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Heart rate and VO_2 responses to treadmill running with body weight support using the GlideTrak™

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A B S T R A C T

Background/Objective: The heart rate (HR) and metabolic (VO_2) responses to treadmill running using the GlideTrak™ body weight support system have not been reported. The purpose of this study was to compare the submaximal and maximal HR and VO_2 responses to normal-weight treadmill running (TMR) to treadmill running with body weight support provided by the GlideTrak™ (GTR).
Methods: Twenty participants (11 males; 9 females) 18 to 26 years of age voluntarily participated in this study. Each participant completed two exercise tests in each mode of running: a maximal graded exercise test to compare maximal HR and VO_2 values and a submaximal exercise test to compare the HR-VO_2 relationship.
Results: Maximal HR and VO_2 values were significantly ($p < 0.001$) lower during GTR (183.4 ± 9.1 bpm, 38.1 ± 7.2 mL kg^{-1} min^{-1}) compared to TMR (194.3 ± 8.6 bpm, 49.5 ± 8.9 kg^{-1} min^{-1}). There was a significant difference in the HR-VO_2 relationship between GTR and TMR. Compared to TMR, exercising at a HR of 140 bpm resulted in a VO_2 that was 4.0 mL kg^{-1} min^{-1} lower during GTR. At the VO_2 associated with a HR of 140 bpm during TMR, the HR during GTR was 16 bpm higher. During GTR at intensities of exercise up to an RER of 1.0, only 8 participants achieved vigorous intensities of aerobic exercise defined as 64-90% of VO_2max.
Conclusion: Exercising with the GlideTrak™ body weight support system may not provide the same cardiorespiratory training stimulus as normal-weight treadmill running.

1. Introduction

Walking and running are common modes of physical activity and exercise yet some people may not be able to bear their full body weight while walking or running due to impaired neuromuscular control, for example following an injury or surgery. Neuromuscular control problems can challenge the ability to exercise safely. Walking or running with body weight support facilitates the rehabilitation process by reducing ground reaction forces (GRF) while maintaining similar neuromuscular function and kinematic timing patterns. Recent reports[1,2] indicate that patients with mild-to-moderate Parkinson's Disease can improve performance on the 10 m walk, 6-minute walk, Sit to Stand, and Timed Up and Go tests after only 5 consecutive days of aerobic training on the AlterG anti-gravity treadmill (AlterG Inc, Freemont, CA, www.alterg.com) and the GlideTrak™ body weight support system (GlideTrak™, Ashland, OR, www.glidetrak.com).

Running with body weight support is also beneficial to athletes in that it may reduce the risk of overuse injury and speed recovery from an injury and return to preinjury training levels while reducing risk of reoccurring injuries.[3–6] One of the challenges during the rehabilitation of an injury in runners is incorporating a training stimulus sufficient to maintain or at least minimize losses of cardiorespiratory fitness.[3] Although running with body weight support is beneficial in the rehabilitation of a running injury, the metabolic demands of running decrease linearly with increasing body weight support.[6–8] Thus, running with body weight support may not be sufficient to maintain cardiovascular training benefits during a lengthy rehabilitation process. Research using the AlterG anti-gravity treadmill suggest that the metabolic demands of

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normal-weight walking[9] and jogging[4] can be maintained when exercising with body weight support, albeit at higher speeds. Maximal oxygen uptake (VO_2max) has also been shown to be similar when performing a maximal graded exercise test while running at a normal body weight and up to a 15% reduction[3] and 20% reduction[10] in body weight. The HR-VO_2 relationship has been shown to be unaltered when walking and running at normal body weight, 75% body weight, and 50% body weight, suggesting that modifications to training programs based on target HR are not required when training with body weight support.[11]

The similarity of the cardiovascular and metabolic responses to normal weight running and running with body weight support likely depends, in part, on the amount and manner in which body weight support is provided. Many of the previous studies have made use of the AlterG anti-gravity treadmill which allows body weight support to be adjusted by increasing air pressure in a canopy surrounding the lower body. The GlideTrak™ body weight support system provides 0-100% body weight support by sitting on a saddle suspended by an adjustable harness from a frame placed over an existing treadmill. Pilot research in our lab showed that compared to normal-weight treadmill running (TMR), exercising with body weight support using the GlideTrak™ (GTR) resulted in a 60% and 75% reduction in GRF during treadmill walking and treadmill running, respectively. Normal-weight walking and running on a treadmill resulted in GRF equivalent to 1.3 and 2.4 times body weight, while GTR resulted in GRF equivalent to 0.55 and 0.60 times body weight, respectively. Recent research indicates that patients with mild-moderate Parkinson's Disease were able to train safely on the GlideTrak at intensities corresponding to 60%-80% of an age-appropriate maximal heart rate (HR).[1,2] As reports of the HR and VO_2 responses to GTR are limited, the purposes of this study were to (a) compare maximal HR and VO_2 values achieved during a maximal graded exercise test performed using GTR and TMR, and (b) compare the HR-VO_2 relationship of GTR to that of TMR in apparently healthy young adults.

2. Methods

2.1. Participants

Twenty participants (11 male; 9 female), 18 to 26 years of age, with an average height, body mass, and BMI of 1.73 ± 1.3 m, 73.8 ± 15 kg, and 24.5 ± 3.8 kg/m^2 respectively, voluntarily participated in this study. Participants were free of injuries and not taking any medications that would alter their cardiovascular or metabolic responses to exercise or reduce their exercise tolerance. This study was reviewed and approved by the Institutional Review Board for Human Subjects prior to the collection of data. After being informed of study procedures, risks, and benefits of their participation in the study and completing a pre-participation questionnaire, each participant provided written informed consent. Participants were familiarized with treadmill walking and jogging and use of the GlideTrak™. The GlideTrak™ makes use of two harnesses: an adjustable harness that supports the saddle on which the participant sits, and an optional shoulder harness that can be used to reduce or eliminate the fear or risk of falling while seated on the saddle. Participants were familiarized with GTR until they performed GTR without the support of the shoulder harness and with unrestricted arm and leg movements. During the familiarization trial, participants were also familiarized with the 6–20 rating of perceived exertion (RPE) scale and its anchors.[12]

2.2. Procedures

Participants reported to the exercise physiology lab on two other occasions separated by at least 48 hours. Participants were instructed to refrain from ingesting food, alcohol, and caffeine within the 4 hours prior to testing, and avoid strenuous exercise for at least 12 hours prior to testing. On one visit, participants performed a normal-weight submaximal exercise test followed by a maximal exercise test on a treadmill. On the other visit, participants performed a submaximal exercise test followed by a maximal exercise test with body weight support using the GlideTrak™. During all exercise tests, participants were fitted with a mouthpiece and a nose clip to facilitate the measurement of VO_2 using a Parvo-Medics TrueOne 2400 metabolic measurement system (Parvo Medics, Sandy, UT). Prior to testing, the oxygen and carbon dioxide analyzers were calibrated using medical grade gases of known concentrations and the flow meter was calibrated using a 3.0 L syringe. The metabolic measurement system was configured to display 15-second averaged data. Heart rate (HR) was continually monitored using a radiotelemetry HR monitor (Polar Electro Inc., Lake Success, NY) and participants reported an RPE value during each stage of the exercise test.

2.3. Submaximal exercise tests

The purpose of the submaximal exercise test was to collect HR and VO_2 data over a wide range of intensities to allow the comparison of the HR-VO_2 relationship between GTR and TMR. The endpoint for each submaximal exercise test was either a respiratory exchange ratio (RER) of 1.0 or 90% of the participant's age-predicted (220-age) maximal HR. The submaximal exercise test protocol proceeded through the following stages: (a) walking at a brisk walking pace between 5.6–7.2 km h^{-1} for 3 minutes, (b) jogging at a self-selected jogging speed between 8–11.2 $km \cdot h^{-1}$ at level grade for 3 minutes, and (c) maintaining the self-selected jogging speed but increasing the grade by 2% every 3 minutes until the participant reached either one of the two endpoints.

For the GTR submaximal exercise test, the GlideTrak™ frame was positioned over the treadmill so that the participant could exercise on the treadmill while seated on the saddle. The adjustable harness was used to position the saddle so there was a 40° knee angle with the feet flat on the belt of the treadmill when the treadmill was at level grade. This was done to normalize the knee joint angle and body weight support provided by the seat for all participants. The 40° knee angle was chosen because it closely mimics the normal angle of the knee while running.[13] Preliminary pilot experimentation revealed that when participants ran at a self-selected pace, they were able to reach the maximal grade capacity of the treadmill without reaching the endpoints of the submaximal exercise test. Thus, the submaximal exercise test protocol was modified to include both an increase in treadmill speed (1.6 $km \cdot h^{-1}$) and a 2% increase in treadmill grade in the third and subsequent stages until the participant reached either one of the two endpoints. As treadmill grade was increased, the position of the saddle was adjusted to maintain participant comfort and a 40° knee angle, thus maintaining a consistent body position throughout the exercise test.

2.4. Maximal Exercise Tests

After completing the submaximal exercise test, the participant rested at least 15 minutes and then performed a maximal exercise test using the same mode of exercise (i.e., TMR or GTR). The rest period was considered adequate since the submaximal exercise test progressed from light-to moderate-intensity exercise and lasted only 12–24 minutes. The submaximal exercise tests were also considered part of the warm-up for the maximal exercise test.

The TMR maximal exercise test followed the protocol typically used in our Exercise Physiology Lab that allows participants to complete a maximal exercise test within 10–15 minutes.[14,15] After walking at a self-selected brisk pace for 1 minute, the speed of the treadmill was increased to the self-selected jogging speed (8–11.2 $km \cdot h^{-1}$) used during the submaximal exercise test. Participants were then asked if they wanted to increase or decrease the treadmill speed. The treadmill speed remained constant during the remaining stages of the exercise test. After the third minute of level grade jogging, the treadmill grade was increased 2% every minute thereafter. The protocol for the GTR maximal exercise test was modified to include a 2% increase in grade and a 1.6 $km\ h^{-1}$ increase in speed after the third minute and every minute thereafter. As with the submaximal exercise test, the position of the saddle was adjusted to maintain a consistent 40° knee angle. Each maximal exercise test was terminated when the participant was unable to continue despite verbal encouragement. After terminating the test, participants walked at a self-selected speed at level grade for any desired amount of time.

Maximal HR and maximal or peak VO_2 were defined as the highest 15-second average HR and VO_2 values during the final minutes of the exercise test. The participant's effort was considered maximal if physical signs representative of exhaustion were obvious and at least two of the following four criteria were met: (a) maximal RER was greater than or equal to 1.10, (b) maximal HR was no less than 15 bpm below age-predicted maximal HR, (c) an RPE of 19 or 20 was self-reported at the time the test was terminated, and (d) there was a plateau of VO_2 during the final minute(s) of the exercise test.

2.5. Statistical analysis

All data were analyzed using SAS statistical software (SAS Institute Inc., Cary, NC). One-way ANOVAs were conducted to determine differences in maximal VO_2, HR, RER, and RPE responses between the two exercise modes (TMR and GTR). All tests were Bonferroni-corrected to maintain a critical alpha value of 0.05 when multiple tests were performed.

The comparison of the HR-VO_2 relationship between TMR and GTR was of particular interest in this study. The appropriate way to evaluate this data was to express HR and VO_2 in bpm and $mL\ kg^{-1}\ min^{-1}$, respectively and in relative terms (percent of maximal HR and percent of maximal or peak VO_2). The 20 participants in this study completed the submaximal exercise test within 4 to 8 stages. Thus, each participant contributed 4 to 8 data points for each test so that the analysis of submaximal data for GTR was represented by 116 data points and the submaximal data for TMR was represented by 129 data points. Because slopes and intercepts were used in the data analysis, it was appropriate to center the data so that intercepts were calculated within the range of data observed rather than when the independent variable was zero. When analyzing the VO_2 response as a function of HR, the HR data were centered at a HR of 140 bpm. When analyzing the VO_2 response (% VO_2max) as a function of HR (% HRmax), the HR data were centered at 75% of HRmax. Because each participant had multiple measures, linear mixed models (Proc Mixed in SAS) were used for the analysis of the HR-VO_2 relationships so within-subject covariances were appropriately accounted for. Because we centered the data, tests on intercepts were conducted at the center of the independent variable values and thus are appropriate even when the slopes are not parallel.

3. Results

During the TMR maximal exercise test, 5 participants met all four criteria for achieving a maximal effort, 10 met the HR, RER and RPE criteria, and 5 met the HR and RPE criteria. During the GTR maximal exercise test, 3 participants met the VO_2 plateau and two other criteria, 9 met the HR and either the RER or RPE criteria, and 8 met the RER and RPE criteria. Maximal RER values were similar during TMR (1.11 ± 0.04) and GTR (1.10 ± 0.05). Maximal HR and VO_2 values during TMR were significantly ($p < 0.001$) greater than during GTR (Table 1).

The analysis of the HR (bpm) and VO_2 data ($mL \cdot kg^{-1}\ min^{-1}$) revealed that the slopes of the HR-VO_2 relationship during TMR (0.370) and GTR (0.280) were significantly different ($p < 0.05$; Fig. 1). The intercept of the HR-VO_2 relationship at a HR of 140 bpm was significantly less ($p < 0.05$) during GTR (23.2 $mL \cdot kg^{-1} \cdot min^{-1}$) compared to TMR (27.2 $mL \cdot kg^{-} \cdot min^{-1}$). At the same VO_2 as that associated with a HR of 140 bpm during TMR, the HR during GTR was 16 bpm higher. When HR and VO_2 data were expressed relative to maximal values, the intercepts and slopes of the HR-VO_2 relationship were nearly identical (Fig. 2).

4. Discussion

To the best of our knowledge, this is the first study to report data on the cardiovascular and metabolic responses to treadmill running with body weight support using the GlideTrak™. Our findings indicate that VO_2max values achieved during normal weight treadmill running cannot be achieved during GTR, and that there is a difference in the HR-VO_2 relationship between TMR and GTR.

Because the cardiovascular and metabolic responses to GTR have not previously been reported, the results of this study can only be compared to the results of previous studies using different methods of providing body weight support. In this study, VO_2peak achieved during GTR was on the average 11.4 $mL \cdot kg^{-1} \cdot min^{-1}$, or 23% lower than VO_2max achieved during TMR even though maximal RER values were similar. The results of this study are contrary to previous studies[3,10] that report similar VO_2max values during normal-weight treadmill running and running with 5-20% body weight support on an AlterG treadmill. Use of the GlideTrak™ body weight support system does not allow measuring the amount of body weight support. In addition, the saddle of the GlideTrak™ body weight support system bears a large portion of the participant's body weight, resulting in a "gliding" motion of the legs that mimics running. The results of this and previous research suggest that there may be a threshold of body weight support at which VO_2max values cannot be achieved.

Results from the submaximal exercise tests in this study indicate a difference in the HR-VO_2 relationship between TMR and GTR. At a HR of 140 bpm, GTR elicited a VO_2 that was 4.0 $mL\ kg^{-1}\ min^{-1}$ lower than during TMR (Fig. 1). At the VO_2 corresponding to a HR of 140 bpm during TRM, the participants in this study had HRs that were on the average 16 bpm higher during GTR. Differences in the maximal VO_2 responses and the absolute HR-VO_2 relationship observed in this study between normal weight running and

Table 1
Maximal exercise test results.

	Treadmill	GlideTrak™	p value
Maximal HR (bpm)[a]	194.3 ± 8.6	184.0 ± 8.8	0.001
% Age Predicted HRmax[a]	98.2 ± 4.2	93.0 ± 4.3	<0.001
Maximal RER	1.11 ± 0.04	1.10 ± 0.05	0.464
Maximal RPE	19.4 ± 0.6	18.3 ± 0.9	0.029
VO_2max($mL\ kg^{-1}\ min^{-1}$)[a]	49.5 ± 8.9	38.1 ± 7.2	<0.001

N = 20. All values are mean ± SD.
[a] Significant difference between normal weight treadmill running and treadmill running using the GlideTrak™ body weight support system after Bonferroni correction for multiple tests.

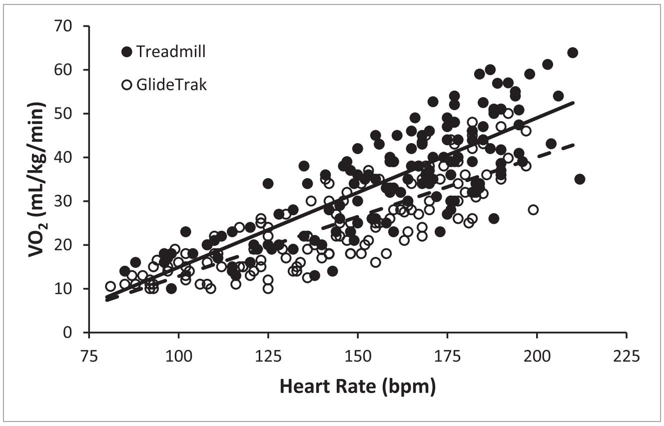

Fig. 1. The HR (bpm) and VO_2 (mL/kg/min) responses to treadmill and GlideTrak running.

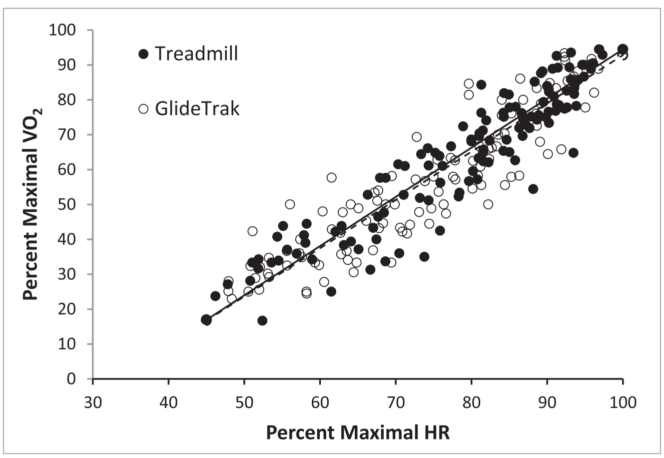

Fig. 2. The relative (%max) HR and VO_2 responses to treadmill and GlideTrak running.

running with body weight support are likely explained by the differences in the movement patterns, quantity of muscle mass activated during exercise, body position, and upper and lower body movement patterns.[16–18] The differences in the HR-VO_2 relationship due to mode of exercise were abated when HR and VO_2 were expressed as a percent of mode-specific maximal values (Fig. 2). This suggests that the intensity of GTR exercise would ideally be expressed relative to the mode-specific VO_2max. Our results are contrary to the findings of previous studies indicating that the HR and VO_2 responses to unweighted exercise are similar to those of normal-weight treadmill walking and running.[4,9–11] Differences between the results of this study and previous studies are likely due to the method of providing body weight support.

Of particular interest in this study was whether a person can perform GTR at an intensity equivalent to TMR. The American College of Sports Medicine defines moderate intensity exercise as 64–76% HRmax or 46–63% VO_2max, and vigorous intensity exercise as 77–95% HRmax or 64–90% VO_2max.[19] During the submaximal exercise tests, all 20 participants reached vigorous intensities of exercise during TMR. During submaximal GTR, only 8 (40%) participants achieved vigorous intensity exercise even though the end point for the submaximal exercise test was an RER = 1.0. Although 18 of the 20 participants could exercise on the GlideTrak™ at moderate intensities of exercise appropriate for maintaining or increasing cardiorespiratory fitness, some individuals may not be able to achieve the same high intensities as have been reported when running with body weight support on the AlterG anti-gravity treadmill.[3,4,9–11] The results of this study concur with those of recent quality assurance studies[1,2] reporting that a group of 11 senior men and women (mean age = 69.1 ± 2.8 yr) were able to exercise at a target HR of 60% to 80% of their age predicted (220-age) maximal HR.

This study is not without limitations. It is foreseeable that sitting on a saddle during GlideTrak™ walking and jogging would be an appropriate way to provide body weight support to overcome mobility issues and while rehabilitating injuries or neuromotor issues in obese, geriatric, or other patients. Nevertheless, this study does not address the benefits of GlideTrak™ walking and jogging in these populations. Two previous studies report the efficacy of the GlideTrak™ body weight support system in exercise interventions for Parkinson's Disease.[1,2] As a preliminary study, our purpose was to compare the submaximal and maximal HR and VO_2 responses between TMR and GTR. This could best be accomplished using healthy participants without movement limitations. Although we intentionally adjusted the harnesses of the GlideTrak™ to maintain a knee flexion angle that mimics the normal knee angle while running, a biomechanical analysis of GTR may reveal a better saddle position. Even though participants in this study included moderately fit, physically active males and females, use of endurance trained athletes as participants may shed further light on the efficacy of GTR as a viable mode of high-speed training with body weight support. Future studies may also evaluate the benefits of GlideTrak™ walking and jogging as a mode of exercise for the rehabilitation of those who have mobility issues, pain during locomotion, and lower extremity injuries.

Based on the results of this study, we conclude that compared to normal-weight TMR, GTR resulted in lower maximal HR and VO_2 values and a HR-VO_2 relationship that would require exercising at higher speeds or grades to achieve the same metabolic (VO_2) challenge. At intensities of exercise represented by RER values less than 1.0, most participants were unable to achieve vigorous intensities of exercise as defined by the ACSM VO_2 criteria. Other benefits of GlideTrak™ walking and running in various applications require further investigation.

Conflicts of interest statement

The authors have no conflicts of interests to declare.

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