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The Effect of Heavy Handrail Support on Blood Pressure Response in Normotensive Adults During Treadmill Walking

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A Thesis Submitted to the Graduate Facility of

JAMES MADISON UNIVERSITY

In

Partial Fulfillment of the Requirements

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Master of Science

Exercise Physiology

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Abstract

Physiological and hemodynamic responses to handrail support during treadmill walking have shown a blunted response when compared to non-handrail support. The effects of treadmill walking, with the inclusion of “heavy” upper limb and torso activation through handrail support is yet unreported. The effect of “heavy” support through side handrail support (SHRS) and front console support (C) versus no handrail support (NHRS) treadmill walking was studied utilizing both slow/low (2.5 mph & 3% elevation) and high/fast (3.5 mph & 11% elevation) energy expenditure levels. Seventeen healthy adults (43.89 +/- 6.07 years) completed trials at both energy expenditure levels incorporating all three handrail support conditions within 1 week, separated by at least 1 day. SBP, DBP, HR, and RPE were measured. SBP was 8.6% and 5.9% lower during C compared to NHRS ($p<0.001$) and SHRS ($p=0.005$), respectively, in the slow/low trials and 17.9% lower compared to NHRS ($p<0.001$) in the fast/high trials. SBP was 15.6% lower during SHRS compared to NHRS ($p<0.001$) during the fast/high trials. DBP was 10.9% and 9.1% lower during C compared to NHRS ($p<0.001$) and SHRS ($p<0.001$), respectively, during the fast/high trials. HR was 10.3% and 5.8% lower during C compared to NHRS ($p<0.001$) and SHRS ($p=0.006$), respectively, during the fast/high trials. No gender effect was noted. The amount of decrease in each variable was intensity dependent, which may be practically significant when prescribing exercise to a participant who relies on handrail support. Likewise, the removal of handrail support during treadmill walking in the healthy exerciser is no contraindicated.

Chapter 1 - Introduction

The use of handrail support while walking on the treadmill is neither new to fitness participants nor the scientific literature. In a report of hospital-based rehabilitation, use of handrail support was seen more than 90% of the time with 60% actively gripping the apparatus (1). Furthermore, exercisers in health club settings are often observed using continuous heavy handrail support during exercise (4). Numerous researchers have examined the effect of the use of “light” handrail support during treadmill locomotion on heart rate and oxygen uptake (VO2), especially when concerned with the prediction of VO_2max (1, 6, 8, 11, 13, 14, 16, 17, 18, 21, 23, 25). What appears to be missing from the literature is an examination of the effect “heavy” handrail support positions (most frequently seen in health club settings) have on the exerciser’s blood pressure as a result of the increased isometric load imposed on the upper limbs and torso.

Lind, et al (14) reported that sustained hand-grip contractions induced a linear rise in blood pressure when a threshold of 15% maximum voluntary contraction was met. Lind and McNicol (15) reported a 18% and 21% increase in systolic and diastolic blood pressure, respectively, while performing a 5 minute sustained hand-grip at 20% maximum voluntary contraction while performing inclined walking on the treadmill. Similarly, Bhambhani, et al (2) reported a mild hypertensive effect from the sustained low-intensity isometric contractions involved during load carriage equaling approximately 25% of the subject’s body weight. Conversely, Zeimetz, et al (25) reported no significant difference in blood pressure between no handrail support, side rail support, and front handrail support while performing a Bruce protocol exercise test for stages 1-4. Furthermore, a significant decrease in systolic blood pressure during stage 5 of the conditions with front handrail balance support and front handrail heavy hold was observed. Gardner, et al (8) reported non-significant reductions in ankle systolic pressure and brachial systolic pressure during treadmill walking with “light” handrail support.

The magnitude of alteration in physiological response during treadmill walking appears related to the magnitude of handrail support experienced, especially during higher intensity exercise (1, 11, 16, 25). Handrail support position falls into five categories: front handrail support touching (1, 8, 16, 17, 18, 25), front handrail support gripping (21, 23), side handrail support touching (1, 4, 12), side handrail support gripping (3, 4, 12), and undefined (11). The four defined positions require a horizontal load application in line with the belt with the hands slightly in front of the torso, thus enabling only a small support of 2.3-6.8 kg (24). Howley, et al (12) and Butt, et al (3) are the only known authors to date who examined a heavy hold treatment in which subjects “clearly supported their weight”; though these studies were conducted on a stepping ergometer. This latter condition occurs most often in fitness participants with: 1) hands atop the treadmill console, arms extended, and a posterior lean to the torso, or 2) hands gripping the side rails, arms locked, shoulders raised and clearly supporting the exercisers weight.

Although handrail support is a common occurrence, clinicians and established exercise testing protocols do not consider it in the interpretation of results or exercise programming (17, 23). Prescribed training stimuli may elicit unexpected or undesired results based on any realized alteration of the results achieved either during preliminary exercise testing or the subsequent practice of the prescription (1, 12). The addition of widespread vasoconstriction due to static exercise involving dynamic motion can result in a dramatic increase in blood pressure (6, 14). The effects of walking during mechanical treadmill locomotion, with the inclusion of “heavy” upper limb and torso activation through handrail support is yet unreported. Therefore, the purpose of this study is to evaluate the effect of handgrip aid on systolic and diastolic blood pressure during treadmill walking in 35 – 55 year old normotensive adults.

Chapter 2 - Literature Review

Handrail Support Defined

Handrail support is loosely defined as contact with the apparatus outside of the necessary requirements of use of that apparatus; specifically with the hands and/or arms. The definition can be further specified as a resting or holding of the hands to the apparatus in an attempt to assist themselves by leaning or pulling on the apparatus (17). Handrail support positions examined in the literature may fall into one of five categories: front handrail support touching (1, 8, 16, 17, 18, 25), front handrail support gripping (21, 23), side handrail support touching (1, 4, 12), side handrail support gripping (3, 4, 12), and undefined (11).

Sub-categorization of the literature further defines handrail support by “very light”, “light”, “moderate”, and “heavy”. A “very light” handrail support has been defined as allowing the participant to rest their hands on the handrail (17), to lightly touch the handrail to maintain balance with palms flat (8), the resting of hands on the rail without grasping (1, 18), placing the fingers barely in contact with the handrails (4), and, most specifically, limiting the extent of touch to the distal phalanx of the left index and middle fingers (16). “Light” handrail support, in which the fingers rest on or against the supports for balance (12) or in reference to placing the hands on the handrails (4), is not easily distinguishable from the “very light” condition. Berling, et al (1) provides the least specific definition of a “moderate” handrail support by which the participant is “gripping the front handrail”. Greater specificity is provided by von Duvillard and Pivirotto (23) when they instructed their participants to hold with only the middle and index fingers of both hands. Rutledge, et al (21) furthered the description as grasping firmly without squeezing hard enough to produce white knuckles or substantially supporting the body weight. The “heavy” condition is most clearly defined as the subjects clearly supporting their body weight (3, 4, 12). Further specification was offered by Zeimetz, et al (25) who quantified the “heavy” handrail support as a known horizontal resistance of 6.8 kg using an apparatus to control horizontal resistance applied to the front handrail.

In their work with patients with peripheral artery disease, Gardner, et al (8) speculated that unless the same pressure was applied to the handrails over the duration of a single test, and over repeated tests, the reliability of the measures may be reduced. McConnell and Clark (17) also observed the participants’ ability to vary the amount of force applied throughout the procedures and question its effect on the overall variability. Participants were carefully observed and reminded to maintain appropriate touch parameters because they tended to increasingly grasp the handrails as claudication pain increased. Reliability of the hemodynamic response variables was not affected by changes in handrail support (8). Other authors took similar precautions in an attempt to standardize their participants’ level of handrail support (17, 23, 25).

Handrail Support Prevalence

Despite manufacturer’s recommendations that handrails may be used intermittently for balance only, exercisers in health club settings are often observed utilizing continuous handrail support (4). Exercisers have a tendency to exert more tension on the handrails as the intensity of the work increases (25). Handrail support is also a common occurrence in the clinical setting (23). In a report of hospital-based rehabilitation, use of handrail support occurred more than 90% of the time with 60% actively gripping the apparatus (1). Gardner, et al (8) reported no patient difficulty walking without the use of handrail support and hypothesized that it may be an unnecessary safety precaution as long as they are periodically permitted to touch the handrail to maintain balance.

Physiological Response to Handrail Support

A number of studies have shown attenuation in the physiological responses to exercise when an exerciser supports any portion of their weight through handrail contact, causing a subsequent reduction in mechanical work experienced by the exercising limbs (1, 4, 8, 11, 12, 16, 18, 21, 23, 25). The majority of these studies have focused on the effect of handgrip on the prediction of VO_2max (1, 4, 11, 12, 16, 18). Secondary findings most often examine the relationship of handgrip to heart rate, total treadmill time, minute oxygen uptake, and rating of perceived exertion (1, 4, 11, 12, 16, 18).

Berling, et al (1) reported a 15-20% reduction in aerobic demands, a 20 beats/min reduction in heart rate, and a 0.6 reduction in rating of perceived exertion during handrail support. A particularly large reduction in oxygen consumption, heart rate, and rating of perceived exertion were observed under conditions of handrail gripping when compared to handrail resting (1). Christman, et al (4) reported a 4-8% reduction in mean oxygen consumption during both continuous light and continuous very light handrail support as compared to the no handrail support condition. During continuous light handrail support, mean heart rate was significantly reduced by 4.5-4.8% (4). A significant reduction of 7.1% and 5.8% in minute VO_2 and heart rate, respectively, was shown by Howley, et al (12) when comparing a heavy hold versus a no hold condition. Von Duvillard and Pivirotto (23) reported significantly higher VO_2 responses during stages 2-4 of the non-handrail support condition (with the greatest difference during stage 4) of the Bruce protocol. Mean VO_2 scores during the non-handrail support condition at submaximal workloads were approximately 4.88 ml/kg/min higher, while maximal scores did not vary significantly with the use of handrail support. Differences in heart rate were only noticed during the fifth stage (23).

Ziemetz, et al (25) found an increase in treadmill time of up to 18 minutes when comparing handrail support to no handrail support during the performance of the Bruce Protocol. Fifteen men, averaging 24 years of age, completed six graded exercise tests to compare the effects of no handrail support, side handrail support, and four intensities of front handrail support. Significant decreases in systolic blood pressure were separately reported during both a 6.8kg horizontal pull trial and balance only trial during stage 5 of the Bruce Protocol when compared to the no handrail support trial. Significant increases in exercise duration were reported in healthy women (72s or 9.0%) and males with cardiac disease (60s or 7.7%) when the use of handrail support was permitted (16). Manfre, et al (16) limited the extent of handrail support to the distal phalanx of the left index and middle fingers. Each participant completed a no handrail support and handrail support graded exercise tests utilizing a modified Bruce Protocol, which included two additional stages at 1.7 mph and 0% grade and 1.7 mph and 5% grade (16). No significant differences between handrail support and non-handrail support in measured VO2max, heart rate, or rate pressure product were reported within each group (16). Gardner, et al (8) reported significantly longer walking distances for participants with coronary artery disease with stable, but limiting, claudication pain with every handgrip condition. Each participant performed both single stage and progressive treadmill protocols with and without handrail support completing a total of 12 testing sessions (8). In an examination of 45 health women age 18-25, von Duvillard and Pivirotto (23) reported the required addition of an extra 1-2 stages during the Bruce Protocol when utilizing handrail support. Ragg, et al (19) found a 68% increase in treadmill time with the use of handrail support when compared to no handrail support during an unchanging speed protocol in their investigation of six men, averaging 26 years, completing two trials to maximal VO_2.

Predicting VO2max from a submaximal prediction model while using handrail support significantly overestimates the maximal capacity of the participant (11, 12, 18). Haskell, et al (11) reported an overestimation of 19% ($p<.001$) in 12 men age 70 years or less who were hospitalized for myocardial infarction. On an electric stepping ergometer, Howley, et al (12) showed a significant reduction in oxygen consumption with a subsequent overestimation of maximal capacity ($p<0.03$) in their study of 12 healthy males, age 20 to 33 years. Though handrail support has been shown to reduce the momentary aerobic demands and heart rate, McConnell, et al (18) provided evidence that the VO2peak achieved during maximal testing is not significantly different with handrail support. In the review of 41 participants (30 male and 11 female) age 31 to 61 years, 11 had had myocardial infarction, 14 had undergone myocardial revascularization surgery, and 16 were healthy. Peak oxygen consumption during handrail support was 2.9% lower than during non-handrail support and heart rate was 0.7% lower. Neither of these differences were statistically significant (18). The total treadmill time reported during the handrail support condition was in agreement with previous research, especially in tests lasting longer than 8 minutes (23% increase during handrail support) (18).

Hemodynamic Response to Handrail Support

Only three authors have reported the effect of supported treadmill walking with relation to blood pressure. In their study of 15 healthy men (average age 24 years), Ziemetz, et al (25) reported a significant decrease in systolic blood pressure during stage 5 of the Bruce protocol between the lightest and heaviest horizontal pull conditions (12.5% and 15% respectively). No significant differences in systolic blood pressure were discovered in any of the other protocol stages examined during this investigation. Rutledge, et al (21) reported non-significant reductions in both systolic and diastolic pressures during their examination of the Bruce protocol. Gardner, et al (8) reported non-significant changes in both brachial systolic and diastolic pressure at similar time intervals during tests utilizing handrail support, though the direction of relationship was not published. All three studies utilized front handrail support with either a “light” or “moderate” contact with either one or both hands. In the work of Gardner, et al (8) and Rutledge, et al (21) participants were observed for excessive gripping and reminded to maintain the appropriate level of contact. The participants of Ziemetz, et al (25) had their handrail support level dictated by an added apparatus to the treadmill to control the amount of horizontal pull allowed during testing.

This author will utilize two different “heavy” handrail support positions often observed by participants in community Wellness Centers; hands atop the treadmill console with posterior lean and weight supported through the hands and arms, and hands placed on the side rails with arms straight and weighted to help support the mass of the participant. Participants will be reminded to maintain support of their mass throughout the hand grip conditions. For reasons of practical application to the exercising public, the Bruce protocol will not be utilized in favor of longer stage intervals at a constant speed with alterations in elevation to more similarly mimic a wellness center participant’s treadmill workout.

Hemodynamic Response to Load Carrying During Walking

Jackson, et al (13) suggests that when a static component, simulated by 40 lb load carriage, was added to the dynamic task of treadmill locomotion, the pressure overload associated with isometric exercise can be additive to the volume overload produced by the dynamic exercise alone (9, 10). This response may be due to an increased total peripheral resistance caused by greater mechanical compression of the vasculature (9, 24) or the greater relative percentage of maximal tension required to perform a given amount of work by a smaller mass of active muscle (2, 9, 10, 13, 24). The addition of isometric stress to dynamic stress augments the anticipated hemodynamic response to levels higher than previously noted for the original dynamic exercise alone (2, 9, 10, 13, 24).

Graves, et al (10) reported significant increases in both systolic and diastolic pressure during 3 lb. hand weight carriage (8.3% & 7.3%) when compared to no weight and 1 lb. carriage (10.4% & 6.9%) in the examination of 12 men ages 25 to 38 years. Participants were asked to walk at a speed and gradient that produced a heart rate response of 60% and 70% or HR_{max} reserve, which on average corresponded to 3.7 mph and 7.9% and 3.7 mph and 10.5% respectively. In subsequent work Graves, et al (9) examined comparisons between hand weights, ankle weights, and wrist weights in 12 sedentary men age 18 to 23 years. These participants were asked to walk at a speed (6.3 km/hr) and grade (adjusted to keep prescribed HR intensity) that produced 75% of HR_{max} reserve with no weights, 3 lbs. in each hand, 3 lbs. on each wrist, and 3 lbs. on each ankle. The data showed a significant rise in diastolic blood pressure while carrying 3 lb. hand weights when compared to the other conditions. No significant difference in systolic pressure was reported (9). Graves, et al (9) reported unpublished data on work with hypertensive men that showed a wide range of systolic blood pressure responses (-23 to +28 mmHg) with the addition of 3 lb. hand weights. Since a rise in blood pressure was only noted in hand weight condition, one may infer that the small amount of isometric hand-gripping is responsible for the observed increase. If an increased involvement of upper body musculature was responsible for exaggerating the blood pressure response, it would have been expected that both hand weights and wrist weights would induce an increase in blood pressure (9).

Zarandona, et al (24) reported a significant rise in systolic pressure in 30 trained runners and joggers carrying 5 lb. hand weights. Each participant was required to walk (3.5 mph) and run (7 mph) with no weight, 1 lb hand weights, and 5 lb. hand weights for 4 minutes (24). Carrying 5 lb. hand weights caused a significant rise in systolic blood pressure in the walking condition (24). Blood pressure from the running tests was not accurate enough to report due to difficult interpreting the appropriate korotkoff sounds while taking manual readings of the sphygmomanometer (24). In their work with 11 healthy males (age 22 to 28 years), Bhambhani, et al (2) showed significant increases in both systolic (10.2-14.7%) and diastolic (13.4-17.3%) pressures while carrying loads of 15 kg or 20 kg in front of the body with bilateral equality when compared to no load walking; no significant differences were identified between the carrying conditions. The sustained low intensity isometric contractions experienced by the participants induced a more mild than expected blood pressure response. The minimal effect was likely due to the fact that the difference in maximal grip strength between the two load carriage conditions was quite small (10% vs. 12%) and failed to reach the 15%-20% MVC threshold required to induce larger changes in the pressor response (2). The protocol and load carriage technique of Bhambhani, et al are unique to the other research presented. Participants were required to carry the loads bilaterally in front of the body with a technique that was most comfortable to them. The 12-minute testing session involved 4-minutes of stationary standing on the treadmill, 4-minutes of unweighted walking, and 4-minues of load carriage (2). Jackson, et al (13) showed significant 31 mmHg and 22 mmHg rises in systolic and diastolic pressures, respectively, during handgrip load carriage of 40 lbs. in the right hand when compared to each of the other conditions. The participant pool included 13 healthy untrained men aged 30 to 34 years with no physical or historical evidence of chronic disease and no history of sustained hypertension (13). Participants were asked to walk on a treadmill at 1.7 mph and 0% grade while carrying 40 lbs. in the right hand, 20 lbs. in each hand, 40 lbs. on their back, and no added weight. The data suggested that myocardial oxygen consumption demand increased more rapidly during asymmetrical limb load carriage when compared to symmetrical limb or torso load carriage; perhaps due to the smaller muscle mass required to carry the stress, which represents a higher percent of MVC for the same load (13).

Hemodynamic Response to Voluntary Contraction During Walking

The hemodynamic response to sustained contractions depends on the relative tension developed by the groups of muscles under examination and not by their absolute tension or the mass of muscle tissue involved (6). A number of researchers have documented a rise in blood pressure during sustained contractions at tensions above 15% of maximum voluntary contraction (MVC) (2, 5, 6, 7, 14, 22). When the tensions are equal between two or more muscle groups, the hemodynamic responses are not additive (14). It has also been noted that if tension is exerted by two limbs simultaneously, at different comparative levels, the hemodynamic response was equivalent to that expected when the higher comparative tension was applied alone (6).

The work of Lind and McNicol (14) shows a clear relationship between blood pressure response and sustained handgrip contractions. During 20%, 30%, and 50% MVC while walking at an intensity that elicited a cardiac output of approximately 10 L/min (2.5 mph and 3% gradient) participants systolic blood pressure rose 18%, 17%, and 18% respectively while diastolic pressure rose 19%, 22%, and 20% respectively (14). At the same % MVC and a cardiac output of approximately 13.5 L/min (3.5 mph and 11% gradient), systolic pressure rose 34%, 31%, and 22% respectively while diastolic pressure rose 38%, 40%, and 34% respectively (14). These findings support the notion that elevated hemodynamic responses can be evoked during rhythmic exercise with a heavy cardiovascular component despite the fact that sustained contractions elicit vastly different responses from the cardiovascular system (14).

Conclusion

The literature related to handrail support and load carriage is supported by the literature on maximal voluntary contractions which shows a systemic response resulting from isometric stress that is related to the percent of maximal voluntary contraction of the specific muscle groups utilized. Heart rate, VO_2, systolic pressure, and diastolic pressure were most significantly impacted at the higher treadmill loads, higher intensity of handrail support, continuous versus intermittent handrail support, greater imposed isometric load, and/or an additive combination of multiple factors (1, 4, 11, 13, 14, 12, 25). Specifically pertaining to blood pressure and handrail support, only three authors have reported findings during treadmill walking. During each of these studies, a heavy handrail support condition was omitted.

An aging individual consciously accepts the limitations imposed by a reduction in cardiovascular capacity due to a natural decline or the effects of disease. Static exertion, however, which often occurs unexpectedly in the normal activities of daily life and is often most dangerous to the individual may be accepted unknowingly. Blood pressure monitoring, even in an apparently normotensive individual, as part of a pre and post-exercise routine may prove insufficient as the hemodynamic response rises abruptly during dynamic exercise with a static component and falls just as rapidly (6, 14, 22). Lind and McNicol (14) and others (6, 22) showed a return to pre-contraction blood pressure within a minute of releasing the contraction. The individual, and the fitness professional, has little appreciation or warning of how close one may be to dangerous circulatory overload (6).

Chapter 3 - Methods

Participants

A total of twenty volunteer, male (10) and female (10) participants provided written, informed consent for this study per the policies and procedures of the James Madison University Institutional Review Board. The mean (SD) age, height, and body mass of the subjects were: 43.89 (6.07) years, 161.69 (11.81) cm, and 76.39 (13.95) kg, respectively. The participants were all active members of the company provided onsite Wellness Center and free from any cardiovascular, metabolic, and orthopaedic problems. All participants completed the familiarization session and began each of two required testing sessions; only 17 completed both sessions. Two participants were unable to complete the "fast/high" condition, and one participant had to be removed due to the revelation of a precluding health condition during testing.

All participants were employees of a large medical insurance company and worked in the office complex which houses the onsite Wellness Center. Testing sessions were scheduled around the participant's normal work schedule, and at the convenience of the participant. Participants were asked to maintain a consistent nutritional regimen over the course of the study. A 12-hour cessation of smoking, caffeine consumption, and strenuous exercise was required prior to each testing session. Once a time of day was selected, all familiarization and testing sessions were completed at the participant selected time. Three appointments on different days, each separated by at least one day, were required to complete the familiarization and testing sessions. All three sessions were scheduled at once and were completed within one calendar week of the familiarization session.

Session 1: Protocol Review and Familiarization

In this session, each participant reviewed their medical history and study protocol with the primary investigator. Participants were allowed as much time as required to cover any concerns and receive full, complete answers to their questions. All participants were thoroughly familiarized with the operation and use of a Cybex Sport+ Treadmill (Cybex International, Medway, MA). Each participant was allowed to sample the handrail support positions, treadmill speeds, and treadmill elevations for a duration determined by the participant to achieve a sufficient level of comfort to continue on to the first testing session. Participants were also familiarized with the OMRON HEM-71DLX automatic sphygmomanometer (OMRON Healthcare Corp, Bannockcurn, IL) through at least two sample pressure readings. For participants previously unfamiliar, proper instruction and demonstration of the Polar F1 heart rate monitor (Polar Electro Oy, Kempele, Finland) and Borg scale was conducted.

Session 2 & 3: Handrail Support Conditions

Following the familiarization session, participants completed two testing sessions each consisting of 30 minutes of continuous walking. Each session began with ten minutes of no handrail support achieve a steady state during which time no other test procedures were employed. The participant, while continuing to walk, proceeded through the following activities:

1. 5 min walk with the hands atop the treadmill console (C), arms extended, and a compensatory posterior lean of the torso (Figure 1),
2. 5 min period of no handrail support (NHRS) for return to steady state
3. 5 min walk with the hands positioned below the shoulders (SHRS), gripping the side rails, arms locked, shoulders raised, and clearly supporting the exercisers weight (Figure 2).
4. 5 min period of no handrail support for return to steady state

This procedure was completed twice by each participant, once at each of two levels of energy expenditure when the treadmill operated at: 1) 2.5 mph and 3% grade (slow/low) and 2) 3.5 mph and 11% grade (fast/high). This protocol was adapted and modified from Lind and McNicol (16). The order of the two exercise bouts and the handrail support positions was randomized for each participant.

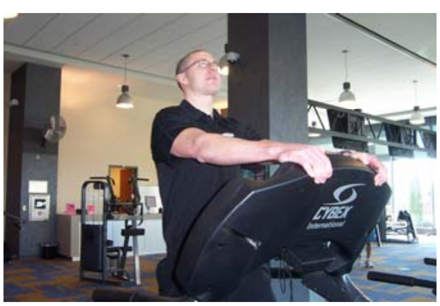

Figure 1. Console

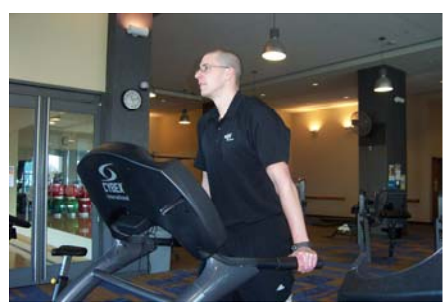

Figure 2. Side Handrail Support

Measurements

All data was collected and entered live-time into a portable laptop computer. Each participant had a unique spreadsheet, pre-designed with their session parameters and identified by a participant number. A separate log of the participant/participant number matrix was kept on the desktop computer of the lead investigator. The desktop computer, laptop computer, consent forms, and any additional paper notes related to the study were locked in a file cabinet within the lead investigator's office. Only the lead investigator had access to the materials related to this study.

Blood pressure (BP) was manually monitored each minute with an OMRON HEM-71DLX automatic sphygmomanometer (OMRON Healthcare Corp, Bannockcurn, IL). To obtain blood pressure during the no handrail condition, the participants were instructed to continue the arm swinging motion as usual for their gait pattern. No changes in hand position, grip, and/or arm tension were allowed while obtaining blood pressure readings during the handrail support conditions.

Heart rate (HR) was constantly monitored and recorded every minute with a Polar F1 heart rate monitor (Polar Electro Oy, Kempele, Finland). Rate pressure product (RPP) was calculated by multiplying heart rate by systolic blood pressure. Rating of perceived exertion (RPE) was collected during the last 60 seconds of each 5 minute section during the exercise bout using the Borg scale.

Data Analysis

Repeated measures ANOVAs were computed for the systolic and diastolic blood pressure, HR, and RPP responses to front console, side handrail support, and no handrail support. Separate ANOVA calculations were run for the "slow/low" and "fast/high" conditions. Two-tailed dependent t-tests were run using a Bonferroni correction to clarify significance with an alpha level of $p<0.017$ required for significance. Pearson product-moment correlations were calculated to determine the correlation coefficient (r) the variables of age, height, and weight possessed with respect to the criteria variables of systolic and diastolic blood pressure for each the slow/low and fast/high trial conditions. An alpha level of $P \leq 0.05$ was required for statistical significance. All results were calculated using the SPSS software package.

Chapter 4 – Results

Table I shows the effect of the location of handrail support on mean SBP response for the slow/low expenditure level. There was a significant reduction in SBP during C (115.37 +/- 11.14) compared to NHRS(126.09 +/- 14.38) (p<0.001) and in C (115.37 +/- 11.14) compared to SHRS (122.55 +/- 15.26) (p=0.005). No significant differences were observed in DBP between any of the handrail support conditions during the slow/low trials, though there was a trend for effect (p=0.07).

Table I
Mean Systolic and Diastolic Blood Pressure for Slow/Low Trials

Mean Systolic Blood Pressure

Condition	Mean	No.	Std. Dev	SE	t	p
Front Console Support	115.37					
		19	7.67	1.76	6.095	<0.001*
No Handrail Support	126.09					
		19	11.54	2.65	1.340	0.197
Side Handrail Support	122.55					
		19	9.65	2.21	3.24	0.005*
Front Console Support	115.37					

Mean Diastolic Blood Pressure

Condition	Mean	No.	Std. Dev	SE	t	p
Front Console Support	64.59					
		19	4.97	1.14	2.089	0.067
No Handrail Support	70.39					
		19	5.42	1.24	-0.059	0.953
Side Handrail Support	70.46					
		19	5.21	1.19	1.912	0.109
Front Console Support	64.59					

*Significant at the 0.05 alpha level.

Table II shows the effect of the location of handrail support on SBP and DBP response for the high/fast expenditure level. There were significant reductions in mean SBP between C (131.62 +/- 8.69) and NHRS (160.24 +/- 11.78) (p<0.001) and between NHRS (160.24 +/- 11.78) and SHRS (135.18 +/- 10.24) (p<0.001). Significant reductions in mean DBP were observed between C (62.26 +/- 7.96) and NHRS (70.87 +/- 6.58) ($p<0.001$) and SHRS (69.48 +/- 9.34) and C (62.26 +/- 7.96) ($p<0.001$).

Table II
Mean Systolic and Diastolic Blood Pressure for Fast/High Trials

Mean Systolic Blood Pressure

Condition	Mean	No.	Std. Dev	SE	t	p
Front Console Support	131.62					
		17	9.92	2.41	11.898	<0.001*
No Handrail Support	160.24					
		17	10.95	2.66	9.440	<0.001*
Side Handrail Support	135.18					
		17	8.00	1.94	1.830	0.086
Front Console Support	131.62					

Mean Diastolic Blood Pressure

Condition	Mean	No.	Std. Dev	SE	t	p
Front Console Support	63.13					
		16	4.88	1.22	6.351	<0.001*
No Handrail Support	70.87					
		16	6.03	1.51	0.745	0.468
Side Handrail Support	69.48					
		17	4.59	1.11	6.495	<0.001*
Front Console Support	63.13					

*Significant at the 0.05 alpha level.

Table III shows the effect of the location of handrail support on mean HR response for fast/high expenditure level. Significant reductions in mean HR were observed between NHRS (127.13 +/- 27.77) and C (114.90 +/- 21.76) ($P<0.001$) and SHRS (121.88 +/- 23.24) and C (114.90 +/- 2.76) ($p=0.006$). No significant differences were observed in mean HR during the slow/low trials.

Table III
Mean Heart Rate for Fast/High and Slow/Low Trials

Fast/High Trials

Condition	Mean	No.	Std. Dev	SE	t	p
Front Console Support	114.90					
		24	13.16	2.69	4.551	<0.001*
No Handrail Support	127.13					
		24	11.62	2.37	2.213	0.037
Side Handrail Support	121.88					
		24	11.20	2.29	3.051	0.006*
Front Console Support	114.90					

Slow/Low Trials

Condition	Mean	No.	Std. Dev	SE	t	p
Front Console Support	103.50					
		16	9.31	2.33	2.809	0.013
No Handrail Support	110.04					
		16	11.77	2.94	-0.279	0.784
Side Handrail Support	109.22					
		16	10.64	2.66	2.149	0.048
Front Console Support	103.50					

*Significant at the 0.05 alpha level.

Table IV shows the effect of location of handrail support on mean RPP response for fast/high expenditure level. Significant reductions were observed between NHRS (23573.14 +/- 3073.10) and SHRS (16628.35 +/- 1899.22) ($p<0.001$) and NHRS (23573.14 +/- 3073.10) and C (17915.51 +/- 3125.81) ($p<0.001$). No significant differences were observed in mean RPP during the slow/low trials.

Table IV
Mean Rate Pressure Product for Fast/High and Slow/Low Trials

Fast/High Trials

Condition	Mean	No.	Std. Dev	SE	t	p
Front Console Support	17915.51					
		17	1987.33	481.99	11.738	<0.001*
No Handrail Support	23573.14					
		17	2018.33	489.52	14.187	<0.001*
Side Handrail Support	16628.35					
		17	2512.12	609.28	-2.113	0.051
Front Console Support	17915.51					

Slow/Low Trials

Condition	Mean	No.	Std. Dev	SE	t	p
Front Console Support	12045.20					
		19	1812.09	415.72	0.517	0.611
No Handrail Support	12260.27					
		19	1696.32	389.16	1.935	0.069
Side Handrail Support	13013.21					
		19	2220.36	509.38	1.900	0.074
Front Console Support	12045.20					

*Significant at the 0.05 alpha level.

Examination of a gender effect in any of the slow/low and/or fast/high energy expenditure level handrail support combinations returned no significant findings with respect to SBP, DBP, HR, and RPP. Mean HR did show a trend for a significant effect during the slow/low trials (p=0.051).

The Pearson product-moment correlations indicated a significant positive correlation for age and SBP in relation to SHRS (r=0.491; p=0.033) and NHRS (r=0.474; p=0.041) during the slow/low trials; weight and SBP in relation to NHRS (r=0.569; p=0.011) during the slow/low trials; age and DBP in relation to C (r=0.578; p=0.019) during the slow/low trials; weight and DBP in relation to SHRS (r=0.533; p=0.034) during the slow/low trials; and height and DBP in relation to SHRS (r=0.506; p=0.045) during the slow/low trials. Full results of these procedures are presented in Table V.

Table V

Correlation Between Independent Variables and Criterion Variables

Variable	Energy Expenditure	SHRS		NHRS		C	
		r	p	r	p	r	p
Height	Slow/Low SBP	0.101	0.681	0.193	0.427	-0.136	0.58
	Slow/Low DBP	0.506	0.045*	0.400	0.125	0.073	0.787
	Fast/High SBP	0.398	0.114	0.277	0.298	0.138	0.599
	Fast/High DBP	0.336	0.188	-0.062	0.820	0.540	0.025*
Weight	Slow/Low SBP	0.391	0.098	0.519	0.011*	0.134	0.585
	Slow/Low DBP	0.533	0.034*	0.335	0.204	0.093	0.732
	Fast/High SBP	0.366	0.148	0.432	0.095	0.283	0.272
	Fast/High DBP	0.446	0.073	0.118	0.663	0.538	0.365
Age	Slow/Low SBP	0.491	0.033*	0.474	0.041*	0.441	0.059
	Slow/Low DBP	0.121	0.955	0.299	0.261	0.578	0.019*
	Fast/High SBP	0.016	0.952	0.175	0.516	0.304	0.235
	Fast/High DBP	0.147	0.574	0.136	0.614	0.235	0.365

*Significant at the 0.05 alpha level

Chapter 5 - Discussion

Even in relatively young, healthy exercisers the use of handrail support during steady-state treadmill walking is common practice. This is especially true of exercisers inexperienced in treadmill use, who experience balance or equilibrium difficulty, or who are looking to increase the implied load through greater speed and/or incline than can be done without the use of handrail support. Lind and McNicol (15) report 18% and 21% increases in SBP and DBP, respectively, during treadmill walking while performing a sustained hand-grip at 20% MVC. If the heavy handrail support conditions elicit an isometric force equivalent to 15-20% MVC (14, 15), then an exaggerated hemodynamic response would be expected. Graves, et al (10) suggests that patients who are hypertensive, have a hypertensive response to exercise, or have a diminished functional reserve may be negatively affected by an isometric pressure overload. Giri, et al (27) reported 26 cases of myocardial infarction (MI) when exertion was a mixture of aerobic and lifting activities compared to 26 cases of aerobic activity only and 12 cases of isometric or heavy lifting activity. During vigorous exertion, the relative risk of MI was reported to be 10.1 time higher than during lesser exertion (27).

No previous study that examined the hemodynamic response to either loaded or unloaded treadmill walking with handrails support utilized the two “heavy hold” conditions included in this study. This author examined positions often observed by participants in community Wellness Centers; hands atop the treadmill console with posterior lean and weight supported through the hands and arms, and hands placed on the side handrails with arms straight and weighted to help support the body weight of the participant. Only three authors have reported the effect of supported treadmill walking with relation to blood pressure (8, 21, 25). In all three studies the participants' degree of handrail support was dictated by the researcher to prevent excessive gripping. In the current study participants were asked to maintain the maximal level of support possible within the construct of the positions required.

The findings of significantly lower SBP during handrail support is consistent with the work of Ziemetz, et al (25) observed decreases during handrail support utilizing the Bruce protocol. The current study observed reduction of 5.8% and 8.8% during the slow/low conditions, which is a finding unique to the literature. The observed reduction of 15.7% and 18.2% in the fast/high conditions, though higher than reported by Ziemetz, et al (25), is consistent with the 12.5% and 15% reductions observed during a balance only front handrail support and a 6.8 kg horizontal-pull front handrail support, respectively, in stage 5 of the Bruce protocol. A finding of significant reductions in DBP during the high/fast trials is also unique to this study as the three previous comparable studies all reported non-significant changes at all stages of their applied treadmill protocols (8, 21, 25). No significant findings of an increase in either SBP or DBP and subsequent significant decreases in both metrics is indicative of the handrail support positions inability to reach the threshold of 15% maximum voluntary contraction reported in the work of Lind, et al (14).

Significant reductions in heart rate due to the use of handrail support are well reported in the literature (1, 4, 11, 12, 16, 18). The present observation of significant reductions in HR during C of 10.3% (12.23 bpm) and 5.8% (6.98 bpm) when compared to NHRS and SHRS, respectively, are consistent with the work of Berling, et al (1) who reported a 20 bpm reduction, Christman, et al (4) reporting a 4.5-4.8% reduction, Rutledge, et al (21) reporting a 6.66% and 11.57% reduction, and Lind and McNicol (6) reporting a 9.1-9.4% reduction in HR during handrail support when compared to non-handrail support.

To further understand the imposed load of handrail support versus non-handrail support in these conditions, we compared the rate pressure product for each trial combination. Summarily supportive of the findings of both the SBP and HR statistics, RPP showed significant reductions during the fast/high handrail support condition. During the fast/high trials significant reductions in RPP were noted between C and NHRS as well as between SHRS and NHRS. Manfre, et al (16) reported no significant difference between handrail support and non-handrail support in relation to RPP in his work with healthy males and females, and male symptom limited coronary artery disease and myocardial infarction patients.

The Pearson product-moment correlation indicated significant positive correlations in DBP during the slow/low condition between weight and SHRS, height and SHRS, and age and C. Additional positive correlations were observed in the relationships between height and C (p=0.025) with respect to fast/high DBP; weight and NHRS (p=0.011) with respect to slow/low SBP; and age and SHRS (p=0.033) and NHRS (p=0.041) with respect to slow/low SBP. Non-significant findings were reported by von Duvillard and Pivirotto (23) for the independent variables of age, height, and weight when correlated to handrail support and VO2. No correlations have been reported in relation to handrail support and blood pressure. While we would expect SBP and DBP to be higher with age and weight, perhaps the more practically significant finding is the relationship of height and SHRS and C. This suggests an element of leverage and ability to support one-self inherent to increased height and the manufacturer's design of the treadmill utilized. Side HRS as dictated by this study required straight arms with the participant clearly supporting their body weight through their arms. For participants of appropriate height in relation to the treadmill utilized (approx. 73 inches in this participant pool), the requirement would be to lean slightly forward and drop additional weight into the arms and side handrails. Participants in shorter stature would not be able to mimic this additional weighting as locked arms in a similar fashion would raise the feet of the participant off of the treadmill. A similar result of leverage would be assumed for C as well. The taller participant would likely have longer arms, thus positioning them further away from the console and increasing the angle of lean. In this study, both handrail support conditions the increased load appears to have surpassed the 15% MVC threshold required for significant increases in BP during isometric hand grip exercise as reported by Lind, et al (14) and/or a load carriage value above the 25% threshold reported by Bhambhani, et al (2).

One limitation of this study was the lack of quantification of HRS applied within this study. Participants were given verbal instructions to clearly support their body weight through their arms during C and SHRS with reminders as required. However, because pressure was not more empirically controlled, it may have been highly variable. Utilizing a population between the ages of 35-55 years answers a need observed by Berling, et al (1) for older individuals; their call for patients with cardiovascular disease and related co-morbidities is still yet unanswered. Given the observation of a potential leverage relationship in respect to the participant's height and DBP, further investigations of Elliptical trainers, Arc trainers, and stair climbing apparatuses would be desirable.

The results of this study suggest that both heavy side handrail support and heavy console support during steady-state treadmill walking will significantly decrease the hemodynamic response as represented by SBP, DBP, HR, RPP to varying degrees during slow/low and fast/high conditions. The amount of decrease in each variable experienced is intensity dependent, with a higher intensity provoking a greater difference. This may be practically significant when prescribing exercise to the beginning exerciser or to an exerciser who relies on handrail support. It may also be practically significant to consider performing exercise tests in the manner in which the client intends to use the apparatus. Further clinical applications may exist in the implementation of a progression from NHRS to HRS as the exercise bout progresses at the necessity of the client. Should HRS be initiated, subsequent increases in workload would need to accompany HRS to maintain consistent relative energy expenditure levels.

Systolic BPs above 250 mmHg have been suggested as endpoints for graded exercise tests (26), though there is little data that establish guidelines for an upper limit for BP during exercise training (9). Mean SBP during handrail support in the present study ranged from 113-165.8 mmHg and DBP ranged from 61.43-73.2 mmHg. Thus, in normotensive individuals, the moderate rise in BP caused by the subtraction of the handrail support would not necessarily contraindicate its implementation. Extrapolation of the current data to the hypertensive population should be cautious.

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