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A Comparison of Cardiovascular Responses during Walking and Jogging on the Treadmill with and without Handrail Support

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ABSTRACT

Dalton NC. A Comparison of Cardiovascular Responses during Walking and Jogging on the Treadmill with and without Handrail Support. **JEPonline** 2013;16(1):64-71. The purpose of this study was to determine if holding onto the handrails during treadmill exercise influenced VO_2 and, if so, would the adjustment be central (Q) or peripheral (a-vO_2 diff)? Twelve male and female subjects ranging in age from 20-30 yrs volunteered to take part in this study. Protocol A consisted of 10 min of walking at 3.5 mi·hr^{-1} without handrail support followed by 10 min of jogging at 5.5 mi·hr^{-1} with handrail support. Protocol B consisted of 10 min of walking at 3.5 mi·hr^{-1} with handrail support followed by 10 min of jogging at 5.5 mi·hr^{-1} without handrail support. During both protocols, the 10-min walking stage was followed by a small break to collect data and allow the subjects' HR return to a normal resting value. The results of this study indicate that in normal healthy college-aged adults, VO_2 was not significantly altered when handrails were used during walking and jogging on the treadmill for 10 min. When the data was analyzed in regard to jogging at 5.5 mi·hr^{-1} on the treadmill, the same exact conclusions are warranted. The only exceptions to the findings just described are VCO_2 and T_V. Both were significantly increased when holding onto the handrails while jogging. There appears to be no scientific reason for not holding onto the handrails if the exerciser feels more confident in controlling his or her exercise session.

Key Words: Treadmill Exercise, VO_2 Max, Cardiac Output, Arteriovenous Oxygen Difference, Expired Ventilation, Tidal Volume

INTRODUCTION

As baby boomers increase in age, their physical independence is tested in the performance of daily tasks. Leading an active lifestyle may help prolong the older person's independence as well as prevent chronic diseases such as diabetes and coronary artery disease (7). To measure how safely older individuals can perform daily tasks, exercise physiologists use a graded exercise test (GXT) to determine maximum oxygen consumption (VO_2 max, $L \cdot min^{-1}$). Knowing the individual's body weight allows for converting the absolute unit to a relative unit ($mL \cdot kg^{-1} \cdot min^{-1}$). This value can then be converted to the metabolic equivalent (MET) unit by dividing the relative VO_2 max value by the resting VO_2 of 3.5 $mL \cdot kg^{-1} \cdot min^{-1}$ (1 MET). Most daily tasks and specific exercise conditions have been assigned an approximate number of METs (4). Thus, a physical activity of 5 METs equals the energy expenditure of five times resting metabolism.

Previous research has shown that increased arm movement while using walking poles significantly increases VO_2. This could be beneficial for cardiac patients in a rehabilitation setting who are limited by slower walking speeds due to lower body mobility issues such as arthritis or peripheral vascular disease. Walking poles may therefore result in a safe increase in the patients' VO_2 while realizing the physiological benefits of a walking program (6). Conversely, it may be assumed that a decrease in the patients' arm movement should decrease VO_2. The resulting decrease in VO_2 during exercise may not be ideal since expenditure of energy is related to exercise intensity and health benefits. This also raises the question about holding onto the handrails during an exercise test. Should subjects be allowed to hold onto the handrails or should they be discouraged from doing so and when would that be the case? This study was designed to evaluate VO_2 and related physiological responses during treadmill walking and jogging with and without handrail support. The question is, "Will holding onto the handrails influence VO_2 and, if so, will the adjustment be central (Q) or peripheral (a-vO_2 diff)?"

METHODS

Subjects

Twelve male and female subjects ranging in age from 20-30 yrs volunteered to take part in this study. Subject characteristics are presented in Table 1. The volunteers were healthy, nonsmoking, and not taking any medications that would influence the outcome of the study. All subjects signed an informed consent according to the procedures of the Human Subjects Review Committee of St. Scholastica. They were asked to refrain from any activity that was not normally part of their daily routine. Between testing sessions, there were at least 24 hrs of separation and all subjects were tested as close to the same time of day as possible for each session.

Table 1. Descriptive data of the subjects.

N	Gender	Age (yr)	Height (in)	Weight (lb)
9	**Female**	23 ± 2	67 ± 3	145 ± 19
3	**Male**	27 ± 3	69 ± 3	170 ± 20
12	**Total**	24 ± 3	68 ± 3	151 ± 22

This was conducted using two protocols. During the first testing session, the subjects were randomly assigned to one of two protocols. The second testing session consisted of the subject performing the protocol that was not completed during the first testing session. Protocol A consisted of 10 min of walking at 3.5 $mi \cdot hr^{-1}$ without handrail support followed by 10 min of jogging at 5.5 $mi \cdot hr^{-1}$ with handrail support. Protocol B consisted of 10 min of walking at 3.5 $mi \cdot hr^{-1}$ with handrail support followed by 10 min of jogging at 5.5 $mi \cdot hr^{-1}$ without handrail support. During both protocols, the 10-min walking stage was followed by a small break to collect data and allow the subjects' HR return to a normal resting value. Before continuing to the 10-min jogging stage, HR was recorded at 7 min and 30 sec. The CO_2 rebreathing procedure was performed at the 8-min mark while the subject was still walking/jogging. After CO_2 rebreathing had been performed, the treadmill was turned off to eliminate any noise while measuring blood pressure.

Familiarization

During the first testing session, all subjects were asked to read and sign an informed consent document. The research protocol for gathering data was explained to each subject, and at that point any questions that the subjects had were answered. The subjects were familiarized with the HR monitor and given instructions concerning the placement of the monitor and the wrist watch. Prior to the day of testing the subjects were asked to refrain from any unusual exercise, excessive food intake, and caffeinated beverages. All testing sessions took place from 8:00 am to 7:00 pm in the Exercise Physiology Laboratory.

Collection of Data

Upon the initial arrival of each subject a coin was flipped to see which protocol would be administered first. The subject was then fitted with a Polar HR monitor and asked to straddle the Biodex Rehabilitation Treadmill. The treadmill was set at the appropriate speed and the subject was asked to stroke the belt of the treadmill with one foot until he/she felt comfortable, then use both feet. At this point, collection of the data by the analyzer was started. The physiological measures included: oxygen consumption (VO_2), cardiac output (Q), heart rate (HR), stroke volume (SV), arteriovenous oxygen difference (a-vO_2 diff), systolic blood pressure (SBP), diastolic blood pressure (DBP), myocardial oxygen consumption (MVO_2),mean arterial pressure (MAP), systemic vascular resistance (SVR), volume of carbon dioxide (VCO_2), expired ventilation (V_E), tidal volume (T_V), and frequency of breathing (F_b).

Oxygen consumption and respiratory data (VCO_2, V_E, and F_b) were collected with the MedGraphics CardiO2 metabolic analyzer. The analyzer was calibrated before each testing session using standard gas mixtures. Oxygen consumption values were averaged over a 5-min period during steady-state exercise. Heart rate was observed using a Polar HR monitor and recorded at the 7½-min mark. This was followed by the CO_2 rebreathing procedure by means of the Defares method using a mixture of 4% CO_2 and 35% O_2 to determine Q at the 8-min mark. The CO_2 signal on the computer screen was used to obtain a satisfactory curve.

The subject's blood pressure (BP) was measured after the CO_2 rebreathing procedure had been completed. The brachial artery was chosen for the location to measure BP with a standard mercury sphygmomanometer and stethoscope. To avoid noise from the movement on the treadmill, each subject was asked to straddle the track while BP was taken. Stroke volume, a-vO_2 diff, MVO_2, MAP, SVR, and F_b were calculated.

Statistical Analysis

To determine if statistically significant differences occurred in the cardiovascular responses during walking and jogging with the free arm swing and with handrail support, ANOVA with repeated measures were performed analyzing VO_2, Q, HR, SV, a-vO_2 diff, SBP, DBP, MAP, MVO_2, SVR, VCO_2, V_E, T_V, and F_b. A probability of $P<0.05$ was used to determine statistical significance.

RESULTS

A comparison of the effect of walking without handrail support (Control) and walking with handrail support (Treatment) is presented in Table 2. Note that the table presents standard deviation, mean difference, *t* value, and significance. No statistical differences were found in the physiological responses in question during the walking part of the research protocol.

A comparison was also performed during the jog test session without handrail support (Control) and jogging with handrail support (Treatment). Refer to Table 3. Statistical significance (P<0.05) was found in VCO_2 and T_V. These two variables both increased when the subjects used the handrails for support during jogging. All other variables did not change.

Table 2. Physiological Responses to Walking on a Treadmill at 3.5 mi·hr^{-1} Without Holding onto the Handrails (Control) and Walking on the Treadmill With Handrail Support (Treatment).

Physiological Variables	No Handrail (Mean ± SD)	Handrail (Mean ± SD)	*t* value	Significance
VO_2 (L·min^{-1})	.87 ± .15	.92 ± .18	-1.324	.212
HR (beats·min^{-1})	103 ± 11	106 ± 13	-.809	.435
SV (mL·bt^{-1})	94 ± 17	95 ± 18	-.203	.843
Q (L·min^{-1})	9.6 ± 1.3	9.9 ± 1.1	-.964	.356
a-vO_2 diff (mL·100 mL^{-1})	9.0 ± 1.0	9.1 ± 1.0	-.549	.594
SBP (mmHg)	131 ± 11	131 ± 10	.158	.878
DBP (mmHg)	77 ± 7	80 ± 6	-1.299	.221
SVR (mmHg·L·min^{-1})	10 ± 1	10 ± 1	.321	.754
MVO_2 (mL·100 g LV ·min^{-1})	13 ± 3	13 ± 3	-.536	.603
VCO_2 (L·min^{-1})	.82 ± .14	.82 ± .13	.210	.838
V_E (L·min^{-1})	26 ± 3	26 ± 3	-.376	.714
T_V (mL·breath^{-1})	1120 ± 149	1110 ± 151	.270	.792
F_b (breaths·min^{-1})	23 ± 3	23 ± 2	-.469	.648

*(P<0.05)

One indicator of how hard the body is working is VO_2. With VO_2 remaining unchanged throughout this investigation, one could conclude that the work performed by the body during the Control and Treatment sessions was unchanged (i.e., the key ingredient of MET was unchanged). This shows that the use of handrail support during treadmill walking did not alter the work performed by the body.

Table 3. Physiological Responses to an Acute Bout of Treadmill Exercise Without Holding onto the Handrails (Control) verses With Handrail Support (Treatment) While Jogging at a Speed of 5.5 mi·hr^{-1}.

Physiological Variables	No Handrail (Mean ± SD)	Handrail (Mean ± SD)	*t* value	Significance
VO_2 (L·min^{-1})	1.79 ± .38	1.80 ± .33	-.319	.755
HR (beats·min^{-1})	158 ± 18	160 ± 15	-1.263	.233
SV (mL·bt^{-1})	99 ± 24	95 ± 16	.870	.403
Q (L·min^{-1})	15.3 ± 2.8	15.2 ± 2.1	.130	.899
a-vO_2 diff (mL·100 mL^{-1})	11.7 ± .6	11.9 ± 6	-1.136	.280
SBP (mmHg)	150 ± 13	151 ± 13	-.290	.777
DBP (mmHg)	76 ± 6	76 ± 7	.684	.508
SVR (mmHg·L·min^{-1})	7 ± 1	7 ± 1	.364	.723
MVO_2 (mL·100 g LV ·min^{-1})	27 ± 5	28 ± 5	-.765	.461
VCO_2 (L·min^{-1})	1.83 ± .32	1.98 ± .36	-3.037	.011*
V_E (L·min^{-1})	52 ± 8	54 ± 8	-1.912	.082
T_V (mL·breath^{-1})	1645 ± 263	1779 ± 297	-5.508	.000*
F_b (breaths·min^{-1})	32 ± 4	31 ± 3	1.817	.097

*($P<0.05$)

In regards to Table 3, only VCO_2 and T_V were significantly different when jogging with and without the use of the handrails. All other variables demonstrated the same physiological pattern as was the case during walking on the treadmill with and without handrail support.

DISCUSSION

The results of this study did not support the belief that using handrail support during treadmill exercise decreases VO_2. This finding is in agreement with Manfre et al. (3) and, in particular, with Zeimetz et al. (8) who found that VO_2 in the initial stages was not changed. Interestingly, Manfre and colleagues (3) analyzed total treadmill time between healthy male and female subjects versus male subjects suffering from coronary artery disease and myocardial infarction. Free arm swing was the Control and the Treatment was front handrail support provided by the tips of two fingers. They found no difference in total treadmill time regarding healthy male subjects. Since total treadmill time was unchanged, it is reasonable to assume that VO_2 did not change either.

The findings of Manfre et al. (3) and the present study contradict the findings in studies that reported a decrease in VO_2 when handrail support was utilized. As an example, Christman et al. (1) studied the effects of handrail support while exercising on a step treadmill. Oxygen consumption and HR were significantly decreased with light handrail support compared to no handrail support. The significant decrease in HR suggests a decrease in Q that very likely caused the decrease in VO_2. The decrease in HR is also suggestive that MVO_2 would have been decreased with light handrail support.

According to these studies, the use of handrail support decreases the benefits that could otherwise be gained from an aerobic training program. This may be in regards to the physiologic responses of the body that depend primarily on the workload of the major weight bearing muscles in the legs. This thinking was confirmed by Gardner, Skinner, and Smith (2) who tested 10 patients who suffered from peripheral vascular occlusive disease. The patients performed two separate protocols. One consisted of a single stage of walking at 2 $mi \cdot hr^{-1}$ with a 12% grade. The second protocol consisted of walking at 2 $mi \cdot hr^{-1}$ with the grade progressively increasing at a rate of 2% every 2 min, starting at 0% for the first stage. Both protocols had no set time limit and were terminated when the subject could no longer meet the demands of the protocol. The subjects completed both protocols 3 times each for a total of 6 exercise bouts. In regards to handrail support, the total distance walked was significantly greater when compared to walking without handrail support (2). Given the differences in distance it can be concluded that handrail support should not be used to determine an estimate of VO_2 max unless handrail support is absolutely necessary due to an impaired gait.

Similar findings were also observed by Christman et al. (1) during the evaluation of 15 healthy women through step treadmill exercise. The experimental conditions used consisted of: (a) light handrail support; and (b) very light handrail support. The data were compared to the no handrail support condition. These conditions were administered at 25 steps per min and 33 steps per min. Both experimental conditions (i.e., light handrail support and very light handrail support) found a decrease in mean VO_2 during exercise.

The use of handrail support decreased the load placed on the muscles of the lower extremities, much like the effect of buoyancy during water exercise. In fact, the effect of buoyancy is important when exercising clients who suffer from obesity. It allows for an exercise program that is very safe and, potentially, very effective as well (5).

What is apparent in the present study is this: There are no physiological responses while walking on the treadmill at 3.5 $mi \cdot hr^{-1}$ without handrail support that are different from walking on the treadmill at 3.5 mph while holding onto the handrails. Oxygen consumption was .82 $L \cdot min^{-1}$ with no handrails and .92 $L \cdot min^{-1}$ with handrails. The mean difference between the two volumes of O_2 during walking was not significantly different. In other words, it does not matter whether the client holds onto the rails or not.

As to the manner in which the O_2 was made available to the tissues during walking, the fact is there is no difference centrally or peripherally. The subjects responded exactly the same under both conditions. Cardiac output was 9.6 $L \cdot min^{-1}$ with no handrails and 9.9 $L \cdot min^{-1}$ with handrails. That is, the central adjustment to Q was achieved with similar HR (103 and 106 $beats \cdot min^{-1}$) and SV (94 and 95 $mL \cdot beat^{-1)}$ responses during both exercise conditions. Also, in terms of the subjects' peripheral adjustment to the exercise conditions, the muscles extracted the same O_2 for every 100 mL of blood that perfused the capillary bed. The tissue extraction at the muscle cell level during walking (9 $mL \cdot 100\ mL^{-1}$) was greater than resting a-vO_2 diff (i.e., approximately 5 $mL \cdot 100\ mL^{-1}$).

The myocardial performance of the subjects was exactly the same (13 vs. 13 mL ·100 g LV ·min^{-1}), regardless of whether their exercise was supported by the handrails or not. This finding is directly related to the subjects' lack of mean differences in HR and SBP between the two exercise conditions. The same implications can be stated with respect to the subjects' respiratory performance. There were no mean differences in V_E due to no differences in T_V and F_b.

When the data are analyzed with regard to jogging at 5.5 mi·hr^{-1} on the treadmill, the same exact conclusions are warranted. The only exceptions to the findings just described are VCO_2 and T_V. Both were significantly increased when holding onto the handrails while jogging. However, it very likely that the mean differences, although significant, do not have practical significance. That is, VCO_2 was different only by .15 L·min^{-1} and T_V was different only by 134 mL·$breath^{-1}$ when holding onto the handrails versus not holding on during exercise.

CONCLUSIONS

Handrail support during treadmill exercise is nothing new or even uncommon to observe clients practicing in the health club setting. Many people in a gym setting use the handrails because they feel it allows them to exercise harder and longer, therefore expending more calories. The way these machines determine the amount of calories burned is through a regression equation. These equations take into account such variables as speed, grade, height, weight, and heart rate, but not handrail support.

This study was designed to evaluate the impact on VO_2 while the subject utilized the handrails located on the sides of the treadmill for support. Oxygen consumption may be used to determine how many calories are burned over an exercise bout, thus an increase in VO_2 will produce an increase in calories burned. The cardiovascular and hemodynamic variables measured in this study were related to VO_2.

The results of this study indicate that in normal healthy college-aged adults, VO_2 was not significantly altered when handrails were used during walking and jogging on the treadmill for 10 min. Also, what is important is that these findings represent new information regarding the central and peripheral adjustments to the subjects' VO_2. There appears to be no scientific reason at this time indicating that handrail support decreases the workload of the body during zero grade steady state exercise.

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