. (1998) reported walking times of 15.4±1.4 min for older women (64.6±3.1

years). In our study, the log transformed LoA for walking time showed individuals with relatively long walk times to have greater variation when performing the second walk. For example, when walk time was 21 min 59s, another walk time could be 2 min 25s longer or 1 min 59s shorter, a variation of ±9-11%. Fenstermaker et al. (1992) found the walking time of 44% of participants within 30s of their previous time after three walks. In our study, 48% of the participants did the two walks within 30 s of each other. More importantly, Fenstermaker et al. (1992) showed no differences in predicted VO_2max despite difference in walking times between tests. The effect of a difference in walking time for the prediction of VO_2max could have been balanced by a difference in heart rate. However, there were other methodological differences between our study and by Fenstermaker et al. (1992). In the Fenstermaker study, participants walked in groups of 10 for the first walk whereas for walk 2 and 3 they were tested in pairs and stagger started in order of walking time of the first walk. In our study, particpants walked alone and it is not known whether such differences in protocol could influence functional walking performance.

Heart rates at completion of the RFWT and $RFWT_{Cosmed}$ were similar (i.e. 126 beats·min^{-1}). This would be 78% of their age-predicted maximal heart rate (Tanaka et al., 2001) at the end of the test. In other studies, participants of similar age, utilized 86%HR max (Kline et al., 1987) and 91%HRmax (Bazzano et al., 1995), although the exercise model in the latter study used treadmill walking. The final heart rate of $RFWT_{Cosmed}$ should be within ±8-19% of the RFWT according to ratio LoA. Predicted VO_2max fell within ±11-14% (–0.41 L·min^{-1} and +0.32 L·min^{-1}) of the first test. The predicted values were not significantly different between walking conditions. Fenstermaker et al. (1992) found a difference in predicted VO_2max of 0.34 L·min^{-1} (between 3 walk means). Our difference between conditions was 0.05 L·min^{-1}.

In conclusion, results of this study support the hypothesis that there was no effect on the predicted maximal oxygen consumption in older adults during the 1-mile walking test while wearing the Cosmed K4b² metabolic system and face mask. Therefore, the 1-mile walking test in older adults while wearing the Cosmed K4b² portable metabolic system would allow examination of the physiological and metabolic responses that result from a controlled exercise intervention.

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