Original Research

The Reduction of Metabolic Cost While Using Handrail Support During Inclined Treadmill Walking is Dependent on the Handrail-Use Instruction

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ABSTRACT

International Journal of Exercise Science 7(4) : 339-345, 2014. Inclined treadmill walking is a commonly performed activity to increase cardiovascular health. Handrail support on a treadmill provides an individual the opportunity to change their posture with respect to the walking surface. Differences in metabolic cost during inclined walking due to postural changes with handrail use are unknown. To test the hypothesis that metabolic cost will differ depending on how handrail support is used, respiratory gas analysis was performed during inclined walking in 13 healthy subjects. Energy expenditure was quantified while each subject walked in four conditions: 5% incline unsupported, 10% incline unsupported, 10% incline holding the handrails while maintaining an upright posture, and 10% incline holding the handrails while leaning backward. Energy expenditure (kcal min^{-1}) was significantly higher for 10% unsupported (8.83 ± 1.60, $P < .001$) and 10% upright (7.77 ± 2.51, $P < .001$) relative to 5% unsupported (6.32 ± 1.14). No significant difference was found between 10% leaning backward (6.02 ± 2.19) and 5% unsupported. Altering posture with respect to the inclined walking surface by holding the handrails and leaning backward significantly reduces metabolic cost; however, utilizing the handrails and remaining upright does not result in a significant reduction at a 10% incline. These data, in concert with subjective measures of perceived effort, may prove valuable in the instruction and/or prescription of treadmill walking for a general fitness or weight loss regimen.

KEY WORDS: Oxygen consumption, exercise prescription, inclined treadmill walking, caloric expenditure, cardiovascular exercise response

INTRODUCTION

Treadmill walking is a commonly performed activity to increase cardiovascular health and aid in weight maintenance. A standard feature in most commercially available treadmills is the ability to change the incline of the walking surface. The effect of varying incline on metabolic cost during walking and running is well understood (9,10). Treadmills also commonly have different handrail support (HRS) configurations that offer stability, psychological comfort, or the means with which to change one's orientation while using the device. When incorporating an incline during treadmill use, HRS affords additional opportunities to change posture with respect to the walking surface. The influence of these common treadmill-user interactions on metabolic cost is unclear based on past research.

By utilizing HRS and leaning backwards, one provides an anteriorly directed assisting force to the body's center of mass. When assisted with an anterior load equal to 10% of body weight by an external apparatus, it was found that the metabolic cost of level walking was reduced by 53% (6), and running by 33% (4). Past research suggests that using HRS during locomotion reduces metabolic cost to some degree (2,8,14,7), but whether a similar effect occurs during incline walking is not clear. During inclined walking, the increased muscular demand of using the upper extremity to provide an assisting horizontal load, as opposed to an external apparatus, may somewhat offset the previously demonstrated (6) reduction in metabolic cost. In addition, leaning backwards with the assistance of HRS by definition will alter the angle of the user with respect to the walking surface, potentially making this inclined leaning posture more similar to walking unsupported at a lower incline.

Providing HRS may also increase the ability of an exerciser to maintain lateral balance during locomotion. The primary mechanism by which humans maintain balance laterally during running is by varying step width (1), although arm swing also is a contributing factor (11). Restricting arm swing during walking results in an increase in metabolic cost by approximately 5% (11,13), which may be a function of the increased demands of maintaining lateral balance. However, providing external lateral support and restricting arm swing has resulted in a reduction of metabolic cost of 3% during walking (11), providing evidence of an interaction between the two variables. Utilizing HRS restricts arm swing, and may add additional medio-lateral support via a different mechanism (i.e., the use of the upper extremity) than the aforementioned studies.

Recreational exercisers in a commercial gym setting utilize treadmills with a wide variety of HRS and incline combinations. In order to examine the metabolic costs associated with some of the postures derived from fitness setting observations, the present study sought to quantify the differences in metabolic cost associated with using HRS with two distinct instructions. It was hypothesized that using HRS while maintaining an upright posture would not significantly alter metabolic cost relative to unsupported inclined walking, and that using HRS and leaning backward would result in a significant reduction in metabolic cost compared to unsupported inclined walking. In addition, it was also hypothesized that inclined walking while using HRS and leaning backward would be comparable to walking with no support at a less severe incline.

METHODS

Participants

Thirteen healthy subjects (age: 39 ± 13 y, height: 175 ± 8 cm, weight: 78 ± 12 kg, resting heart rate (HR): 67 ± 12 beats min^{-1}) were made aware of the study's objectives and provided informed consent prior to participation. All subjects were confirmed to be of low risk for cardiovascular disease by use of the PAR-Q, and all had performed some variation of treadmill walking in the past. All experimental methods were approved by the Institutional Review Board of the University of Massachusetts-Lowell.

Protocol

The present study was a repeated measures cross-over design. All subjects were instructed to avoid nicotine, alcohol, and heavy meals for four hours leading up to the experimental trial. Other than these recommendations, pre-trial diet was not controlled. Ambient room temperature was not explicitly controlled, and ranged from 21 to 25 degrees C at the start of the trials. Subjects wore a nose clip and a one-way breathing mouthpiece connected to the TrueOne 2400 Metabolic Measurement System (ParvoMedics, Sandy, UT, USA) for respiratory gas analysis. HR was collected via telemetry, quantified with a flexible strap (Polar WearLink+ Coded Transmitter 31 strap, Polar, Kempele, Finland) placed around the chest at mid-sternum. All trials were performed on a commercial treadmill (525T, Cybex International Inc., Medway, MA, USA) equipped with support handrails along the sides of the console (Figure 1). Subjects were instructed to perform five minutes of level walking (i.e., 0%) as a warm up, then five minutes of inclined walking on a treadmill in a counterbalanced order according to the following conditions: 1. 5U - 5% incline, unsupported; 2. 10U - 10% incline, unsupported; 3. 10LB - 10% incline, while instructed to utilize HRS and lean back by straightening the arms; and 4. 10UR - 10% incline, while instructed to utilize HRS but maintain an upright posture.

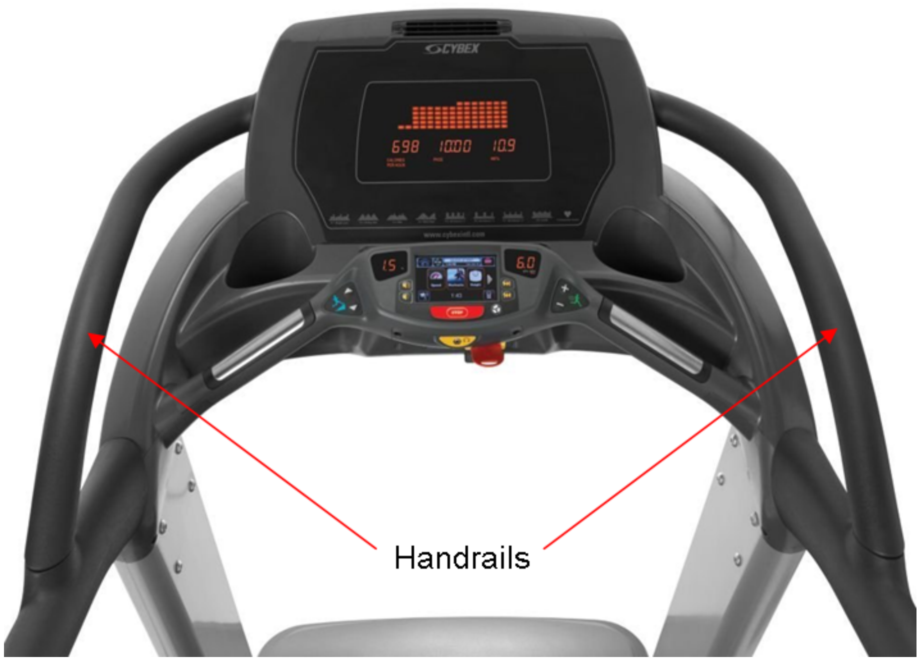

Figure 1. The treadmill and handrail configuration used in the present study. Subjects were instructed to grasp along the handrails at a self-selected comfortable height, and to either 'lean back' (LB), 'remain upright' (UR), or walk unsupported (U).

Ratings of perceived exertion (RPE) were collected by use of the Borg Scale (3) after two minutes and four minutes in each condition. Male subjects were instructed to walk at a speed of 1.34 m s^{-1} (3.0 mi hr^{-1}) throughout the duration of the experiment, while female subjects were instructed to walk at a speed of 1.12 m s^{-1} (2.5 mi hr^{-1}). The speeds were selected given the reported age-dependent differences in maximal aerobic capacity between males and females ranging from 11.1% to 35.3% (12). Performance criteria were determined based on a standard of modest effort changes within the framework of a repeated measures design, not the achievement of a specific, pre-determined HR. Subjects performed each experimental condition for five minutes; steady state was defined as HR measures of ± 5 beats min^{-1} for two successive minutes. Five minutes was confirmed for all subjects to be an adequate amount of time to reach steady state and was selected, in part, to minimize the total length of the experimental trial to mitigate the effects of cardiovascular drift (5).

Averages for HR (beats min^{-1}) and volume of oxygen uptake (VO_2, ml min^{-1} kg^{-1}) were computed over the final two minutes for each experimental condition. Energy expenditure (EE, kcal min^{-1}) was predicted by the default TrueOne software (OUSW 4.34, ParvoMedics, Sandy, UT, USA). The two RPE measures reported during each condition were averaged.

Statistical Analysis
One-way ANOVA with repeated measures was performed to determine the effect of experimental condition on the grand mean of each outcome variable, with Bonferroni corrections applied *post hoc*. Statistical analyses were performed with SYSTAT (V12, SYSTAT Software Inc., Chicago, IL, USA), with $\alpha = 0.05$.

RESULTS

Statistical analyses revealed differences in each of the outcome variables across the four experimental conditions (Table 1). The 10U condition was significantly greater than 5U with respect to VO_2 ($P < 0.001$), EE ($P < 0.001$), and RPE ($P = 0.001$). 10U was significantly greater than 10LB with respect to HR (= 0.011), VO_2 ($P < 0.001$), EE ($P < 0.001$), and RPE ($P < 0.001$). 10UR was significantly greater than 5U with respect to VO_2 ($P = 0.023$), EE ($P = 0.047$), and RPE ($P = 0.045$). 10UR was significantly greater than 10LB with respect to HR ($P = 0.010$), VO_2 ($P < 0.001$), EE ($P < 0.001$), and RPE ($P = 0.001$). There was no statistically significant different between 10UR and 10U for any of the outcome variables under investigation ($P = 0.066 – 0.705$).

Relative to 5U, a 4.7% reduction in metabolic cost occurred during 10LB, and a 39.7% increase occurred during 10U. Relative to 10U, a 12% reduction in metabolic cost occurred during 10UR (although not statistically significant, $P = 0.135$), and a statistically significant 31.8% reduction occurred during 10LB ($P < 0.001$). When normalized to body mass, EE (kcal min^{-1} kg^{-1}) during each condition was 0.081 ± 0.007 for 5U, 0.112 ± 0.010 for 10U, 0.098 ± 0.018 for 10UR, and 0.075 ± 0.015 for 10LB.

Table 1. Mean (±SD) results for oxygen uptake (VO_2), heart rate (HR), energy expenditure (EE), and rating of perceived exertion (RPE) as a result of steady state walking at four handrail and incline variations

	5U	**10LB**	**10UR**	**10U**
HR (beats min^{-1})	108.28 ± 30.12	100.61 ± 25.75	110.82 ± 23.38 [b]	118.97 ± 14.92 [b]
VO_2 (ml kg^{-1} min^{-1})	16.79 ± 1.42	15.58 ± 3.05	20.28 ± 3.70 [ab]	23.33 ± 2.05 [ab]
EE (kcal min^{-1})	6.32 ± 1.14	6.02 ± 2.19	7.77 ± 2.51 [ab]	8.83 ± 1.60 [ab]
RPE	8.54 ± 1.49	9.5 ± 2.22	10.62 ± 2.12 [ab]	11.42 ± 1.92 [ab]

LB – Leaning back, UR – Upright, U – Unsupported; [a] indicates > 5U; [b] indicates > 10LB; both $P < 0.05$

DISCUSSION

The objective of the present study was to quantify metabolic cost as a result of different postural configurations afforded to an exerciser using HRS during inclined walking. Past research suggests that the use of HRS will result in a decrease in EE during level walking and running (2,7,8), and that instruction or intention (e.g., hands 'resting on' versus 'gripping' the handles) will influence the extent to which metabolic cost is decreased (2). This study demonstrates that this is not necessarily the case for inclined walking, i.e., the instruction or intent of the use of HRS will dictate whether or not a statistically significant decrease in metabolic cost will result.

These data suggest that there is no statistically significant reduction in metabolic cost when utilizing HRS and remaining upright compared to unsupported walking at a 10% incline. It is concluded that, in support of the first hypothesis, if one were to utilize HRS to maintain an upright posture, a similar metabolic effect was found during unsupported walking at the same incline. This is possibly due to the similarities in whole-body orientation between the person and the walking surface of the treadmill when instructed to 'remain upright.'

Also in agreement with our hypothesis, if an exerciser is using HRS in order to facilitate a backward leaning posture, our results suggest that this will result in a statistically significant reduction in metabolic cost. This may be partially explained by that fact that leaning backward creates a near-perpendicular angle between the body of the exerciser and the surface of the treadmill, similar to walking upright with no incline. An additional consequence of the reclined posture is that the user may have been able to provide an anteriorly directed assisting force with the upper extremity. Forces were not quantified in the present study, but our data are consistent with previous reports suggesting approximately a 50% reduction in metabolic cost as a result of an anteriorly directed supporting force during level walking (6). The findings of the present study demonstrate a smaller magnitude reduction of 31.8%, which may be partly due to the added demand of the upper extremity musculature as opposed to an external apparatus (6). In addition, these findings may also be a consequence of the anteriorly directed force providing more assistance (i.e., a greater reduction in energy expended) during inclined walking than during level walking.

For a similar subjective effort rating, a similar cardiovascular benefit would result from either walking at a 5% incline unsupported, or walking at a 10% incline and leaning backward with the aid of HRS. Therefore, it is recommended that either may be appropriate in a general fitness programming structure, with the optimal condition being selected with considerations of upper extremity health and the perceived exertion of the individual.

It is important to acknowledge the limitations of the present study. The most significant of which is the fact that the applied force exerted on the handrails by the subjects was not measured. As such, this study is limited in its ability to attribute changes in metabolic cost to muscle demand of the upper extremity or to the posture of the individual. As a result, it is suggested that the differences in energy expended between conditions be attributed solely to the instruction associated with the use of the handrails. Between-subject variations in applied force within a particular HRS condition may also have influenced overall trends in metabolic cost. Despite these limitations, it is recommended that the findings are still applicable to a general fitness setting, given that the handrail-use instruction is known. The lower extremity kinematics and kinetics of each exerciser were also not quantified, as the focus of the study was on the metabolic effect of the exercise conditions. These data would substantially add to the study's ability to determine the causes of the differences in energy expenditure between conditions. Although the total experiment time was limited to 25 minutes, the effects of cardiovascular drift or subject fatigue may nonetheless be present. In an attempt to mitigate these effects, a limited number of experimental conditions were tested, and the order of the conditions was counterbalanced across all participants. Subjects were provided general guidelines for food intake leading up to the trial, but pre-trial food intake was not controlled.

In conclusion, the metabolic cost of inclined walking is altered by the use of treadmill handrails, specifically as a function of the handrail-use instruction and resulting posture. This should be taken in account when utilizing established metrics or predictive formulae related to the metabolic cost of inclined walking. The differences demonstrated herein, in combination with subjective measures such as RPE, can be utilized when performing or prescribing a walking regimen to maximize the cardiovascular benefit.

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